
ABSTRACTS

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1-C

APPLICATION OF RADIOMETRY TECHNIQUE FOR QUALITY CONTROL OF DIFFERENT COMPONENTS IN NUCLEAR INDUSTRY

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Abstract

Radiometry is a specialize non-destructive technique where attenuated gamma beams are detected by radiation detector. The result is available in the form of counts and it provides real time information of the job. In nuclear industry, radiometry is being increasingly used for quality control of different components such as packing density variation of poison material in control rod, shielding adequacy check of reactor components, pipe line corrosion detection etc. Unlike radiography inspection, this technique require low strength radiation source and therefore is associated with less radiation related hazards. The whole set up is inexpensive and radiation detection efficiency can be increased by use solid scintillation detector. Also in case of insulated pipeline inspection, it does not require to remove insulation layer and thus avoiding shut down of operation during inspection. This paper describes two such application of radiometry technique. In one application, radiometry technique is used for checking packing density variation of poison material in control rod. In other case, corrosion detection of pipeline by radiometry is discussed.

2-C

ASSESSMENT OF LOCALIZED PLASTIC DAMAGE DURING FATIGUE BY NON-COLLINEAR NONLINEAR ULTRASONIC TECHNIQUE

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Abstract

In this paper we describe non-collinear ultrasonic wave mixing technique that has been used to study the localized plastic deformation during high cycle fatigue. A pair of shear wave was generated and then mixed non-collinearly to obtain a different frequency component of longitudinal wave under a resonant condition. The amplitude of this newly generated longitudinal wave is much sensitive to plastic deformation even if the material nonlinearity is not significant. Interrupted high cycle fatigue tests were carried out on three point bend specimen of 9Cr-1Mo (P-91) steel and the nonlinear acoustic parameter generated through non-collinear wave mixing defined as non-collinear nonlinear ultrasonic parameter (NCNLU) was measured after each interruption till the crack propagation took place up to certain limit. In this paper the design of experiment and the variation of NCNLU parameter with damage accumulation due to the fatigue crack propagation are described.

Keywords: Nonlinear ultrasonic, high cycle fatigue, Non-collinear wave mixing, harmonics.

3-C

FLASH X-RAY RADIOGRAPHY TECHNIQUE TO STUDY THE HIGH VELOCITY IMPACT OF SOFT PROJECTILE ON E-GLASS/EPOXY COMPOSITE MATERIAL

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Abstract

Flash x-radiography technique is extensively used in interior, intermediate, exterior and terminal ballistics and detonation research applications due to its ability to penetrate events normally obscured by kinetic flash, luminescent gas clouds and explosive debris. In terminal ballistics, it is used to study the real time deformation patterns, of the projectile and target materials while the projectile is traversing through the target. However to acquire radiographic images of high quality, it is very essential to control various parameters such as x-ray source voltage, source to target and target to film distances as well as the angle between the various x-ray channels. In the present paper optimization studies were carried out to avoid over exposure of the x-ray films. This has been carried out by using a metallic diaphragm and varying its distance between source and target. The study also involved, acquiring the real time deformation patterns of a 30 mm thick E-glass / epoxy composite laminates when subjected to impact of soft projectile at different time intervals. It is observed that the deformation of the projectile increases with increase in the path length of the projectile in the target.

Keywords: Flash x-ray, E-Glass/epoxy composite material, computed radiography, high velocity projectile impact

4-C

EXPERIMENTAL STUDY OF ULTRASONIC LAMB WAVE MIXING DURING TEMPERING OF MODIFIED 9CR-1MO STEEL

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Abstract

An approach has been made to study the tempering effect on modified 9Cr-1Mo steel by mixing two Lamb waves. As-received material was normalized at 1080°C and then tempered in temperature range of 600 - 850°C with a step size of 50°C for 1.5hrs and followed by furnace cooling. Two types of Lamb waves were mixed under resonance conditions to generate a mixing harmonic wave of sum frequency of the two fundamental waves and nonlinear ultrasonic parameter â was determined from the mixing wave at each temperature and correlated with microstructural characteristics like size of precipitate and density of dislocation. It was seen that acoustic nonlinearity parameter (â) was sensitive towards precipitate-matrix coherency strain, generated during tempering.

5-P

DEVELOPMENT OF AN AUTOMATED SCANNING MECHANISM FOR PROFILOMETRY OF PRESSURE TUBES OF PHWR

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Abstract

Automated scanning mechanisms are widely employed for ultrasonic imaging and gauging of tubes for assessment of integrity and life-expectancy. Ultrasonic instrumentation with automated scanner provides accurate and repeatable measurements. Indian Pressurised Heavy Water Reactor 220MWe (PHWR) has 306 coolant-channels where each channel consists of Zircaloy Pressure Tube (PT). Due to high temperature, pressure and irradiation, PT undergoes diametral creep due to hoop stress. PHWR needs routine shut-down for maintenance, during which the PT is removed out and subjected to post-irradiation examination (PIE) for metallurgical studies. ED and PIED of BARC and TC&QCD, IGCAR, Mumbai have jointly designed and developed an automated 2-axes mechanical scanner. The scanner is interfaced to 5-Ch Ultrasonic Gauging System for accurate ID and Wall-Thickness measurement of 5.10 metre long, irradiated PT. It is placed inside a lead-filled cask to shield Gamma radiation. During inspection process, cask is filled with water and it is placed in a tilted manner to avoid spillage of contaminated water. Linear and Rotary motions are imparted to the inspection-head containing four ultrasonic transducers for gauging and one more for on-line measurement of acoustic-velocity of water. By movement of inspection-head, profilometry of PT is carried out. Paper describes details of development of the automated scanning mechanism.

Keywords: Profilometry, PHWR, Pressure Tube, Automated Gauging

6-C

DETECTION OF ANNULAR AND SOLID PELLET IN PFBR FUEL ELEMENT USING HIGH ENERGY X-RAY RADIOGRAPHY

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Abstract

Advanced fuel fabrication facility (AFFF) has manufactured (U-Pu)O2 MOX fuel with a wide range of composition for thermal and fast reactors. At present AFFF is engaged in fabrication of the mixed oxide (MOX) fuel with (U-30%Pu)O2for upcoming Prototype Fast Breeder Reactors (PFBR).The fully loaded PFBR fuel element contains a stack of annular (U-Pu) MOX pellets, two stacks one at the top and one at the bottom of solid DDUO2 pellets and hardware components. As a part of quality control step, X-ray Gamma Autoradiography (X-GAR) is carried out to check cross mixing of DDUO2 and MOX pellets. As per the quality control philosophy some characteristics of fuel are checked by more than one technique so as to get better confidence in quality of fuel. In view of this the high energy X-ray radiography was used to check the cross mixing of (U-Pu) MOX pellet in stack of DDUO2 pellets. The many trials were taken to optimize the X-ray radiography parameters. The technique even detects solid MOX pellet if gets mixed with annular MOX pellets and annular DDUO2 pellets in the stack of solid DDUO2 pellets providing full proof system.

Key words: Gamma Autoradiography, X-GAR, X-ray radiography, PFBR.

7-C

MONITORING OF CREEP DAMAGE PROGRESSION IN POWER PLANT MATERIALS USING SECOND HARMONIC OF ULTRASONIC SIGNAL

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Abstract

Pipe systems in power plants are designed to operate in an environment where they are subjected to high temperature and stress loads as well as high pressures. These unfriendly environments require usages of material in its creep range. Creep deformation of a material in its creep range is unavoidable after a certain time. Though a final material failure due to creep deformation cannot be avoided, but it can be controlled by correct system design and regular monitoring of the microstructure by inspections, which can prolong the material failure by several years. Creep in polycrystalline materials occurs as a result of the motion of dislocations within grains, grain boundary sliding and diffusion processes. The formation of voids, multi-poles, micro-cracks and, finally, macro-cracks leading to complete fracture are the manifestations of the creep damage process. In general, stages of creep in power plant components are monitored by in-situ metallography. This is not only cumbersome but also so reliable. The objective of this research is to develop a robust non-destructive technique to reliably measure the acoustic nonlinearity parameter due to microstructural changes during creep in Cr-Mo steel. Further development of this technique would be useful in online prediction of progression of creep damage in thermal power plants.

Keywords: Cr-Mo steel, acoustic non-linearity, Micro cracks, creep damage

8-C

CASE STUDIES IN ULTRASONIC TESTING

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Abstract

Ultrasonic testing is widely used Non Destructive Testing (NDT) method and forms the essential part of In-service Inspection programme of nuclear reactors. Main application of ultrasonic testing is for volumetric scanning of weld joints followed by thickness gauging of pipelines and pressure vessels. Research reactor Dhruva has completed the first In Service Inspection programme in which about 325 weld joints have been volumetrically scanned, in addition to thickness gauging of 300 meters of pipe lines of various sizes and about 24 nos of pressure vessels. Ultrasonic testing is also used for level measurements, distance measurements and cleaning and decontamination of tools. Two case studies are brought out in this paper in which ultrasonic testing is used successfully for identification of butterfly valve opening status and extent of choking in pipe lines in Dhruva reactor systems.

Keywords: Non-Destructive Testing, Nuclear Research Reactor, In-Service Inspection, Liquid Poison system, Drain Line Choke, Butter fly valve.

9-C

ASSESSMENT OF INTEGRITY OF REINFORCED CONCRETE STRUCTURES USING "RELAXATION RATIO" ANALYSIS OF ACOUSTIC EMISSIONS

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Abstract

A parallel between seismic waves related to an earthquake and acoustic emissions (AE) released during fracture process in reinforced concrete (RC) beams under flexural loading was observed and a parameter "Relaxation ratio" was proposed (Colombo et al. 2005). Relaxation ratio is the ratio between average energy released during unloading to the average energy released during loading. In this present study RC flanged beam specimens of span 2.6 m were tested under incremental cyclic loading and simultaneously the released AE was recorded. This article reports on the influence of (i) concrete compressive strength (ii) specimen geometry, (iii) change in rate of loading, (iv) percentage of steel reinforcement used (v) type of failure (shear or tensile) on the results related to relaxation ratio analysis of reinforced concrete (RC) flanged beam specimens. Relaxation ratio parameter is sensitive to the fracture process in RC members. Also the RR results were compared with the NDIS assessment chart recommended by JSNDI. Relaxation ratio analysis is useful to assess the current state of damage in RC structures in-situ.

Keywords: Reinforced concrete; Acoustic emission; Damage; Structural condition monitoring

10-C

LONG RANGE ULTRASONIC TESTING - CASE STUDIES

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Abstract

Long Range Ultrasonic Testing (LRUT) is widely used for detecting corrosion and other metal loss in pipes and pipelines especially where access for inspection is difficult or expensive. Ultrasonic Guided wave testing (GWT) is established in the petrochemical and related industries, primarily for the detection of corrosion flaws.

Developments of testing specialized procedures, the interpretation methods and calibration methods have significantly enhanced the capabilities of GWT. This paper presents the data and results, obtained from bare, cement lined and coal tar coated-buried lines. Inspection was carried out using piezoelectric sensor technology.

Keywords: Guided wave, Piezoelectric, Bare, Coated and Buried line, internal cement lined, Attenuation etc.

11-C

DEVELOPMENT OF AN EMAT ULTRASONIC THICKNESS GAUGE FOR TESTING IN HARSH ENVIRONMENTS

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Abstract

Ultrasonic testing is a widely established method for material testing. Mostly piezoelectric transducers are used in a frequency range of 1 to 10 MHz. Other methods of stimulating ultrasound are also possible, i.e. by laser pulses or electromagnetic excitation (EMAT), but are not widely used because of the lack of suitable instruments.

We report the development of a compact mobile EMAT instrument that can be deployed with all the advantages of EMAT. The test object need not be coupled with a liquid to a test object and can have surface coatings or scale. Normally there is no need for surface preparation.

One more advantage is that the probe can be tilted on the surface with little influence on the test result. Thus human errors in handling frequently found with piezoelectric systems are eliminated.

The test object can be in a wide temperature range, i.e. -20 to 720 degree C. This fact makes it possible to perform inspections in plants during operation or on materials during production at elevated temperatures.

A few examples, mainly thickness gauging, are presented where EMAT testing was advantageously deployed, i.e. testing without couplant, testing through coatings and testing at high temperatures.

12-C

INSPECTION OF MANUFACTURING DEFECTS IN FIBER REINFORCED COMPOSITE LAMINATES USING ULTRASONIC PHASED ARRAY PROBE

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Abstract

Ultrasonic phased array technology is a useful tool for Non-destructive testing in various industries for inspection of composite parts during maintenance and manufacturing. In this study, ultrasonic C-scan technique is used to detect various artificial defects with a 5MHz phased array wheel probe in laminated composite plates. The artificial defects with varying shapes and sizes made of polymer films were embedded in the testing plates at different layers and positions. Both unidirectional glass fiber reinforced epoxy polymer (GFRP) and class fiber reinforced epoxy polymer (CFRP) composite laminates were examined using portable Doppler PA instrument PHASCAN®. Special tuning and optimization techniques including different element combination and focus settings and distance amplitude correction (DAC) were used to reduce noises and to achieve better image resolution. The C-scan measurements are in good agreement with the actual size and position of defects: quantifying the size and location of defects. In addition, the attenuation factors in both materials were measured. It was found that the noise to signal ratio in CFRP laminates is much lower than GFRP laminates, which resulted in better C-scan image.

13-C

ROBOTIC ULTRASONIC THICKNESS MEASUREMENT FOR TURBINE AIRFOILS

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Abstract

Aero engine MRO industry mostly depends on manual method to perform wall thickness measurement on Turbine Airfoils because of its non-uniform surface condition due to engine run & repair processes. NDT Automations in aerospace industry are becoming more and more necessity in terms of achieving reliable and repeatable results, which are not conceivable by manual method. This paper dictates ultrasonic thickness measurement on Turbine airfoils using robot. We have partnered with system integrator (MNDT-USA) to custom design and develop the robot to perform ultrasonic thickness measurement. It was started with prototype and developed for V2500 2nd stage high pressure turbine blade. After the successful results, the system has been further developed with signal normalization feature in order to accurately measure the thickness on non-uniform surface and make the disposition based on preloaded acceptance value. This smart system, inbuilt with periodical calibration feature to en sure the measured thickness values are accurate. It can be set how frequent this verification is needed. Apart from providing this quality features, this system is also capable of producing output which is equivalent to 5 inspectors output. It can be adapted to similar kind of inspection tasks.

Keywords: Non-destructive testing, Robot, Ultrasonic Thickness Measurement.

14-C

AN INNOVATIVE FLUORESCENT LEAK TEST OF PLATE TYPE AIR PREHEATER

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Abstract

In era of globalization and competitiveness, it has become important to run the industry either uninterruptedly or reducing the shutdown time of equipment/plant. This will not only increase the profit of company but also reduce the maintenance cost to a great extent. NDT plays a major role to reduce the breakdown/shutdown time of equipment and thereby of plant.

GNFC, a fertilizers and chemicals company, has established a well organized, full-fledged NDT laboratory to check the condition of any equipment and help the maintenance to carry out maintenance in more planned and organized manner with a view to reduce shutdown time.

A reformer, with air and gas circuits, is provided in Synthesis Gas Generation Unit plant. Passing of air was reported by operation group with an air leak rate of 2600 nm3/Hr from air path to gas path. It was judged that air was leaking only from plate type Air Pre-heater. There was no popular and established NDT method available to check the leaky area in plate type heat exchanger. GNFC has developed a complete test method using company developed fluorescent powder to identify the leaky locations in plate type heat exchanger. A successful implementation of this innovative test method has reduced the leak rate from 2600 nm3/hr to 500 nm3/hr after adopting very precise maintenance practice. This has postponed the management decision of replacing Air Pre-heater, costing Approx. Rs. 65 Millions.

15-C

CHARACTERIZATION OF STRESS CORROSION CRACKING IN PIPELINE WELDS USING ULTRASONIC PHASED ARRAY TECHNIQUE

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Abstract

Presence of stress corrosion cracking in sensitized austenitic stainless steel welds, especially in pipelines of boiling water reactor (BWR) was discovered years back and has been a matter of concern since then. The integrity of these components is central to the safe operation of nuclear plants. It is mandatory to carry out periodic in-service inspection of critical components to monitor their degradation due to various damage mechanisms that are possible depending upon the material-environment combination. It is of utmost importance to apply NDT techniques that are reliable for detection of all the significant flaws and accurate in their characterization. Phased array ultrasonic technique (PAUT) is an advanced technique that offers high reliability in law detection and better accuracy in flaw characterization.

The quality of data produced by PAUT in terms of its usefulness for accurate flaw characterization depends a great deal on the parameters used for PAUT viz. Aperture size and Focal laws. A systematic study has been carried out to optimize these parameters for examination of heat affected zone in primary pipeline welds for detection of stress corrosion cracks. This paper describes the results of ultrasonic simulation and experimental work towards optimization of PAUT parameters to achieve good resolution and accuracy in characterization of IGSCC cracks at ID and OD weld HAZ.

Keywords: Phased array, Austenitic stainless steel welds, IGSCC, Ultrasonic simulation,

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NDE CERTIFICATION ON AEROSPACE

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Abstract

NDE certification is a wide spectrum covering the fields of Nuclear, Oil & Gas, Automobile, Manufacturing, & Construction. There are many different NDT central certification agencies and employer based certification programs, some of the central certification are by ASNT, BINDT, ISNT, etc. The employer based SNT-TC-1A is an ASNT's recommended practice for the qualification and certification of NDE personnel by their employer's, likewise the NDT certification procedure in aerospace industries is based on NAS410 (National Aerospace Standard - 410). It is now 19 years since the issue of the NEW edition and it is more stringent compare to other standards, as the tested components application are serving under adverse conditions. The application of NDT is more critical and important in the aerospace and defence industries. This paper highlight the important aspects of the employer based qualification and certification programme in accordance with NAS 410.

17-C

ULTRASONIC SIMULATION STUDIES FOR SIZING OF PLANAR FLAWS IN THICK CARBON STEEL WELDS

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Abstract

Ultrasonic non-destructive testing typically involves detection of flaws that may affect the integrity of component under test. Once detected, the flaw is sized for its critical dimensions and its nature. The detection of flaw in the component by ultrasonic test is based on the principle of echo or reflection. Once the echo from a flaw is received, there are several approaches for analyzing the signal so that more and accurate information is obtained on the size of the flaw and its nature. The 6dB drop method is commonly used for sizing of flaws. This technique is based on determining the end points where the ultrasonic signal amplitude from the flaw drops to half of the peak amplitude. Though this method works well for large flaws whose size is larger than the beam width, it has a tendency to oversize the flaw which is smaller than the beam dimensions. In addition to beam divergence, flaw sizing also depends upon the orientation of the flaw with respect to incident sound beam.

Two different angle beam probes are commonly used for ultrasonic inspection of thick welds. Simulation studies were carried out to understand the effect of beam divergence and flaw orientation on sizing of planar flaws using 45 & 60 deg probes. During simulation study the flaws of different orientations and sizes present at different depths from the scanning surface are introduced in a thick block. Signal amplitude from these flaws with respect to reference and their 6 dB sizes from the B-scan image are obtained. The flaws are also sized by tip diffraction techniques. A methodology to be adopted for sizing crack like flaws in thick sections is formulated based on the simulation results. The paper describes the results of simulation studies on ultrasonic response from planar flaws of various orientations, their imaging and the methodology to be adopted for their accurate depth sizing. The paper also describes the experimental results to validate the flaw sizing approach.

Keywords: Planar flaws, 6 dB drop, tip diffraction, ultrasonic imaging.

18-C

RADIATION PROTECTION & PERSONNEL SAFETY IN INDUSTRIAL RADIOGRAPHY

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Abstract

Due to availability of a variety of radioisotopes from BRIT, a considerable number of industrial organizations have come up in India which employ radiation sources in one form or the other. More such organizations may come up in the near future due to the "Make in India" policy of the Government

All ionizing radiations, whether electromagnetic (gamma-ã) or corpuscular (particles of alpha-á, or beta-â-), and neutrons (0n1) are harmful to the human body. The damage done by radiations is sinister as human senses are not capable of detecting even lethal doses of radiation. The dose of radiations absorbed by human body which take into account the biological effectiveness of different types of radiations as noted above. The overall outcome of exposure to radiation is initiated by damage to the cells of the organism. The effects of radiation may be deterministic or stochastic, early or late, of somatic or genetic type. The somatic effects (physical) can either be immediate or delayed when the whole body is acutely irradiated with radiation doses:

ICRP, a division of IAEA, is engaged in providing rules and Standards for the radiation protection. ICRP has established the values of permissible cumulative doses for a year for occupational and non-occupational radiation workers. These are indicated in the present paper.

All countries including India have brought their national laws / standards on ionizing radiation in line with the ICRP codes. The conditions for registration, transport, storage, protection and use of radiation sources have been laid down in regulations. The purpose of practical protection against radiation is to prevent any individual receiving a harmful dose.

Radiation measurement Instruments like dose meter, pocket dosimeter, NaI(Tl) scintillation detector and recording instruments such as film/TLD badge have been briefly described.

Radiation hazards control includes:

- Distance: Radiation exposure level which obeys the inverse square law I1 / I2 = (d2)2/ (d1)2
- Time: total dose received by the operator is directly proportional to the total time spent. D " T
- Shielding: whenever X-rays/Gamma-rays/Neutron pass through any medium their intensity will be attenuated exponentially I = B I0 e-ì x

Enclosed as well as field/open radiography Installations have been explained for radiation protection and personnel safety.

19-P

AUTOMATED EDDY CURRENT TESTING SYSTEMS FOR VARIOUS INDUSTRIAL APPLICATIONS

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Abstract

In recent years among different NDE Methods used for inspection in various industries Eddy Current Examination Method has become popular for detection of mainly surface flaws in large number of industrial items. To meet large production inspection requirements, automated ECT using on line or off line systems have been developed and are in very much use by various units manufacturing Black Bars / Bright Bars / Tubes. The paper deals in particular with ECT systems for inspection of Bright Bars.

ECT System for Bright Bar Inspection:

Multi-channel Eddy Current Test System for detection of longitudinal surface flaws using Rotary Probes and Encircling Coil for detection of transverse surface flaws in bright bars.

The paper mainly describes in brief the Test System, Test Technique, ECT Probes / Coils used in the system, Reference Calibration Standard used, Marking & Sorting arrangements, Data Logging and Test Report Generation.

Keywords: ECT Bright Bars, Rotary Probes.

20-C

EDDY CURRENT ARRAY TECHNOLOGY ON CRA – LINER PIPES

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Abstract

Eddy current technology has been used for many years to inspect the surfaces and sub-surfaces of various components across a wide range of industries. Conventional eddy current have limited scope to inspect higher thickness of non -ferrous materials, accessibility and defect orientation in single pass.

Eddy Current Array (ECA) technology is a more efficient technique by usage of couple of advanced coil configurations in sequential manner to improve the sensitivity, large area coverage with high probability of detection and provides real-time cartography of the inspected region, facilitating data interpretation. ECA is well suited for complex geometry. This paper discusses the application of eddy current Array technology on CRA liner pipes (Inconel 625) for volumetric integrity check. Established a setup made for detecting longitudinal and transverse discontinuities located along the long seam, Internal and Outer diameter of the pipe by single side scan. Data display C-scan, 3D view and phase drawing is well suited for Ascertaining the all category of discontinuities. Channel multiplexing of the instrument and probe impedance topology offers an enhanced S/N ratio and high level of sensitivity with capable of detecting discontinuous in any orientation.

Keywords: Eddy current array, multiplexing, topology, cartography, CRA-Liner

21-C

EXTRACTING THE PORE STRUCTURE FEATURES OF CEMENT BASED MATERIALS USING 3D X-RAY COMPUTED TOMOGRAPHY

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Abstract

3D X-ray Computed Tomography (CT) is a powerful tool in assessing the pore structure features of cement based materials. In this study, X-ray CT testing was performed on different cement paste specimens incorporated with nanomaterials such as reduced graphene oxide, aluminium oxide, and colloidal silica respectively. The assessment was conducted to determine the influence of nanomaterials on the pore refinement of cement paste. The acquired tomographic images were processed with the image analysis software and further analyzed to determine the pore area fraction and volumetric porosity of cement pastes. In addition, the paper also presents the pore area fraction of enhanced porosity concrete specimen tested using 3D X-ray CT device.

23-C

DEPLOYMENT OF WELD INSPECTION MANIPULATOR FOR RPV UPPER SHELL WELDS OF TAPS-1&2

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Abstract

The reactor pressure vessel (RPV) of TAPS-1&2 is made up of three cylindrical shell courses and spherical cap shaped bottom head which are joined together with longitudinal and circumferential welds. Periodical in-service inspection of these weld joints is mandatory regulatory requirement to get relicensing for further operation of the reactor. Approaching these welds for inspection from OD side of the RPV is a difficult and tedious task. Inspection from inside surface was also not tried earlier as probes are required to be taken under water at depth of 10-12m remotely. A simplified Weld Inspection Manipulator (WIM) was designed & manufactured within short span of four months to approach upper shell welds. WIM provides automated scanning motions to the ultrasonic and eddy current inspection probes and position feedback to the data acquisition system while assuring proper contact of the probes on inspection surface which have undulations of un-machined cladding. WIM has been deployed successfully in the 22nd refueling outage of Unit#1 in July 2012 followed by Unit#2 in 2013 and again in Unit#1 in 2015, each time with improvements in areas such as automation, probes contact, co-ordinates repeatability and additional probe holders. In this article mechanical design features and operating control system of manipulator are described.

25-C

DETECTION OF VOID IN SODIUM COOLED FAST REACTORS USING EDDY CURRENT BASED TECHNIQUE

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Abstract

In sodium cooled fast reactors, argon is used as cover gas above the sodium free sur-face to isolate the sodium hot pool from outside environment. Entrainment of argon gas into the core of the reactor is always possible in nominal or accidental conditions by means of various mechanisms inside the hot pool viz. free level fluctuation, vortex formation etc. This entrainment of gas creates void (absence of sodium) in the core and is undesirable as it may lead to reactivity fluctuations, reduced heat transfer in IHX and also result in measurement disturbances. A flow meter is developed in-house based on eddy current technique, named as Eddy Current Flow Meter (ECFM) for measurement of sodium flow through individual subassemblies during reactor shut-down. Studies were carried out in sodium loop using Eddy Current Flow Meter to de-tect the gas entrainment during reactor operation. Argon gas was injected into sodium system at different mass flow rates and different sodium flow rates to simulate void fraction in the range of 0 to 2%. ECFM primary and two secondary coil signals were acquired during argon injection experiments. Experiments were carried out at sodium temperature of 300°C.Void induced signals were extracted from the flow induced signals and correlated to the void fraction. It was observed from the experiments that gas entrainment could be detected by means of eddy current flow meter. This paper presents the details of the ECFM, experiments carried out in sodium system, results and conclusion.

Keywords: Fast Reactors, Gas entrainment, Eddy Current Flow Meter.

26-C

HEALTH MONITORING OF AERO ENGINE COMPONENTS BY AUTOMATED EDDY CURRENT INSPECTION

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Abstract

Critical components of Aero Engines (both Helicopter and Aero planes) are subjected to high stress, high temperature, corrosive environments and cyclic loading conditions during service. Hence the serviceability of these parts are to be monitored after certain hours of engine running i.e during overhaul and repair. A few Non Destructive Testing (NDT) methods are involved in assessing health of the critical components during repair and overhaul.

This paper details one of the NDT methods viz. Automated Eddy Current Inspection by using CNC based up and down system with Eddy Current Testing equipment Elotest B 310 and standard calibration blocks with simulated defects to find out fatigue cracks in Critical Components viz, 1st Stage Axial Wheel, Centrifugal Impeller, High Pressure Turbine Disc and Power Turbine Disc of Helicopter Engine during repair and overhaul.

Keywords: NDT: Non Destructive Testing, CNC : Computer Numerical Control

27-C

QUANTITATIVE INTERFACE EVALUATION OF RF CONNECTORS BY NON-DESTRUCTIVE TESTING (NDT)

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Abstract

The high precision microwave passive connectors are widely used in RF cable joints especially in radars for effective signal transmission. The mating efficacy of these connectors should be perfect and as prescribed by relevant standards in order to ensure their reliable functioning. Presently, various international standards like MIL, ASTM etc., are in vogue for making quality interface joints which qualify for class 'A' applications. But, the critical dimensional mating details of the connectors are not inspected or verified after assembly which is highly desirable especially in important Space applications. A few publications available in literature suggest the sparse use of neutron radiography (NR) to ensure adequacy of Teflon placement but not for assessing interface details. The authors embarked upon the idea of employing conventional radiographic imaging of the connector assembly of about 4600 numbers and quantitatively ensuring the integrity of the interface using scanning micro-densitometer and the details are outlined in this paper.

Keywords: Radiography, Microwave Connector, FFD, microdensitometer.

29-C

AUTOMATIC INSPECTION SYSTEM FOR PELLETS OF FAST BREEDER REACTOR

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Abstract

Indian nuclear power program has three stages. Pressurized Heavy Water Reactor (PHWR) is the first stage and Fast Breeder Reactor (FBR) is the second stage. An automatic inspection system for pellets of FBR is under development at BARC, Mumbai.

Fuel material of nuclear reactors is compacted into small cylindrical pellets which are used to fabricate a fuel assembly. Defective pellets may break or hamper heat transfer if put to use in nuclear reactor. Critical inspection needs to be carried out for these pellets to avoid defective pellets going into the reactor. The False Positive of the inspection has to be very low.

Presently these pellets are being inspected manually. The Automatic Pellet Inspection System takes images of the cylindrical surfaces and subjects them to image processing algorithms. Software algorithms are developed for detecting defects viz. Chips on flat ends, Chips on edge, Chips on body, End Flakes, Circumferential cracks, Longitudinal cracks, Branched cracks, Pits, Body Crazing, End Crazing and Inclusions. Depending upon the decision whether to Accept/Reject the pellet, the pellet is placed by a mechanical pellet handling machine either onto a tray or reject bowl.

Though pellets for FBR and PHWR are cylindrical, FBR pellets vary drastically in terms of the material used, its size and surface texture. The system development is all the more challenging because FBR pellet is very small in size and has shiny surface.

The paper shall describe the APIS system in general; and pellet image acquisition and image processing algorithms in particular.

Keywords: Surface inspection, Nuclear, Pellet Inspection, FBR, Image Processing

31-P

DESIGN AND DEVELOPMENT OF ADVANCED DRIVE MACHINE FOR COOLANT CHANNELS INSPECTION OF 540 MWE PHWRS

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Abstract

Periodic In Service Inspection (ISI) of Pressure Tubes of PHWRs is a regulatory requirement to demonstrate their fitness for service. Pressure tubes are susceptible to various degradation mechanisms, which are reflected by various parameters. These multiple parameters are monitored using inspection tools developed for the purpose. Currently available tools are semi automatic, require human intervention at reactor face and offer limited length of inspection head, requiring multiple visit of tooling for comprehensive monitoring. Monitoring of multiple parameters in minimum time with minimum exposure to operating personnel is vital for capacity factor of the plant. Design of Delivery Equipment for inspection tools is governed by above requirements. Advanced Drive Machine (ADM) for 540 MWe PHWRs is designed for delivering inspection tool into the coolant channel meeting above design goals. The machine

is mounted on top of Fuelling Machine Bridge. After installation, machine is operated remotely from a control room and inspections are carried out without any human intervention. ADM has features for auto alignment, clamping with the channels, two stage telescopic ram and synchronized cable feeding mechanism. AC servo motors are used as actuators for various drives and meet the positional accuracy requirements. The striking feature of ADM is use of split plug, which allows entry of 102 mm diameter inspection head and makes the machine compact by avoiding need for magazine. Machine also has capability of delivering maintenance tools like sliver sampling tool, in-situ property measurement tool, replica tool etc. The machine is designed, manufactured and tested in reactor simulated conditions.

32-C

INNOVATIVE TOOL FOR ID MEASUREMENT OF COOLANT CHANNELS OF PHWRS

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Abstract

In PHWRs, fuel bundles are contained in Pressure Tubes. These tubes guide coolant to pass through fuel bundles and enable heat removal. The gap between fuel and Pressure Tube is kept minimum, to allow movement of fuel in anticipated sagged channel and guiding maximum flow through bundle. ID of the tubes increases over the time due to neutron flux and temperature, resulting in lesser heat removal from fuel, which increases chances of fuel clad failure. It is important to monitor increase in diameter to avoid fuel clad failure. The ID is conventionally measured by Ultrasonic Techniques, which requires special machine to be installed on the Fuelling Machine bridge. Increased ID is one of the principal aging mechanism of pressure tubes in PHWRs, hence en-mass monitoring is advised by regulators. An innovative, fuelling machine operated tool is developed for mass scale measurement of Pressure Tube, this tool can be deployed without much preparation and uses existing setup resulting in saving in time and man-rem. The uncertainty in measurement is found to be ±100 ì m. The tool was successfully used in reactor for ID measurement, with some abnormal readings in high sagged channels. The re-engineered version of the tool is developed to get readings in high sagged channel and having enlargement in diameter upto 5%. The tool is tested in full length sagged channel successfully. This paper describes details of the tool with experimental results.

33-C

X-RAY INDUSTRIAL COMPUTED LAMINOGRAPHY (ICL) SIMULATION STUDY OF PLANAR OBJECTS: OPTIMIZATION OF LAMINOGRAPHIC ANGLE

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Abstract

X-ray Industrial Computed Laminography (ICL) is a non-destructive three-dimensional (3D) imaging technique for high aspect ratio planar objects such as printed circuit boards and stacked IC. Complementing to the established method of X-ray Industrial Computed Tomography (ICT), ICL is based on tilt orientation of the planar object with respect to incident X-ray beam by a defined angle. The tilt angle of the planar object is called laminographic angle. Knowledge about the laminographic angle is very important for optimizing reconstruction quality of planar objects. This paper presents optimization of laminographic angle using simulated planar object in cone-beam geometry. Root Mean Square (RMS) contrast is used to characterize the effect of the angle on reconstruction quality. Simulated

cone-beam projections (radiographs) were generated from different angles by rotating tilted planar object. FDK (Feldkamp, Davis and Kress) reconstruction algorithm was then adapted to reconstruct the planar object from the radiographs. Best reconstruction results are obtained when an optimal laminographic angle of 45 degree is used for data acquisition. The simulation study can be employed for in situ testing of planar specimens.

Keywords: X-ray Industrial Computed Laminography (ICL), Non-destructive, X-ray Industrial Computed Tomography (ICT), RMS contrast, FDK reconstruction algorithm.

34-C

RECONSTRUCTION FILTERING IN INDUSTRIAL GAMMA-RAY CT APPLICATION

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Abstract

Motivation: Industrial gamma-ray Transmission Computed Tomography (TCT) scanning is used in Single Photon Emission Computed Tomography (SPECT or ECT) imaging to obtain attenuation maps. The knowledge of attenuation due to waste matrix is required to characterize activity level and distribution of gamma emitting radioisotopes inside nuclear waste containers.The attenuation maps are generally noisy due to sparse sampling and less available photon statistics in data collection in SPECT imaging. Image noise and spatial resolution play very important roles in image quality. The problem of noise in TCT is usually handled with the application of low-pass digital filters. No single set of filter parameters stands out as being best for all applications. Each application requires careful study and evaluation of filter parameters to match test constraints and requirements. In this study, effects of filter parameters have been evaluated for Industrial d-ray CT application.

Materials and Methods: The experimental projection data were acquired on a prototype waste drum using a 12 mCi collimated Cs-137 radioactive source and x 1 inch x 1 inch NaI(Tl) scintillation detector with associated electronics. The attenuation maps were reconstructed using filtered back-projection technique.

Results: The filters were evaluated both qualitatively and quantitatively from reconstructed images. The quantitative analysis was carried out based on Root Mean Square error (RMSE) and Signal-to-Noise Ratio (SNR).

Keywords: Single Photon Emission Computed Tomography (SPECT or ECT), Transmission Computed Tomography (TCT), digital filters, Root Mean Square error (RMSE), Signal-to-Noise Ratio (SNR)

35-C

DEVELOPMENT OF A GAMMA RAY BASED LIQUID LEVEL SENSOR FOR DETECTING LEVEL OF LIQUID INSIDE AN OPAQUE CONTAINER FOR INDUSTRIAL APPLICATIONS

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Abstract

Gamma based level sensor is an equipment to account for the amount of fire extinguishing liquid inside a fire extinguisher by detecting liquid level. It is useful at various places where maintenance of fire extinguishers is essentially required. The principle used in this equipment is linear attenuation coefficient of liquid and gas for gamma ray. Major components in this device are a gamma source, a gamma detector and microcontroller based electronic circuit. When gamma rays pass through fire extinguisher cylinder, it has different attenuation for liquid filled part and empty part of cylinder. This device uses this difference in gamma attenuation for liquid filled part

and empty part of cylinder to detect level of extinguisher liquid while scanning from bottom to top. This device has two modes of operation i.e. Calibration and Detection. Calibration mode used to calibrate device for specific diameter of cylinder. After a single calibration, this device can be used to detect liquid level of any number of cylinders of same dimension. This device has to be recalibrated for different dimension of cylinder. Detection mode is used to detect level of extinguisher liquid in cylinders. This tool simplifies the accounting of extinguishing liquid amount in fire extinguisher compared to pneumatic sensor or weighing method of cylinder as the device is light weight and it didn't required cylinder to be lifted or shifted from their place.

*Keywords***:** Fire extinguisher, level sensor, gamma rays, microcontroller, attenuation coeff.

36-C

DEVELOPMENT OF SOFTWARE APPLICATION TO AUTO-GENERATE RT-1 EXAMINATION QUESTION PAPER

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Abstract

Industrial radiography involves extensive use of x-ray and gamma-ray radiation. Hence trained manpower is required to avoid accidents and control the harmful effects of radiation by safe handling and work procedures. Radiography testing (RT-1) certification program accomplish this need. It educates, prepares, and makes Radiographic Testing personnel capable for the work. Therefore truthful evaluation of each person, after imparting training (RT-1), is very important in making decision to certify a person as a trained radiographer. Radiography testing examinations are conducted by BARC as per the ISO-9712 guidelines. The examinations are conducted setting up question papers covering all the topics covered during the training. However, due to drastic increase in the number of courses in last five years, it became difficult to keep track of recurrence of questions and weightage of each topic during manual setting up of question papers. To overcome this difficulty software called 'Quickpaper' is being developed indigenously. The software has facility to securely create topic wise question bank. These questions can be classified in three grades as easy, medium and difficult. To generate the question paper, software has automatic and manual option. In manual option user can select the questions from the listed topics as per category. The software is tested successfully by generating multiple choice question paper with its answer key for RT-1 general examination.

Keywords : Radiography Testing, RT-1, software, gamma radiation, question paper

37-P

UNCERTAINTY MEASUREMENT IN MOBILE OPTICAL SPECTROMETER

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Abstract

Chemical properties of the raw materials, used during fabrication of various components for industries are identified normally from manufacturer's test certificates. When a separate representative sample of the component is not available, identification of materials are made directly on the component using portable X-Ray Fluorescence (XRF) or mobile OES. In order to compare the results of Mobile OES vs. Lab OES, Uncertainty in measurements between Lab version and mobile version OES was done for major and minor elements of the SS material samples. A CRM sample conforming to SS304L and SS316L along with one set of SS samples from various projects were selected

and the chemical composition of each samples was tested using mobile version OES. The same samples were tested at three different NABL accredited labs at Chennai using Lab version. The expanded uncertainty for each method was calculated using standard NABL 141 and results was plotted. It was observed that Uncertainty of the Mobile OES results is very closer to the Lab version for all elements except a slight variation in Cr and Ni by 0.1% in terms of uncertainty. When comparing the actual compositions, the amount of percent composition of the Cr and Ni element is lesser than the lab version values and the variation is within the permitted tolerance values. The study had given valid information for improving confidence and helps to standardize the test procedures for material identification.

38-P

NON DESTRUCTIVE EVALUATION STUDIES OF WELDED EN-08 MILD STEEL SPECIMEN

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Abstract

Non Destructive Evaluation Studies of Welded EN-08 Mild Steel Specimen paper describes the basic Nondestructive methods like liquid penetration test, magnetic partial, ultrasonic investigation on TIG welded EN-08 mild steel material with dimensions of 250*150*10 mm been taken for these studies. This material largely used for machining and structural work Specimen is fabricated with Tungsten Inert Gas welding (TIG), heat effect zone and weld region is inspected for study and correlated. Flaws are identified with high accuracy of location and intensity. Authors are grateful for AICTE for sanction of grant-in-aid to carry the project work.

39-C

INDIGENOUSLY DEVELOPED FULLY AUTOMATED TOMOGRAPHY GAMMA SCANNER FOR ASSAY OF DRUMMED NUCLEAR MATERIAL

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Abstract

A fully automated, Waste Inspection Tomography (WIT) gamma scanner system consisting of servo mechanism based Vertical source (152Eu) and detector assemblies, Horizontal detector assembly, Drum translation / rotation assembly, Variable size Tungsten collimator assembly has been indigenously designed, fabricated and installed at RSD, IGCAR. It is a high resolution gamma ray spectroscopy based Transmission corrected; single photon emission computerized axial tomography system. This system visually indicates the location and activity of Trans-Uranic (TRU) elements and fission products in a radioactive waste drum. In this system a high resolution gamma ray spectrometry consisting of an HPGe Detector, Multi channel analyzer (MCA) and associated detector electronics is used. The WIT system is fully automated with horizontal detector sliding and attenuator assembly for avoiding the pulse pile up due to high dose rate from the drum. The spatial resolution of tomography measurement is optimized by the variable size tungsten collimator aperture. In line conveyor system transfers the waste drum to a palette centrally located on a translator/rotator platform. The pneumatic solenoid based source shutter open during the transmission scan and close during the emission scan and during the power failure. All the pneumatic operations

are controlled by Programmable Logic Controller (PLC). The MCA data collection, servo movement and PLC I/O operation are synchronized with help of C# based Supervisory Control And Data Acquisition (SCADA) software. The tomographic images are reconstructed using Algebraic Reconstruction Technique (ART) and Maximum Likelihood expectation maximization (MLEM) algorithms. The details of the WIT system are presented in this paper.

Keywords: Radioactive waste; Tomography gamma scanner; Nondestructive assay; HPGe detector; SPECT

41-C

NON DESTRUCTIVE EVALUATION OF PI FLASK OF PFBR BY GAMMA RADIOMETRY

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Abstract

A 500 MW (t) Prototype Fast Breeder Reactor is nearing completion at Kalpakkam by Bharathia Nabhikiya Vidyut Nigam Limited. In this reactor, sodium will be used as a coolant due to its excellent thermal conductivity and very low neutron absorption / moderation. During the course of reactor operation, this sodium becomes radioactive due to neutron activation. In PFBR, PI flask shells are used to handle primary sodium pump and inter mediate exchanger for repairs/replacements, transport to storage locations and decontaminations pits. These flask shells are steel lined annular structure filled with lead shots of packing density of 7.0 g/cm^3. Evaluation of shielding integrity is essential to avoid exposure to operating personnel from streaming radiations. Due to the high attenuation coefficient of lead coupled with large thickness of the order of 73 mm, conventional x-ray techniques cannot be used. High energy radiography is a possible solution. However, moving these to such places is difficult. At the authors lab an gamma radiometry based NDE technique has been successfully adopted for verification of shielding integrity of such shields. ^{60}Co of strength 93.98 MBq and NaI(Tl) detector based portable radiation survey meter was used for testing. This paper focuses on the methodology of radiometric testing of PI flask, challenges involved in successful application.

Keywords: PFBR, Liquid Sodium, PI flask and Radiometry

42-C

NDE IN BIOMEDICAL ENGINEERING

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Introduction:
Biomedical Engineering (BME) is an interdisciplinary field, marking the conjunction of Medical and Engineering disciplines. It combines the design and problem solving skills of engineering with medical and biological sciences to advance health care treatment, including diagnosis, monitoring, and therapy.

Role of NDE in Biomedical Engineering:
Throughout history, a persistent goal of medicine has been the development of procedures for determining the basic cause of a patient's distress. As a result, the search for tools capable of ''looking into'' the human organism with minimal harm to the patient has always been considered important. Today, modern imaging devices, based on fundamental concepts in physical science (e.g., x-ray and nuclear physics, optics, acoustics, etc.) and incorporating the latest innovations in computer technology and data processing techniques, have not only proved extremely

useful in patient care, they have revolutionized health care. NDE plays a pivotal role in Biomedical Engineering. Various NDE Techniques have been used for the analysis of human bodies to diagnose the diseases. They include Computer Tomography (CT) scans, Magnetic Resonance Imaging (MRI) and Diagnostic Ultrasonic Imaging. BME, in India, is largely connected with the sales branch of the industry, rather than the core technical part of the industry, to which it is actually related. Outside India, however, BM Engineers are perceived as Engineers and not as auxiliary technical assistants.

Make In India campaign is promising to achieve the very same goal, as a lot of BM engineers would be required to handle the technical requirements of the NDE machinery manufactured in India.

Conclusion: NDE techniques are used for the same purpose in BME as in mechanical industry – to detect the disease by imaging. But detecting a disease is, in itself, partially curing it.

Keywords: Biomedical Engineering, Non-Destructive Evaluation, Make In India

43-C

PAUT AS TOOL FOR CORROSION DAMAGE MONITORING

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Abstract

Corrosion assessment/monitoring is essential to know the service life of the pipeline/piping assets by estimating the extent of damage due to corrosion/erosion. The present trend of corrosion damage assessment/monitoring is to carry out screening of pipelines/piping and verifying its findings for defect sizing using Ultrasonic Thickness Gauge (UTG). Monitoring corrosion with UTG is not effective and cumbersome technique as one has to make grids to cover maximum area and due to time-consumption.

The sensitivity of corrosion monitoring with UTG increases with maximizing the grids, which account for loss of time and money. This paper discusses the advantage of using Phased Array as a sizing tool for corrosion monitoring in pipeline and static equipment with various site results. A comparative study between PAUT and UTG as a corrosion monitoring tool with respect to accuracy, time of inspection, sensitivity, POD and reporting shows that PAUT as Corrosion Damage Monitoring tool yield's the maximum safety of manpower, nature and equipment's which indirectly helps to boost the growth of organization and country.

44-P

SURFACE MODIFICATION OF DUAL PHASE STEEL BY USING HIGH POWER ULTRASONIC TREATMENT

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Abstract

Ultrasound vibrations are long been known to have potential in improving the quality of large sized castings when liquid metals transform into solid shapes. The important advantages of the application of vibration to solidifying castings are: (i) grain refinement, (ii) homogeneity of structure and properties, (iii) reduced micro-segregation and (iv) improvement of mechanical properties such as hardness, yield strength, ultimate tensile strength, elongation and reduction of area for almost all material tested. However, the application of Ultrasound waves in modifying the structure and properties of solid-state metallic materials appears to be relatively less common in industry. In this

work high intensity ultrasonic experiments were carried out on a few grades of steels, mostly for automotive applications. Grades of steels chosen for the study possessed yield strength varying from 250 MPa to 500 MPa. Samples were taken from industrially processed hot-rolled (HR) strips with either ferritic or a dual-phase (ferrite-martensite type) microstructure. Ultrasound waves of 20 kHz frequency were passed through the specimens for about half an hour time at room temperature. Change in hardness was measured for each sample and correlated with the micro-strain as analyzed by Williamson Hall plot of x-ray diffraction data obtained by an extremely slow speed scan with Cu target. From the result of hardness measurements of various grades of steel before and after ultrasonic treatment it appears that the change in hardness due to Ultrasonic treatment is appreciable for softer variety grades but not so prominent for the high-strength steels.

Keywords: High intensity ultrasound, hardness, surface property

45-I

USE OF ADVANCE NDT TECHNIQUES(TOFD-PAUT) FOR REDUCTION OF PROJECT DURATION

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Abstract

In the present competitive market where project size and cost is going higher and higher , every client wishes to minimize project duration so that project cost can be maintained within the budgeted cost and breakeven point can be achieved within shortest possible time.This has put more pressure on delivery cycle time of shop supplied items particularly critical long delivery items like reactors, main compressors, columns etc coming in the critical path of project delivery schedule.

With the advent of new technologies like TOFD and PAT, digital RT etc in the field of NDT, manufacturing sectors particularly fabrication industries could reduce delivery cycle time for many critical equipments like AD/VD columns, reactors etc to a great extent but still lots of gap are to be filled up to reduce the delivery cycle time of these items. With modular concept, delivery cycle time for many more units are been reduced considerably by completing maximum work at manufacturer's fabrication yard and minimizing site work which is normally time taking due to many adversities.

With all these, probably squeezing delivery of supplied items will reach to a level, beyond which further reduction in delivery time will be a very challenging one.

- On the contrary , very little progress has been made to minimize activities which are to be done at construction site only. Two such activities where NDT plays a major rule are

  Successful completion of piping weld joint/NDT and Hydrotest. Completion of many projects gets lingered till last moment for completion of piping joints welding and radiography of various sizes which are rationalized by Inch diameter count.

- RT of site joints and joints of large equipments which are completely fabricated at site

For piping joints (shop as well as field joint) particularly for large diameter joints which constitutes around 20% of total Inch. diameter count, TOFD in combination with tandem focused beam pulse echo (for top and bottom surface near zone area) technique can be used .

For small dia. Pipe wherein, there is no alternative of RT , can be substituted by digital RT . This will reduce considerable time with respect to conventional manual RT taking long time for manual processing , re-shot , re take etc.

For Large equipment like Horton spheres, mounted bullet etc. which are completely welded at site, TOFD plus PAT or TOFD with tandem focused probe (for top and bottom surface near zone area) can be used very effectively and NDT time requirement can be minimized. However, to achieve the same, lots of customization will be required to be carried out by Indian NDT agencies for effective utilization of advance techniques in the field of NDT. Manufacturer of NDT equipments in India needs to absorb the technology and do necessary modification in the accessories which will help in customization of these modern NDT equipment for effective use at construction site.

Industry leaders in the field of NDT equipment manufacturer needs to be encouraged to set up their manufacturing facilities in India to serve the Indian project site as well as the total Indian sub-continent.

Customer awareness will also play a vital role for progress in this field since ultimately Customer/consultant will decide whether to use these advance technology for reduction in NDT time requirement at project site.

46-C

NEXT GENERATION PHASED ARRAY ULTRASOUND: ADVANCEMENTS IN TOTAL FOCUSING METHOD AND FULL-MATRIX CAPTURE TECHNIQUES

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Abstract

Total Focusing Method (TFM) imaging is revolutionizing phased array ultrasound. TFM is a post-processing technique that can be implemented real-time using Full-Matrix capture (FMC) data and other technological advancements. TFM provides several benefits over conventional Phased Array in terms of a high resolution reconstruction grid, better perspective, improved vertical and lateral resolution, higher signal to noise ratio, improved flaw definition and reduced misinterpretation of geometry echoes vs. defects. One known characteristic of FMC is that it requires large amounts of raw data to compute a TFM image. The instrument used for the experiments has more than enough data transfer capability at 140 MB/s. This paper will present improvements to speed up and optimize both FMC and TFM while keeping and in some cases improving signal-to-noise ratio. Furthermore, with a small form factor, advanced high resolution imaging capabilities that were once only lab capable can now be industrialized and even automated using scanners and robots.

47-P

CHALLENGES IN QA AND NDE DURING PROCUREMENT OF AUSTENITIC STAINLESS STEEL PLATES / SHEETS

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Abstract

An integrated fuel cycle facility is under construction inwhich concentrated nitric acid would be used as a process fluid. Austenitic stainless steel of grade 304L is the candidate material for lining of cells, vessels and piping. Fuel cycle facilities are constructed with minimum or zero maintenance due to high radiation & acidic environment. Hence, stringent quality requirements have to be followed right from the raw material procurement. This paper mainly focuses on the quality assurance & NDE aspects followed during procurement. The tramp/residual elements control in the source for melting is emphasized including Cobalt level to get controlled chemistry than that of ASTM A 240. Stringent requirements are specified in grain size control and inclusion rating, since latter have impact on

tunneling corrosion of stainless steel under nitric acid service. Intergranular corrosion testing as per ASTM A262 are specified to have check on IGC & effectiveness of solution annealing. 100 % Visual and dimensional inspection of around 19000 nos of plates / sheets possess bigger challenge. Ultrasonic testing (UT) of thin plates like 6 mm thickness with Ö2 mm flat bottom hole (FBH) as reference needs proper control over probe selection, scanning and technique selection. An automated facility with 5 probes (4 SW + 1 LW) is used to carry out UT with normal & angle beam with much more stringent acceptance criteria. This well executed & documented quality assurance practices can be used successfully in the upcoming plants too. Keywords: Austenitic Stainless Steel, Quality assurance, Automated UT, Inclusion control

48-C

DIGITAL PROCESSING OF RADIOGRAPHIC IMAGES OF AEROSPACE COMPONENTS FOR HIDDEN FEATURES EXTRACTION

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Abstract

Digital Image processing is a powerful tool in the field of digital radiography. It is highly useful in extracting hidden features that are not seen in normal image. Systematic and sequential application of the different image processing techniques is essential for extracting the required information from the image. Pyro devices are important satellite launch vehicle components used for different applications like ignition, stage separation, satellite separation etc. These devices are single shot devices and any malfunctioning of the items leads to mission failure. Because of the intrinsic construction of certain pyro devices, required information and any minor flaws are not clearly distinguishable on a normal image. Hence image processing techniques are highly helpful to bring out the hidden details.

In the present study, frequency domain and time domain analysis has been carried out on radiographic images of Flexible linear shaped charge (FLSC), charge filled lead tubes and Neutron radiographic images of Explosive transfer assembly (ETA).In each case different processing tools have been applied for getting the required information.

Critical information like asymmetrical charge distribution in FLSC, low density regions in charge filled lead tube, explosive charge column and interface gap between Booster charge and Conical charge in NR images of ETA etc. are clearly distinguishable through image processing. This paper describes the various image processing techniques used and the case studies carried out using optimised techniques.

Keywords: Digital image processing, Frequency domain image processing, FLSC, Charge filled lead tube and ETA

49-P

ESTIMATION OF MOISTURE CONTENT IN EDIBLE PULSES BY THE APPLICATION OF COMPUTERIZED TOMOGRAPHY

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Abstract

Moisture is an important component in food products. Proper information about the moisture quantity in the grains is a valuable parameter for the food engineers to evaluate the quality and stability of the food product. Present work focuses on use of CT mini scanner (installed in IIT-Kanpur) for the estimation of moisture content in three different pulses (Arhar ,Mansoor, Moong). These experiments are carried out with 800 projection and 120 kV

X- ray Source voltage, detector system consist of photodiodes which generate 1024 data rays. Avizo sofware which uses FDK alogorithm has been used to reconstruct the CT images. Each pulses are scanned dry , with 5% , 10% and 15%water content. The concept of Fractal Dimension (FD) has been used to analyze the quality of reconstructed image. FD represents a reasonable quality index for the reconstructed image. For an MxN pixel block image, Normalized Scale Range vector (NSR) consists of possible distances between any pair of pixels and Normalized Multi Scale Intensity vector is the different absolute value differences around each NSR. The curve between Log(NMISD) vs Log(NSR) for I=1,2,3...M consisting of M points is the Fractal curve. The slope of the curve is called Hurst coefficient (H). FD is calculated from the relation FD=3-H. FD varies with the changing amount of moisture content in the pulses and the moisture content is estimated from the change in FD. Thus CT is proved to be a generalized image texture quality index and a quality inspection tool for food industries.

Keywords: Computerized Tomography, Fractal Dimension, Hurst Coefficient, Box-count.

50-C

ROLE OF NON-DISTRUCTIVE EXAMINATIONS IN LEAK TESTING OF GLOVE BOXES FOR INDSUTRIAL SCALE PLUTONIUM HANDLING AT NUCLEAR FUEL FABRICATION FACILITY ALONG WITH CASE STUDY

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Abstract

Non Destructive Examinations has the prominent role at Nuclear Fuel Fabrication Facilities. Specifically NDE has contributed at utmost stratum in Leak Testing of Glove Boxes and qualifying them as a Class-I confinement for safe Plutonium handling at industrial scale. Advanced Fuel Fabrication Facility, BARC, Tarapur is engaged in fabrication of Plutonium based MOX (PuO2, DDUO2) fuel with different enrichments for first core of PFBR reactor. Alpha-Leak Tight Glove Boxes along with HEPA Filters and dynamic ventilation form the promising engineering system for safe and reliable handling of plutonium bearing materials considering the radiotoxicity and risk associated with handling of plutonium. Leak Testing of Glove Boxes which involves the leak detection, leak rectification and leak quantifications is major challenging task. To accomplish this challenge, various Non Destructive Testing methods have assisted in promising way to achieve the stringent leak rate criterion for commissioning of Glove Box facilities for plutonium handling. In view of highest safety, Leak rate criterion for plutonium handling Glove Boxes is set to 0.05% of Glove Box volume per hour to classify them as a Class-I containment as per ISO standard & also as per ASTM Standard C-852, leak rate of less than 0.3% Glove Box Vol./Hr is recommended for plutonium handling glove boxes.

This paper highlights the Role of various NDE techniques like Soap Solution Test, Argon Sniffer Test, Pressure Drop/Rise Test etc. in Glove Box Leak Testing along with procedure & methodology for effective rectification of leakage points. A Flow Chart consisting of Glove Box leak testing procedure starting from preliminary stage up to qualification stage along with a case study and observations are discussed in this paper.

Keywords: Glove Box, Plutonium, Leak Rate

51-P

STUDY ON TENSILE BEHAVIOUR OF HSLA STEEL USING ACOUSTIC EMISSION TECHNIQUE

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Abstract

Acoustic emission (AE) technique is useful for studying deformation and fracture behavior in materials. The AE signals captured during tensile deformation of a material can be advantageously used to discriminate different types of sources. The AE signals detected by using piezoelectric transducer contain a wealth of information about the nature of the AE sources which are responsible for their generation. The HSLA steel which is extensively used in ship building industry has been chosen for this investigation because the knowledge of AE signals generated during deformation of this steel could be useful for the assessment of structural integrity of ship. In this paper, the results of acoustic emission generation during tensile deformation of high strength low alloy steel (HSLA) are presented.

The chemical composition (in wt %) of the HSLA steel used is C-0.09, Mn-1.14, Ni-0.62, Si-0.18, Al-0.026, Nb-0.039, V-0.02, P-0.14, Ti-0.019, Cu/Cr-<0.02, N-56 ppm and Fe-Bal. The HSLA steel normalized at a temperature range of 1123°K to 1223°K was used to fabricate the flat tensile specimens. The specimens were subjected to tensile deformation at different strain rates (1.4 x 10-3 s-1 to 1.4 x 10-2 s-1). AE parameters in time domain such as hits, counts, root mean square voltage, energy, amplitude etc. and frequency domain at different stages of the stress-strain curve were analyzed and correlated with the micromechanical behavior of the material. The AE results were investigated as a function of strain and strain rate.

Keywords: Acoustic emission, tensile deformation, HSLA steel, strain rate.

52-C

NDE ON INDIGENOUSLY MADE STEAM GENERATOR AND PRESSURIZER FORGINGS

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Abstract

L&T Special Steels and Heavy Forgings Pvt. Ltd. (LTSSHF) is a joint venture of Larsen & Toubro (L&T) and Nuclear Power Corporation of India Ltd. (NPCIL). LTSSHF is the first Indian company to manufacture indigenously Steam Generator 700MWe and Pressurizer forgings. These forgings typically weigh from 20-40 MT and are of varying dimensions and shapes. Steam Generator and Pressurizer forgings call for stringent Non Destructive Examination (NDE) requirements. NDE examination methods used in these forgings were Ultrasonic Examination (UE) and Magnetic Particle Examination (MPE). Ultrasonic Examination performed in two (2) different stages i.e.

- After Pre-machining of the forged product, before Heat Treatment
- After Final Machining of the heat treated product, before dispatch

Magnetic Particle Examination performed after Final Machining before dispatch.

This paper details NDE techniques, UT calibration blocks used, extent of examination carried out on the Steam Generator and Pressurizer forgings manufactured at LTSSHF.

53-P

MODELING OF INFRARED THERMOGRAPHY FOR DELAMINATION DETECTION IN BASALT REINFORCED COMPOSITE MATERIALS.

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Abstract

Basalt fibers combine ecological safety and natural longevity which has gained increasing attention as a reinforcing material when compared to traditional glass fibers. This paper presents the results of an experimental study on delamination detection and measurement, in basalt fiber composite materials by infrared thermography. The research work includes, fabricated samples with artificially developed delamination at different depths in basalt composite materials. The main aim of experimental research was to assess delaminations of varying sizes positioned at different depths related to the examination area. The samples were investigated by pulse infrared thermography and ultrasonic c-scan immersion testing techniques. An analytic solution to the heat equation is used to simulate the model response of defect in pulsed thermography, using COMSOL Multiphysics. The model is compared to measurement data and shows good agreement, both in spatial and temporal domain.

Keywords: Non Destructive Evaluation, Basalt Fiber Reinforced Composites, IR Thermography, Modelling.

54-P

THERMAL CHARACTERISATION OF BASALT FIBER COMPOSITE USING PULSE THERMOGRAPHY

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Abstract

Flash method is the widely used Non Destructive Technique to measure the thermal diffusivity of solids. It has been adapted to determine thermal properties of basalt fiber reinforced composites. In order to overcome the anisotropic issue and give a more accurate estimation of the thermal properties of the sample, thermal properties are determined in different directions, along the fibers and across the fibers. The effect of fiber content on the thermal diffusivity in selected fiber reinforced composites is also determined. The experiments in reflection and transmission mode have been performed for measuring the thermal diffusivity of basalt fiber reinforced composites.

Keywords: Non Destructive Technique, Flash method, Thermal properties

55-P

TO STUDY & EVALUATE ADHESIVE BONDING IN COMPOSITE MATERIAL BY PULSE THERMOGRAPHY NDT TECHNIQUE

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Abstract

Infrared analysis tools are nowadays widely used for the non-destructive testing of composite materials, belonging to many different industrial sectors. This paper presents the results of an active pulse thermography investigation in

which adhesive bonding defects of Basalt and glass fiber composite materials were examined. Samples were fabricated with artificial defects such as air gap, foreign material, and improper adhesive filling. An experimental set-up is developed using pulsed thermography in reflection and transmission modes coupled with transient heat transfer modeling. Pulse thermography technique was found to detect defects and foreign inclusions. Pulse thermography heating was FE modeled in 3D using COMSOL Multiphysics. The simulated thermography model was compared and validated with experimental results.

Keywords: Non Destructive Evaluation, adhesion bonding, Thermography,

56-C

HELIUM LEAK TESTING IN ELECTRO-CHEMICAL OXYGEN SENSORS

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Abstract

Development and operation of sodium cooled Fast Breeder Reactors (FBR) form the second stage of India's three stage nuclear power programme which is aimed at preparing the country for utilization of the extensive Thorium reserves and providing means to meet increasing electrical energy demand. Liquid sodium metal is the coolant in fast reactors. Due to reactive nature of sodium, oxygen enters the coolant system through air and moisture. Oxygen impurities in sodium enhance corrosion rate of the structural materials and hence coolant is continuously monitored with reliable sensors.

For measurement of trace level oxygen concentration in liquid sodium, an electrochemical oxygen sensor is used to monitor ppm level oxygen levels. Yttria doped thoria (YDT), is solid electrolyte, is used for monitoring oxygen concentration in liquid sodium coolant in fast breeder reactors. The conventional sintering process route had poor mechanical strength of the ceramic product due to grain growth. Hence, a novel technique using nanocrystalline powders was adopted for the first time in India for manufacture of impervious YDT bodies to withstand large thermal cyclic load. In this sensor, solid grade YDT is fabricated in the form of thimbles. These thimbles are sealed to low expansion ferni alloy so as to conduct only O2- ions from cathode to anode. The acceptable helium leak rate through the seal was ensured < 1 x 10-10 Pa m3 sec-1 as higher leak rate resulted in poor signal discrimination and unstable readings.

Keywords: FBR, sodium, sensor, YDT, leak testing

57-C

ULTRASONIC EXAMINATION OF TUBE TO TUBE SHEET WELD JOINTS IN HIGH PRESSURE HEAT EXCHANGER FOR THE UREA PROCESS

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Abstract

Urea stripper and Carbamate condenser are two main key and critical equipment in any Urea plant. Both the equipment's are operated at elevated temperature(182-250°C) and high pressure(150-220 Bar) with aggressive corrosive fluid inside. Tube to tube sheet welding(duplex stainless steel) is one of the most critical joint in these types of high pressure and high temperature heat exchanger, hence quality of all the welds are very important from service point of view.

Effective Non-destructive testing is needed for the volumetric examination of Tube to Tube sheet weld joints. In general we perform Visual Examination & Penetrant Testing for this type of joints, but some of the customers ask for the Ultrasonic Examination. Ultrasonic Examination of this type of joints is very difficult to perform because of very small size of the joint and coarse grain material structure.

This paper describes the main challenges for development and implementation of Tube to tube sheet joints Ultrasonic Examination in Urea stripper and Carbamate Condenser.

Keywords: Carbamate condenser , Ultrasonic Examination, Visual Examination, Penetrant Testing

58-C

SIMULATION AND EXPERIMENTAL VALIDATION OF PULSED THERMOGRAPHY EXPERIMENT FOR DAMAGE QUANTIFICATION

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Abstract

Infrared thermography is one of the advanced NDT techniques. This is a non invasive method for damage detection. It covers a large area of inspection in a very short time.

Literature in this area is confined to use of analytical models for surface temperature estimation or special purpose codes developed for thermography. The usage of commercially available software packages for simulation of thermographic experiments is scant in literature. The aim of this work is to develop modeling procedure for thermography experiments using commercial FE package that is extensively used in aerospace industry. This work uses Hypermesh and MSC-Nastran with inbuilt modules to simulate the pulsed thermography experiment. The simulation results help establish a relation between various damage parameters with experimental variables.

The present work gives a procedure to model a pulsed thermography experiment. To validate the model an experiment conducted to detect flat bottom hole defects in a stainless steel plate. Surface temperatures from theoretical model and experiment are compared. Peak time of contrast detection is used as a parameter for defect quantification. The depth quantification is attempted with simulation results. An estimation is made for minimum defect depth that can be detected based on experimental and simulation results.

59-P

STUDY OF DEFECTS IN FRICTION STIR WELDED DISIMILAR ALUMINIUM SAMPLE BY USING ULTRASONIC C-SCAN

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Abstract

Friction Stir welding is very effective technique mainly to weld the Aluminum alloy which are very difficult to weld by conventional welding method due to occurrence of defects. Even though FSW has some defects, heat input plays a very important role in occurrences of these defects. Heat input during the welding is dependent on the many factors like welding parameter Rotational Speed and transverse speed, tool design pin geometry, pin diameter, shoulder diameter etc. and axial force. Immersion Ultrasonic C scan testing was carried out using a probe required frequency, focal length and water acting as a couplant. The sample was scanned using a resolution of 0.2mm along the joining as well as across the joining. Thus this technique is useful to detect the randomly located and disoriented

defects like crack, porosity etc. In this paper, the defects in FSW is studied by conventional ultrasonic and then compared result by using simulation software.

60-C

IMAGE SEGMENTATION USING LEVEL SET-APPROACH

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Abstract

Image segmentation is a process of dividing an image into multiple parts. This is typically used to identify objects or other relevant information in digital images. The quantitative image analysis of industrial CT/MRI images is difficult because of their complex texture and fuzzy edges. The reconstructed images are also severely affected by various types of noise. The objective of the present work is to properly identify different regions in two sample brain MRI images. Existing approaches such as image threshold method, optimum threshold method are insufficient for accurate segmentation. Single threshold value for segmenting the image would not necessarily be the same for all other images because many source of variation of CT images do not allow intensity to be absolute measure. Curve evolution serves as a powerful technique of image segmentation. This level set approach is used to improve the existing active contour (AC) method for precise image segmentation. The evaluations of level set contours are guided by PDEs which are obtained through a minimization of functional energy. This energy functional is defined in a way such that its minimum is reached at the objects boundary, which holds the highest image gradient. Intensity inhomogeneities often occur in real-world images and may cause considerable difficulties in image segmentation. In order to overcome the difficulties caused by intensity inhomogeneities, a region-based active contour model is used that draws upon intensity information in local regions at a controllable scale. The irregularity developed during curve evolution, limits the applicability of traditional level set method. The regularity of the level set function is intrinsically preserved by the level set regularization term to ensure accurate computation and avoids expensive reinitialization of the evolving level set function. The resulting images (produced by level set segmentation) are much clearer that the original images.

61-P

PROBABILITY OF DETECTION BASED STUDIES OF DEFECTS IN STAINLESS STEEL WELDS USING EDDY CURRENT TESTING

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Abstract

Defects in engineering structures are unacceptable as it affects the strength and durability of the structures. Eddy Current (EC) testing is useful for ensuring the integrity of the structure by detecting surface and shallow sub-surface defects in engineering structures and components. However, most of engineering structures have welds in which the EC technique cannot be applied. EC signals of welds are highly influenced by the variation in the material properties across the weld, especially the electrical conductivity and magnetic permeability, resulting in poor SNR. For example, in stainless steel welds, formation of magnetic phase like the delta ferrite during the welding process changes the magnetic permeability of the material. Thus, detection of defects in welds using EC technique is

challenging. This paper address the issues related to EC examination of welds using different type of probe configurations to improve the SNR.

The work is aimed in detecting defects in stainless steel welds with conventional absolute probe and transmit-receive (T/R) type probe, towards comparing their performance. For this purpose welds have been made in 5 mm thick stainless steel plates. Artificial notches and flat bottom holes of different dimensions and orientations have been fabricated in the welds by electro-discharge machining. The performance of two types of EC probes have been compared based the SNR and probability of detection (PoD) of defects. Studies reveal that the T/R probe showed 10 dB higher SNR and a PoD of 80% as against 60% for the conventional absolute probe. The paper explores the physics behind the better performance of the T/R probe through finite element model based studies and presents the results of the studies.

Keywords: Eddy current, conductivity, permeability, transmit-receive, weld, stainless steel, probability of detection

62-P

STUDY OF IMPACT DAMAGE ON COMPOSITE MATERIAL AND ANALYSIS OF THE DEFECTS FORMED BY THE IMPACT FORCE USING PHASED ARRAY ULTRASONIC TECHNIQUE (PAUT)

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Abstract

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other. As composites becomes more widely used for primary structural components in aerospace and other applications, the reliable detection of small defects in composite sections is increasingly important. Composite materials are very sensitive to impact damage so the NDE of defects created by impact force on composites is very significant in aerospace structures because the exposure of an aircraft by an impact load is quite common e.g. bird strike, lightning strike on fuselage, ground support tools impact, towing damage etc. So a better understanding of defects on composite can help making aerospace industry more safe and reliable. This article describes an analysis of damage created by an impact on composite material and NDE related to it. Observations made by previous researchers F.J. Yang and W.J. Cantwell [1] is that the impact force required to initiate damage, Pcrit varies linearly with t3/2, where t is the target thickness. Here the idea is to measure this Pcrit and analyze the kind of defects forming due to various impact forces using Phased Array Ultrasonic Technique (PAUT) . Ultrasound pulses are reflected by interfaces between materials of different properties. Mapping the time delay to reception of the reflected signal provides information about the depth of the damage. The information about defect depth can be used to view the ultrasound data as a pseudo-3D image which gives the information about kind of defects formed by the impact like delaminations, matrix crack, porosity, inclusions, fracture or buckling of fibers etc.

Keywords: Phased Array Ultrasonic Testing (PAUT), Composite material, Impact damage, Defects, NDE(Non Destructive Evaluation).

63-P

APPLICATION OF NEURAL NETWORKS FOR DEFECT DETECTION IN NON-STATIONARY THERMAL WAVE IMAGING

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Abstract

Infrared non-destructive testing (IRNDT) makes use of captured surface temperature profile over a stimulated object and subsequently process the obtained temperature profiles to detect surface or subsurface features. Being non-contact, whole field and non-invasive testing modality it had been an attractive modality and recent past witnessed a tremendous growth in the application of variety of stimulation and analysis mechanism to enhance the detectabilty of defects like voids and delaminations using it. This qualitative and quantitative analysis of subsurface anomalies has been widened the scope of research due to the influence of various factors effecting it.

This paper introduces a neural network based approach for defect detection in quadratic frequency modulated thermal wave imaging. The proposed methodology has been tested through experimentation carried over a carbon fiber reinforced plastic specimen for quantitative and qualitative assessment of subsurface anomalies.

64-P

DATA FUSION FOR SUBSURFACE ANALYSIS IN NON STATIONARY THERMAL WAVE IMAGING

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Abstract

Subsurface analysis to determine the location and sizing of an anomaly using thermography opened avenues for investigation of various stimulation mechanisms and processing approaches. Non-stationary thermal wave imaging cater to it by employing a suitable band of frequencies according to the depth resolution of interest at low peak powers supported by various processing approaches. But no single method is capable to explore all the details underneath the test object surface and provide subsequent details. In order to overcome it and to embed a variety of details obtained from various processing approaches, this paper introduces fusion based methodology by combining the details obtained from various subsurface analyses approaches for quadratic frequency modulated thermal wave imaging through experimentation carried over a mild steel specimen.

65-C

PIPELINE INSPECTION USING EMAT

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Abstract

In recent years advancement in NDT Technology has taken place in a very great pace. Among all NDT methods, Ultrasonic testing has undergone many developments and is evolving with more methodologies using sophisticated equipments.

Among that Electro Magnetic Acoustic Transducer – "EMAT" Technique has gained large adaptation and is proving to be highly beneficial. The basic understanding of EMAT is very important for effective, optimum and appropriate application of this technique.

In-service pipeline inspection of critical piping's particularly in refinery and fertilizer plants has always been a matter of concern and challenging to the industry to access the condition of the pipe as well to ascertain the remaining life. These critical piping's are great threat to catastrophic failure and safety. Many fatal accidents have occurred in the past leading to loss of human life and economy. Complete 100 % volumetric inspection of these critical piping's has now become reliable, fast and easy by the application of EMAT.

66-P

DEFECT DETECTION AND QUANTIFICATION WITH ADVANCED ULTRASONIC

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Abstract

Time of flight diffraction technique (TOFD) is considered as one of the fastest methods of Non destructive testing (NDT) since a weld can be characterized to a certain degree with one single scan along its length with two probes. An image of the complete weld is created showing component and, more importantly, any defect information. In this work, a comprehensive review of the TOFD technique covering many aspects, e.g. accuracy, coverage, resolution, repeatability, and last not least speed where the real value of TOFD lies despite of its few inherent limitations is presented. This report presents all positive and negative aspects of TOFD method and examples of its recent applications. It depicts and explains the TOFD mathematical model and shows the experimental results which obtained by the OLYMPUS SX2 with 2x5 MHZ probes on carbon steel weld pads with double V groove joined configurations.

68-C

QUALITY ASSESSMENT OF ELECTRON BEAM WELDS OF INCONEL-718 PLATES USING PHASED ARRAY ULTRASONICS AND ITS COMPARISON WITH RADIOGRAPHY INSPECTION

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Abstract

Inconel Alloy 718 being a super alloy with an excellent combination of high strength, corrosion and oxidation resistance, find vast use in aerospace industry in the manufacture of gas turbine blades, cryogenic storage tanks etc. Electron Beam Welding (EBW) is most commonly employed for the welding of Inconel Alloy 718, since it results in less distortion and Heat Affected Zones (HAZ) compared to Gas tungsten arc welding (GTAW), Laser beam welding (LBW). A study was conducted to determine the optimum parameters that may be employed in starting the electron beam welding. Associated with the same experiments, a study on suitable NDT methods that shall be employed to completely inspect the weldment was carried out. A comparison between the radiographic inspections of the weldments with Phased Array ultrasonic inspection was done. Phased Array Ultrasonic Testing (PAUT) provides the advantage of carrying out inspection in welds with single side access & also gives a recordable image with complete details of the defect like depth, location, size etc. The paper tries to throw light into the application Automated Ultrasonic techniques like PAUT which could be used in lieu to Radiography for the inspection of Inconel welds.

Keywords: Electron Beam Welding (EBW), Inconel Alloy 718, Phased Array Ultrasonic Testing (PAUT), Radiography.

69-C

ADVANCES IN QUADRATIC FREQUENCY MODULATED THERMAL WAVE IMAGING

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Abstract

Subsurface analysis using thermal waves is gaining interest due to its whole field, non-contact and non invasive testing modality. Recent past witnessed a tremendous improvement in application of various non stationary stimulation mechanisms and processing modalities intended to enhance depth resolution of subsurface anomalies.

Usually in realistic objects, anomalies exist at different depths demands stimulations consisting of a set of frequencies and further high resolution processing modalities. Quadratic frequency modulated thermal wave imaging, is one of those stimulation mechanisms cater to theses needs by providing a preselected band of frequencies and facilitates the detection of anomalies with enhanced depth probing due to more energy with low frequencies in addition to depth resolution. This contribution highlights various processing mechanisms used for defect detection and quantitative sizing analysis in this proposed methodology.

70-P

REDUCTION OF SCATTERING ERROR USING IMPROVED COLLIMATION IN A GAMMA CT SET-UP

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Abstract

Gamma ray imaging introduces scattering error in the measured Tomographic data and consequently error in reconstruction algorithm. In the work presented here, the contribution and effect of scattering in different designs of gamma ray set-up was investigated in IIT-Kanpur. In order to minimize effect of scattered radiation, several shielding designs of gamma set-up was checked and the best possible design set-up which reduces the scattering error was given. The gamma source which we are using is of source strength of 16ì Ci, and gives peak at 0.662keV. 9 NaI (Tl) Detectors are used for data collection. The RMSE and goodness of fit from the KT1 plot for the scattered image is found with reference to scatter-free image, the best set-up design of gamma set-up was concluded taking these values as reference. Among these Design The least scattering was given when collimators were put in front of the source and were not put in front of detector. The reconstruction was made using Convolution back projection algorithm. Moreover the dependence of Klein Nishina Cross section from different set up was investigated. Parameters were calculated to make system more portable along with safety by reducing lead block size.

Keywords: Tomography; Gamma ray; Kanpur Theorem

71-C

A STUDY ON THE CRACK GROWTH OF AA2219 ALUMINIUM ALLOY MATERIAL USING ACOUSTIC EMISSION SIGNAL ANALYSIS

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Abstract

The crack growth of the metallic materials usually produces intense acoustic emission. Acoustic emission from hardware can be monitored and used for NDT once these emissions are characterized. The paper reports an experimental study carried out to determine the characteristics of the acoustic emission signals emitted from AA2219 Aluminium alloy material during crack opening. The acoustic emission data obtained from the AA2219 pre-cracked compact tension specimens has been analyzed. Unsupervised pattern recognition technique has been used to segregate the genuine AE signals emitted from the material during the tensile testing. Three classes of signals segregated through the K-means cluster algorithm has been analyzed in detail. A good correlation is observed between the class– 3 signals corresponding to crack growth and the data obtained from the tensile coupons prior to failure. The AE signature corresponding to crack growth of the material has been obtained through the detailed analysis of the extracted AE parameters viz. amplitude, duration, energy, counts and RMS.

Keywords: Acoustic emission (AE), AA2219 Aluminium alloy, Pattern recognition, Counts, RMS etc.

72-P

MICROCONTROLLER BASED DATA ACQUISITION SYSTEM FOR OPTIMIZATION OF ULTRASONIC TESTING PARAMETERS

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Abstract

The work consists of developing a data acquisition system based on a micro controller for acquiring the defect echo amplitude to continuously monitor the Pressurized Heavy water reactor fuel element end cap weld integrity. The Application software was developed in VB and the application continuously acquire the defect echo amplitude and plot a graph between defect amplitude and time. After acquiring the full weld checking the maximum value of all acquired amplitudes will be reported and based on this value the acceptance or rejection decision was made. The work also involved the optimization of pulse repetition frequency for a given defect size, beam diameter and rotational speed of the fuel element to detect the maximum amplitude signal from a defect.

73-P

STUDY ON TENSILE BEHAVIOUR OF HSLA STEEL USING ACOUSTIC EMISSION TECHNIQUE

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Abstract

Acoustic emission (AE) technique is useful for studying deformation and fracture behavior in materials. The AE signals captured during tensile deformation of a material can be advantageously used to discriminate different types of sources. The AE signals detected by using piezoelectric transducer contain a wealth of information about the nature of the AE sources which are responsible for their generation. The HSLA steel which is extensively used in ship building industry has been chosen for this investigation because the knowledge of AE signals generated during deformation of this steel could be useful for the assessment of structural integrity of ship. In this paper, the results of acoustic emission generation during tensile deformation of high strength low alloy steel (HSLA) are presented.

The chemical composition (in wt %) of the HSLA steel used is C-0.09, Mn-1.14, Ni-0.62, Si-0.18, Al-0.026, Nb-0.039, V-0.02, P-0.14, Ti-0.019, Cu/Cr-<0.02, N-56 ppm and Fe-Bal. The HSLA steel normalized at a temperature range of 1123°K to 1223°K was used to fabricate the flat tensile specimens. The specimens were subjected to tensile deformation at different strain rates (1.4 x 10-3 s-1 to 1.4 x 10-2 s-1). AE parameters in time domain such as hits, counts, root mean square voltage, energy, amplitude etc. and frequency domain at different stages of the stress-strain curve were analyzed and correlated with the micromechanical behavior of the material. The AE results were investigated as a function of strain and strain rate.

Keywords: Acoustic emission, tensile deformation, HSLA steel, strain rate.

74-C

STUDY OF INFLUENCE OF GRAIN SIZE VARIATION IN ULTRASONIC NON-LINEAR MEASUREMENTS

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Abstract

Non-linear ultrasonic testing is an emerging method in material characterization. This technique is based on the study of higher harmonics generated during the propagation of high power ultrasonic waves through a material. This technique has been widely used to study the microscopic defects like precipitations, voids; micro cracks etc and has been successfully applied on materials subjected to creep, fatigue and different heat treatment processes.

Due to the presence of microscopic defects inside the material, the crystalline lattice arrangement gets disturbed, and, as a result, a localized stress field is generated at that point which will interact with the ultrasonic waves propagating through it. This interaction deforms the ultrasonic waves and generates higher harmonics. The nonlinearity parameter derived from the amplitude of first and second harmonic components is a direct measure of lattice disturbance and can be linked to the type of material degradation.

In order to have an accurate assessment of material degradation due to the presence of microscopic defects, the influence of grains on the generation of higher harmonics is to be studied. Grain boundaries act as a source of higher harmonics and influence the observed beta parameter. A number of specimens were prepared with different grain sizes and nonlinear ultrasonic measurements have been performed. The results were correlated with microscopic observations and conventional ultrasonic back scattering and attenuation measurements.

Keywords: Nonlinear ultrasonics, grain size, material degradation

76-P

NON-CONTACT PROFILOMETRY USING LED MICROMETER

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Abstract

LED micrometers are presently used for non-contact metrology. This LED micrometer consists of a sensor unit and a controller, which are attached to a mounting rail. The sensor unit comprises a light source with high power LED and a receiver with telecentric lens and CCD array. When an object to be measured is placed in the light curtain, the shadow it creates is detected by the CCD array. The measured data is output via analogue and digital interfaces. Using this concept of shadowgraph this micrometer is being used in measurement of diameter & ovality of rods and thickness of sheet.

A technique has been developed using this micrometer to generate the profile of the object while it is in motion along x-axis. This shows how the diameter measurement feature of this micrometer can be utilized for generating the profile of the object being scanned. The micrometer was mounted on a high precision scanner made in-house having linear motion. Scanning of pin generates an array of data of Diameter vs. Time. Time when multiplied by linear speed of scanner gives X-co-ordinate. The output data of micrometer is conveterd and processed further and sent as input to Auto-CAD/Matlab to generate the desired profile.

Standardization of the measurement technique has been done by an accurately machined standard block consisting of surface features like a step diameter, an angle, an arc and a thread and scanned using this micrometer. The result obtained from this scan was compared with the values measured by a normal micrometer. The result matches satisfactorily.

This technique was developed for estimation of length and angle of a typical swaged clad tube of a twisted nuclear fuel pin. Diameter increases very slowly and becomes constant after swaged portion. This method measures the swaged length and angle accurately which otherwise is difficult using conventional metrology.

Keywords: **O**ptical metrology, **S**urface profilometry and **D**iameter measurement.

77-C

*Real story with a lesson…..***Bridging NDT's Digital Divide**

In 2015, Medical imaging in North America is fully converted to digital radiography. The same is true for the Photographic industry. And NDT? Let's just say NDT is many-years away from converting to digital. Yes, there certainly are substantial mitigating reasons "explaining" why NDT is the laggard.

However, there are some misconceptions, coupled with a lack of knowledge, which contribute to the NDT industry's slo-mo conversion to digital.

One of those misconceptions is that NDT specialists seeking a means to increase revenues must fully invest into DR/CR in order to offer end-users digital images. This is totally false – so let's clear this up right here.

In fact, two industries exemplify smooth transitions to digital – having overcome the human species tendency of resisting change – via crossing the digital divide *while* increasing profits.

Just the facts:

FACT: *Digital radiography (DR) improves throughput, reduces consumible expenditures, and provides improved image evaluation*

FACT: *DR saves inspection time, consumable costs, and improves productivity*

FACT: *DR reduces consumables, re working, eliminates chemical disposal charges & storage costs, improves image evaluation, ability to share, store and access digital files*

FACT: *Digital and computed radiography is expensive, has portability issues related to inspecting hard-to-reach components/structures, and testing thick materials.*

FACT: *X-ray film continues playing a critical role in NDT applications.*

NEWS FLASH: Radiographic film and DR/CR systems are compatible!

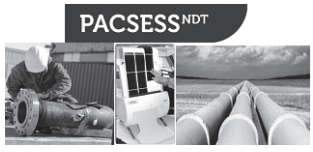
NEWS FLASH REPEAT: Radiographic film and DR/CR systems are compatible!

In 2004, ASTM established the NDT imaging and archiving standard: DICONDE

Digital **I**maging and **CO**mmunications for **N**on-**D**estructiva **E**valuation.

NDT, as with its predecessors, is in fact, slowly making its own stuttering transition to digital via compatible digital files. What follows is the proven formula to crossing that digital bridge smoothly and affordably:

Bridging NDT's Digital Divide:



VIDAR SYSTEMS CORPORATION, the world's leading supplier of Film Digitizers, has leveraged 3 decades of imaging experience to develop the NDT PRO Industrial Film Digitizer.

Linchpin Solution

The NDT PRO Digitizer combines custom-designed AcuScreen NDT software and a Multi-Strip Film Feeder to arm NDT Inspectors with an affordable bridge-to digital, fully compatible with all DR/CR DICONDE S/W. This complete solution is the NDT industry's most cost-efficient precision industrial digitizer - saving time, money, and film storage/maintenance costs. It is a 'linchpin' solution because it addresses digitizing both new and legacy films, without having to make the financial investment into DR/CR. When DR/CR investment is made, the NDT PRO Digitizer solution continues delivering digital files of all prior films in the NDT industry's single file standard, DICONDE.

Bridge To Digital:

- NDT film-to-digital full compatibility
- Complements DR/CR systems
- Digital workflow compatibility: One DICONDE file format
- Legacy film preservation
- NDT PRO Industrial Film Digitizer meets all standards for ISO 14096 Class DS and ASME Section V.

78-C

ULTRASONIC SIGNAL ANALYSIS TO DETECT MC TYPE PRECIPITATION IN NIMONIC ALLOY

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Abstract

The velocity and attenuation of ultrasonic waves have been widely used for several decades to characterize the microstructure of solids in an accurate, fast and nondestructive manner. The interaction between ultrasonic measurements and microstructures can also be evaluated through background echo and backscattered signal processing techniques. Conventionally, precipitation behaviour in nickel base alloys is studied using electron microscopy and hardness measurements. The ultrasonic velocity and attenuation measurements are dependent on the elastic modulus of the alloy and any change in the chemical composition will be reflected in the ultrasonic velocity. Similarly hardness measurements depend on the resistance to dislocation movement. These, can be attributed to the combined effect of complex and competing precipitation of intermetallics and metallic carbides of type MC. The kinetics of intermetallic precipitation is faster and attains saturation within a certain time. Simultaneously, carbide precipitation starts after a certain length of time and then may contribute to the above changes in hardness and ultrasonic wave velocity. The goal of this investigation is to evaluate the sensitivity of ultrasound measurements, the effectiveness of the background echo and backscattered signal classification, and to detect and characterize the microstructure changes, i.e., the formation of the secondary phases/precipitates, occurring in a thermally aged Nimonic-263 alloy.

In the present study, Nimonic-263 alloy was solutionized and aged at a temperature of 750°C for different time ranging from 8hours to 75 hours. Ultrasonic A-scan signal was acquired using a 5MHz longitudinal probe. The RF signals were digitized and the gated back wall echoes were stored for further processing. Subsequently, the A-scan data between two successive back wall echoes was extracted and a Fast Fourier Transform (FFT) algorithm was applied to transform the signal into frequency domain. It is observed from frequency domain analysis, that the frequency spectra show a distinct change in the frequency distribution for the samples aged for different duration of time. The sample aged at 750°C for 50 hours showed a single broad frequency peak in comparison to two such peaks for the samples aged at 8 hours and 25 hours respectively. Scanning electron microscopy studies have also been carried out to correlate the observed precipitates through ultrasonic signal processing.

79-I

RESIDUAL STRESS EVALUATION IN AS CAST AND FORGED ROLLS USING MAGNETIC TECHNIQUES

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Abstract

Residual stresses are stresses that remain in a solid material after the original cause of the stresses has been removed. Residual stress may be desirable or undesirable. However, unintended residual stress in a designed structure may cause it to fail prematurely. Residual stresses can occur through a variety of mechanisms including inelastic (plastic) deformations, temperature gradients (during thermal cycle) or structural changes (phase transformation). There are several techniques that are used to measure the residual stress. Recently, the magnetic Barkhausen noise (MBN) method, is also being explored as a non- destructive industrial tool to measure residual stress. The MBN method relies upon the abrupt motion of domain walls in ferromagnetic materials that are undergoing a change in magnetization.

The present study involves the assessment of rolls quality produced and subjected to different processing treatments. The measurements were made on rolls (about 33 in numbers) which are typically as-cast, forged, tempered, sub-zero treated and induction hardened. Magnetic Barkhausen Analyser (Roll Scan -300) and a magnetic NDE device 'MagStar' developed at CSIR-NML were used for the assessment of the residual stress in the rolls. At each location several measurements were made along the entire length of the roll at a distance of 10cm each in both the axial direction and in the transverse directions.

It is found from this study that these two values (MBE signal along longitudinal and transverse direction) when plotted were fluctuating in many of the measured rolls. The fluctuation in MBE signal should be as minimum as possible for sound rolls. However, if the fluctuation within each direction or among the two directions is noticeable, it can be concluded that there is inhomogeneous distribution in residual stress and /or microstructure of the test object. Magnetic Barkhaussen technique can be used to assess the residual stress state in rolls if the microstructure and composition of the materials remain same.MBE technique can also be useful to understand the consistency in designed heat-treatment schedules, deviations from which may lead to inhomogeneous microstructure with consequent large scatter in MBE signal.

81-P

ADVANCED NDE TECHNIQUES FOR INDUSTRIAL APPLICATIONS

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Abstract

The world where we live today is fast changing in technology and development. New innovations everyday are forcing products of yesterday obsolete. Success, survival or failure of any organization depends on the ability to sustain uninterrupted operation at minimum cost of production and eliminate unplanned outages.

Any System, Structure and Component (SSC) is likely to face degradation over a period due to service induced stresses and environmental factors. Non Destructive Evaluation (NDE) is a tool for assessment of health of any System, Structure and Component (SSC) without harming its characteristics and end use. Several NDE techniques are available for an assessment of the integrity of SSC. They play a crucial role in industries during pre-service inspection in selection and installation of components. NDT techniques also contribute in regular condition monitoring

& in service inspection, identification of the origin and propagation or growth of any harmful defect and evaluation of the residual life.

Advancement in science & technology has brought forth several NDE techniques with enhanced capabilities for scanning, characterization and sizing of discontinuities. Many of these advanced techniques have been adopted commercially by industries worldwide. It is a great feat that plants which had been designed only for twenty years of service life have seen life extension over two decades without any reportable degradation.

Heavy Water Board is the largest producer of Heavy Water in the world with five decades of excellence in operation and earned distinction as a credible global supplier of heavy water to several countries. This paper presents some widely used advanced NDT techniques in Heavy Water Plants for Condition Monitoring, In Service Inspection and Ageing Management. We have salvaged many service aged Inconel components, qualifying them with these techniques and saved several millions in foreign currency.

82-C

COMPUTED TOMOGRAPHY (CT) - FOR FAILURE ANALYSIS OF DELAY PYRO

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Abstract

Aerospace industry has several mission critical components of complex shape and size that are manufactured to meet functional requirements and flight worthiness. Delay pyro is one such mission critical component of single shot application device as any kind of its malfunction can lead to mission failure.

Non Destructive Evaluation (NDE) deals with the evaluation of structural integrity of hardware without affecting its functionality and useful lifetime. X-ray Radiography is one such method extensively used in evaluating the internal details of an object under test. However, Radiography compresses 3D information of an object into a 2D image due to which the internal details get overlapped that hinders in obtaining certain features of interest. This may result in drawback at times. Further, the features in the path of X-rays are difficult to obtain.

Computed Tomography (CT) generates a thin cross-sectional (slice) image of an object and the image represents point-by-point distribution of linear attenuation coefficients of the object. CT images are free from overlying and underlying areas of the object and are highly sensitive to small density differences (<1%) between structures. 3D information of an object can be obtained by stacking the slices one over the other in case of linear detector array or by using flat panel array detector with proper reconstruction algorithm. These 3D images can be viewed for extent of internal features in 3 dimensions.

The paper discusses how Computed Tomography (CT) has assisted over X-ray Radiography to assess the cause of failure in Delay pyro. In view of this, we studied the changes in internal configuration of failed, used (successfully tested) and un-used delay pyros using CT and RT, results were compared for assessing the cause of failure.

Tomograms of failed pyro revealed the absence of resistor wires, whereas the corresponding Radiographs did not reveal the same. CT further revealed the presence of explosive in failed pyro indicated that ignition of the charge did not take place. Thus Tomogram of failed pyro revealed the absence of resistor wire that lead to non-ignition of explosive material that inferred as the cause of failure, whereas Radiography has not detected the same as overlaying structure of pyro was superimposed with this feature. Hence CT has eliminated the ambiguity in identifying the cause of failure over Radiography. Thus CT has an edge over Radiography and emerged as an indispensable NDE tool in failure analysis of delay pyros.

Keywords: Delay pyro, Computed Tomography, Radiography, Resistor wire, Explosive material

83-C

ADVANCES IN ULTRASONIC INSTRUMENTATION FOR CORE-MAPPING OF FAST BREEDER REACTORS

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Abstract

Indian Fast Breeder Reactors are sodium-cooled, pool-type reactors. 500MWe Prototype Fast Breeder Reactor (PFBR) is being commissioned at TamilNadu. The FBR core has 1000+ sub-assemblies consisting of Fuel Sub-assemblies (FSAs) and other sub-assemblies which are submerged in hot liquid-sodium. Due to high operational-temperature >500°C, radiation and coolant flow, FSAs tend to grow/bow/protrude above the core-plenum (CP) level. ED, BARC and IGCAR have jointly designed and developed 8-Channel ultrasonic instrumentation, automated scanning-mechanism and transducers for detection of protrusion of in-core FSAs and the system is designated as Under Sodium UltraSonic Scanner (USUSS). Before every Fuel Handling (FH) campaign of PFBR, USUSS is employed for confirmation to absence of FSA's protrusion and proper placement of safety shut-down rods, their mechanism with reference to CP. Future Indian FBRs will have Ultrasonic Instrumentation based-on Sweep-arm-Scanner for detection and quantification of growth, bowing and protrusion of in-core FSAs. Automated Grippers are used during FH operation to load/unload a specific FSA having slots on it. For this operation, ultrasonic instrumentation can be employed to accurately position the gripping-mechanism close to the slots on FSA. Countries like USA, UK, Japan, France, Lithuania, Belgium and Korea have developed ultrasonic visualization systems for core-inspection of FSAs for Liquid-Metal FBRs. The paper provides technical features and advances made in ultrasonic instrumentation for core-mapping of FBRs, within and outside the country.

Keywords: FBRs, Core-mapping, Sweep-Arm Scanner, Under-sodium imaging

84-C

INTERNAL OXIDE TESTING OF BOILER TUBES FOR RESIDUAL LIFE ASSESSMENT

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Abstract

The service life of boiler tubing can be limited by a number of processes. If tubes are operated in a temperature range where thermal activation is an important process, aging of the material, creep deformation, corrosion and internal and external oxidation can be observed.

A good indicator for the thermal situation is the thickness of internal oxide build up (IOT). We performed a large number of measurements in thermal power plants ranging from a few thousand to 230000 operation hours. Testing was done with an Olympus DL38Plus instrument using normal incidence shear waves or longitudinal waves.

In this presentation some of the data are reviewed and the benefits and limitations of internal oxide testing are discussed.

85-C

ADVANCES IN NDE AND IMAGE-BASED MODELLING FOR AUTOMOTIVE AND DEFENSE

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Abstract

There have been many recent advances in image-based modelling as a method for converting 3D image data (such as CT and micro-CT) into robust models for Computer-aided Design (CAD), Computer-aided Engineering (CAE) and 3D Printing. New solutions can be used to obtain models for use in automotive and defense applications, with this paper providing an overview of key techniques.

Reconstruction of 3D image data allows for capture of internal structures for inspection and quantification of manufactured automotive parts throughout production. Models can also be exported as image-based meshes suitable for analysing mechanical properties in FEA and CFD applications. Analysis of original scan data enables exploration of cracks and pores at an early stage in the manufacturing process, and internal structures to be captured without destruction of components.

Novel techniques can similarly be used to replace the internal volume of CAD and image-based parts with lattice structures, which can reduce the weight of a built part without compromising performance. Defense industries can use these image-based modelling techniques for a variety of tasks, including the design of soldier-specific helmets, analysis of parts and components, and the creation of very accurate models for simulating different types of impact.

Keywords: software, automotive, defense, NDE, numerical modelling

86-C

USING 3D IMAGE DATA BEYOND VISUALIZATION FOR NDE AND MATERIAL CHARACTERIZATION: NUMERICAL ANALYSIS TECHNIQUES

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Abstract

Image-based modelling technology represents a fast-growing tool for using 3D image data such as CT, micro-CT and SEM as the basis for finite element and computational fluid dynamics. This paper discusses the latest developments in using numerical analysis techniques with image data, going beyond visualization, measurement and statistical analyses.

Some of the key breakthroughs in software techniques for NDE and materials characterization include the ability to characterise properties such as permeability, porosity and elasticity, and meshing methods that ensure multi-part models for design, simulation and Additive Manufacturing.

Techniques have also been developed to calculate the effective material properties of scanned samples. Finite-element based homogenization can be used to calculate effective properties (elastostatic, flow, electrical…), enabling insights into material properties for scan data such as manufactured composite structures.

For non-destructive evaluation, the ability to rapidly generate 3D models from image data allows for applications such as: visualization and inspection of defects during manufacturing and design; creation of simulation-ready models for FEA/CFD solvers, and quantification of material properties and problems such as cracks in samples.

This paper will demonstrate the ease by which image to visualization, analysis and model generation workflows can be combined.

87-C

CLASSIFICATION OF PORES AND SEGREGATION IN CONTINUOUSLY CAST HIGH CARBON BILLETS THROUGH ULTRASONIC IMAGE RECONSTRUCTION

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Abstract

In present scenario, demand for clean and high quality steel is increasing day by day and over 90% of the world steel production is through the continuous casting route. In this context it is important to assess the quality of the cast steels, in terms of internal defects and macro-structural features like central porosity, equiaxed zone, etc. In continuous casting, when steel billet solidifies during primary and secondary cooling, alloying elements have a tendency to segregate at the centre of billet around central porosity in equiaxed zone. At the time of solidification, initially it is chilled zone just adjacent to mould wall, followed by columnar and then an equiaxed zone at the core. It is observed that central porosity and central line segregation are major defects in continuous casting process. The quality of cast billet is determined by percentage of area of equiaxed zone, carbon segregation at centre and central porosity. Desirable characteristics of high quality steel billets are equiaxed zone area should be greater than 16%, Segregation Index should be less than 1.12 and central porosity should be less than 3mm. In high carbon steel, carbon segregation may result in cementite formation at localized regions thereby increasing hardness, ultimately causing breakage during wire drawing operation. Macro-etching, sulfur printing and ultrasonic imaging, are various techniques for studying the central porosity in cast billets. Macro-etching and sulphur print provide surface information where as ultrasonic imaging gives the through thickness information of billet. However, the plane- /depth- wise distribution of defects within the equiaxed region and their classification into pores and segregation is not possible using ultrasonic imaging. An image processing algorithm has been evolved in Matlab to determine distribution of defects at different planes in the test material. This algorithm is not only capable of detecting and 3D-positioning of the defects in the billets, but can also classify them into pores and segregation. The distribution of segregation at a particular depth obtained through image processing has found to match with sulphur print of the billet at that depth. Ultrasonic imaging in combination with the image processing technique can be considered as a single tool for studying the internal macro-structure of billets. This technique, if put into practice would be useful in online detection, 3D-positioning and classification of defects in cast steel products, paving the path for achieving clean steel.

Keywords: Ultrasonic imaging, continuously cast billet, central porosity, carbon segregation, 3D-positioning.

88-C

ESTIMATION OF REBAR DIAMETER IN CONCRETE STRUCTURAL ELEMENTS USING GROUND PENETRATING RADAR

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Abstract

In recent times, advanced non-destructive testing (NDT) techniques such as Impact echo (IE), Ground Penetrating Radar (GPR), Infrared thermography, etc., are gaining popularity in the field of civil and structural engineering for

determining the geometrical details and identification of defects. GPR is a valuable NDT method for detecting buried objects, internal details, steel reinforcement bars (rebar) etc. However, not much research is reported on the diameter estimation of rebars. Hence, the objective of the present study is to locate the rebar and estimate the rebar diameter in reinforced concrete (RC) structures non-destructively, using GPR. Laboratory studies have been carried out on specially cast specimens with known rebar diameter. Radargrams have been collected with 1.6 GHz antenna. The collected radargrams have been converted into ASCII files that contain the amplitude values of the reflected signals at every interface. The key function of the process is converting the analog signals into digital signals. The digital signal is represented by numerically encoded values corresponding to the amplitude of the electromagnetic waves reflected from the concrete-steel interface. Based on the available procedures, a methodology is proposed to get the relation between the power reflectivity and length of the scan. Using migration analysis, the dielectric constant of concrete is estimated and finally the energy radius is computed. Power reflectivity length is being measured based on the number of scans and the scanning length. Based on the limited laboratory studies, the rebar diameter is estimated which in close agreement with the actuals.

Keywords: NDT, GPR, Concrete, Rebars, Diameter

89-C

CHARACTERIZATION OF DEFECTS HAVING COMPLEX GEOMETRY BY EDDY CURRENT TESTING

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Abstract

Characteristics of eddy current test signals viz. amplitude and phase depend on defect characteristics such as shape, size, location, proximity and orientation. Generally, the test equipment is calibrated using artificial reference defects of regular shape. As a result, characterization of 'complex shaped' defects by comparing their eddy current signals with that from the reference defects is in-accurate. An irregular shaped defect can be assumed to be comprised of several simple, regular shaped defects. The eddy current signals corresponding to each of these simple regular defects can be measured separately and then vectorially added to get the composite response from the complex shaped defects.

The study was carried out on austenitic stainless steel tube of 20 mm OD and 1.65 mm wall thickness. Defects of simpler shapes were introduced on outside surface by drilling flat bottom holes and through-wall holes of different dimensions. Eddy current response using bobbin coil were recorded over all defects. Also a complex shaped flaw, which is the combination of regular shaped defects was created. The eddy current response from complex shaped defect was compared with the vectorially addition of the response obtained from regular defects. A good match is observed. An empirical relation between the estimated and the expected value of defect depth of complex shaped defect with the eddy current response in terms of phase and amplitude has been established.

This paper describes the mathematical model to combine the signals of simple regular shaped defect in a linear/ nonlinear manner such as to emulate measured signal of the irregular shaped defect. The details of test bench for experimental work and the analysis of results are discussed in the paper.

Key Words: Eddy current testing, Modelling, Defect Characterization, Heat Exchanger Tube

90-C

EDDY CURRENT TESTING FOR DETECTION OF CRACKS IN AUSTENITIC STEEL CLADDED PRESSURE VESSEL

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Abstract

The reactor pressure vessel (RPV) in Boiling Water Reactor (BWR) at Tarapur, India is made of low alloy steel and is cladded on inside surface by austenitic stainless steel. The operating conditions in the reactor may lead to initiation of stress corrosion cracking on RPV inside surface. Another phenomenon of cracking, which is possible in the stainless steel clad low alloy steel material, is the underclad cracking. An eddy current based technique was developed for detection of surface cracks on the inside cladded surface of RPV. The major challenges were: (i) the surface undulations on the cladded surface, (ii) variation in chemical composition (ä-ferrite) of the clad surface from one point to the other and (iii) detection of crack-like defect on the rough surface. A differential probe coil was designed and fabricated for this purpose. A reference defect standard with fine EDM surface notches were made on the rough austenitic clad deposited by welding for standardization of testing parameters. It was observed that an EDM notch of 1 mm deep on the rough cladded surface could be detected. It was possible to establish, whether an underclad crack, which has originated at the clad-base metal interface has reached the clad surface or not.

This paper deals with the design of eddy current test coil and standardization of eddy current test parameters for detection of crack-like defects in the austenitic clad pressure vessels. The details of reference defect standard and the analysis of eddy current test signals are described in this paper.

Keywords: Eddy current testing, Reactor Pressure Vessel, Stress Corrosion Cracking, BWR

91-C

NDE OF SOLID ROCKET MOTOR CRITICAL INTERFACES USING LONG RANGE ULTRASONIC TESTING.

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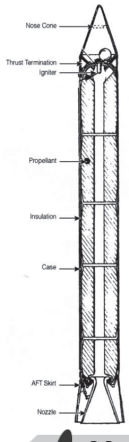
Abstract



Solid rocket motor systems are used worldwide for satellite launching and other purposes. They comprise of multiple interfaces between variety of materials (as illustrated in the fig. below) to function as thermal barriers and structural backups during the full duration performance or action time.

These materials are built into the system at various stages of production, from subsystem levels to an integrated rocket motor. At all these stages Non-destructive Evaluation (NDE) is employed to ensure material integrity and bonding adequacy between various interfaces. Owing to large sizes and complex configuration of SRMs, Radiography is the main NDT technique used to ensure final product integrity. Due to inherent limitations of radiography, very often ambiguous situations crop up as to the severity level of a particular interfacial defect since one has to depend on the shadowgraph/image of an object. Long range ultrasonic techniques can be applied in such situations to resolve the issue and increase the confidence level of inspection. However, such NDE methods are not readily available in literature for SRMs though they are specifically used for underground metallic pipe lines in heavy industries/gas/

petroleum transportation, etc. Thus, the authors have developed a long range UT technique indigenously which is applicable to non metallic and highly sound-attenuating materials used in SRMs. It is a versatile and low frequency ultrasonic testing method which can be used at component stage, semi assembled as well as in final assembled stage. The principle of testing involves use of low frequency ultrasound pulses transmitted at specific location of the complex article and the leakage signal at adjacent material is captured/received and used to assess the soundness of interfaces closer to this location. Interestingly, the leakage of transmitted signal can be picked up at any convenient location of the SRM even at a distant place. The details of the technique and a few applications vis-à-vis SRMs are described in this paper.

92-P

FLAWGUARD: A COST EFFECTIVE SOLUTION FOR ONLINE DEFECT DETECTION OF HIGH END COLD DRAWN WIRES

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Abstract

In industrial process, high end drawn wires are drawn through multi pass wire drawing machines. Quality assurance of wires is of paramount importance to the wire drawing industries. Any surface defects such as seams, cracks, pits, slivers, weld-line defects and internal discontinuities on these wires would compromise to the performance of the wires. Presence of such defects in wires can lead to premature failure at the customer end while in use or in-service. At present, quality assurance of these wires is more-or-less based on visual inspection. Although, few sophisticated systems are available, they are prohibitively expensive and more or less generic in nature. Therefore, a solution for low cost online defect detection system is highly indispensable. In this work, a cost effective online defect detection system for the detection and identification of surface defects in high end wires is developed. This non-contact sensing system is based on eddy current in which the variation of impedance of the calibrated sensing coil caused by defect region of the wires. The system is equipped with the audio-visual alarm along with logging the time stamp for further analysis. For offline analysis and predict defect location of the wire, a software has been developed based on speed of wire and time offset. System has been installed for trial basis data collection at one of the lines of Tarapur wire mill. Incorporation of this system into the wire drawing line may help to supply quality materials at customer end which in turn may lead to prevention of significant economic losses to the industry.

Keywords: eddy current, quality assurance, surface defects, internal discontinuities, cold-drawn wires.

93-C

AIR COUPLED ULTRASONIC TESTING FOR IN-SITU INTEGRITY EVALUATION OF MULTI-LAYERED INTERFACES OF COMPOSITE CASE - INSULATION BOND-LINES.

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Abstract

Solid rocket motors use outer casings made up of different materials like metallic and composites to meet structural and overall ballistic requirements of the Space Mission. During the operation of solid motors, high temperature

and pressures are developed internally. To protect the outer motor case from high temperatures, non metallic and specialized rubber insulations are used which are bonded to the internal surface of the case. These insulations are built up to the required thickness by bonding layer by layer to the inside surface of motor case. To ensure structural integrity during operation, all the bond-lines have to be inspected by NDT, before the hardware is cleared for further processing. If metallic motor cases are used, bond quality can be ensured by using conventional ultrasonic testing from outer side of the casing surface. In case of composite motor cases which are made of fibers and resin plied in multiple directions, conventional ultrasonic testing is not possible to be implemented. In such situations, X-ray inspections are to be used which are very cumbersome and hazardous. Also, the delicate composite article has to be necessarily transported to radiography Facility involving lot of time and risk. Because of fragile nature of the composite parts they are structurally sensitive at intermediate stage and frequent transportation and also need vibration free special environments. This consumes significant time of total production cycle of composite motors. The Organizational demands of increased launch frequency of Space Missions call for optimization of production cycles of various components. Accordingly, the authors have developed a scheme and demonstrated the feasibility of an air coupled ultrasonic-based NDE method for in-situ inspection of bonded insulation layers of composite case. Being air-coupled technique, this method does not require any couplant to be applied on the article and also there is no need for any surface preparation, paint removal etc. Essentially, this UT scheme is a combination of through- transmission and pulse-echo techniques and recording of results is possible as the implementation of this method is done through advanced computer based system developed indigenously. This paper outlines the details of the study carried out and implementation of the scheme at product level.

The schematic of typical insulation scheme along with loaded propellant of solid rocket motors is shown below for which bond evaluation is required at initial stage of insulation laying.

Three dimensional cut view of typical solid rocket motor as available in literature

95-I

APPLICATION OF FRACTALS IN THE ACOUSTIC EMISSION STUDY OF MICROCRACKING AND FRACTURE DEVELOPMENT IN BRITTLE ROCK

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Abstract

Fractal is a new concept that has caught the attention of researchers in materials science, engineering and industrial production over the last two decades. It is specially used to quantify and describe several objects that possess irregular geometries and random processes that occur in nature in terms of fractal dimension, D. We have applied the principles of fractal geometry and investigated successfully the scaling properties of microcrack damage using the '*Power law exponent method*' and AE *b*-value data; and spatial distribution of microcracks and fracture development in rock using '*Correlation dimension method*' and 3-D source location data of AE events that are released during the brittle fracture of rock at the laboratory scale. The results show that the application of fractals has added a new dimension to the acoustic emission study in tracking, quantifying and evaluating the successive phases of microcracking and the state-of-criticality in rock under stress for the purposes of seismological research

and rock engineering applications. The fractal methods are briefly outlined and the results obtained from the AE monitoring experiments carried out on some of the rock samples of seismically active areas of India are presented and discussed.

96-C

EVALUATION AND ANALYSIS OF RESIDUAL-STRESS IN DISSIMILAR WELD-JOINT BY FEM

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Abstract

TIG welding of stainless steel (SS) with conventional SS-filler material results in generation of carcinogenic hexavalent Cr^{+6} fumes. To mitigate the problem, four new Cr-free nickel-based filler-materials of %wt compositions varying from 39.9-43.5Ni,4-20Mo,0-16Co,10Cu,23-25Fe,0-6.5Mn,0.5Al,1.0Ti and 0.001C was developed to weld with austenitic-grade SS304 and SS316L.

Results of temperature-distribution, distortions and residual-stress in the weld joints using thermo-mechanical analysis and its comparison with XRD-techniques are presented. The temperature-distribution of all weld joints showed elliptical contours after 250s of welding. Longitudinal-distortion varied from 0.563mm to 0.667mm and transverse-distortion varied from 0.256mm to 0.36mm.

Calculated longitudinal residual-stress by thermo-mechanical analysis for different combinations of weld-joints varied from 367.7-398.32MPa whereas transverse residual-stress varied from 193.7-224.32MPa. Residual-stresses calculated by XRD-technique varied 398-461MPa for different combination of weld-joints. The residual-stresses as calculated by Thermo-mechanical analysis were found to be 5-10 % more than stresses determined by XRD-technique.

It was concluded, variation of weld joints strength is due different values of coefficient of thermal expansion of different electrode materials. Also longitudinal stress played major role in the failure of the weld joints. The filler-materials designated as 2H, 1S and 4S induced low tensile stress at different regions of the weld joints for both SS304 and SS316 base metal compared to other filler materials.

Keywords**:** Hexavalent-chromium, HAZ, ANSYS PDL, FEM.

97-P

USE OF ULTRASONIC PHASED ARRAYS FOR EXAMINATION OF AUSTENITIC STEEL WELDS – AN EXPERIENCE

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Abstract

Penetration of Ultrasonic waves in the frequency range commonly used in material testing is very limited in case of Austenitic welds due to (1) anisotropic grain structure inherent in the austenitic materials, (2) Cast microstructure of the weld pool and (3) Preferential orientation of grain growth (elongated grains or dendrites). The size, elastic anisotropy and preferential orientation of grains result in the following effects: (1) High sound scattering; (2) Mode conversion; (3) Beam distortion and (4) Variation in ultrasonic velocity in the material.

The problems may differ based on the product form e.g. cast, rolled, drawn or forged etc., welding process and parameters including heat input and heat treatment conditions. Conventional ultrasonic shear wave and longitudinal wave angle beam techniques have long been tried to evaluate the welds with very limited success. Developments in the ultrasonic Phased Array technology have got much success in overcoming those limitations of ultrasonic testing. Use of PR Modules (Pulser-receiver) with 1D or 1.5D linear probes & Dual Matrix Array probes enhanced the detection capability of the system even in thicker welds with accurate focusing ability. A few air cooler headers in refinery service were manufactured with SA 240 Gr. 316L material of 10mm and 20mm thick welds by manual metal arc welding. The coolers conform to ASME Sec VIII Div. 1 Code of construction. Therefore demonstration and qualification of the procedure was a requirement of the Code. Use of manual ultrasonic did not result in adequate detection of all the induced flaws in a mock up weld. Hence ultrasonic Phased Arrays have been used and resulted in good detecting capability and even accurate sizing of all the induced flaws in the welds and the validation of the procedure were performed satisfactorily.

Keywords: Ultrasonic Phased Arrays, Anisotropy, Austenitic welds, 2D linear Array probes.

98-C

AUTOMATED ULTRASONIC TESTING OF PLATES IN LINE FOR LONGITUDINAL SUBMERGED ARC WELDED PIPES

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A Multichannel, (176 Nos.) Ultrasonic Plate Testing System indigenously designed, developed & installed In-line for evaluation of the internal quality of plates, used to fabricate the L-SAW Pipes is described in the Paper.

This Paper covers the Ultrasonic Test Electronic, UT Probes, Test Procedure, Calibration Procedure, Test Technique, Automation Documentation/Test reports & typical applicable Inspection Codes under which the plates are inspected.

Keywords: Indigenous Multichannel Ultrasonic Plate Testing System

99-C

RF MEMS BASED ULTRASOINC TESTING IN SERVICE INSPECTION

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Abstract

Radio Frequency Micro Electro Mechanical System used as a source for the actuation of ultrasonic transducer on the material undergoing for nondestructive evaluation and transmitter will radiate the signals to the control station with the use of programmable logic controller systems without direct contact to the test material.

At the control station signals were decoded and converted into desired form and simultaneously inspection reports will be generated.

This may be useful to do in service inspection and specifically suitable for oil and gas pipeline systems and tankers.

It will also useful as alarm system for safety purpose.

Keywords: RF MEMS, Ultrasonic Testing, NDE, Robotics, PLC

100-P

QUALITY EVALUATION OF CuCrZr TO SS DIFFUSION JOINTS USING ULTRASONIC C-SCAN IMAGING TECHNIQUE

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Abstract

Plasma facing targets of the ITER divertor are structurally supported by 316L Stainless Steel (SS) to copper alloy (CuCrZr) joint. Dissimilar material joining such as SS to CuCrZr has been prepared using Gleeble 3800 machine with and without Nickel interlayer at various temperature regimes from 850°C to 1000°C with uniaxial pressure of 5MPa to 15MPa of holding time of 15min to 30 mins. The quality of diffusion bonding was tested by an ultrasonic nondestructive method and evaluated in terms of interface bonding ratio.

In the present work, Bond interface was examined by ultrasound of frequency 20MHz and the C-scan image of interface was obtained from both sides. The bonding ratio was calculated after the C-scan image was segmented into bonded region and non-bonded region based on an appropriate threshold. To obtain desired threshold, response of 2 mm dia. Flat Bottom Hole (FBH) up to CuCrZr to SS interface were taken in consideration. Different parameters such temperature, pressure and hold time have been evaluated in the diffusion process based on bonding ratio. The paper details the evaluation of SS to CuCrZr joints prepared in different diffusion conditions using ultrasonic C-scan imaging.

Keywords: Diffusion Bonding, Gleeble 3800, Ultrasonic testing, Bonding ratio.

101-C

NON-DESTRUCTIVE EVALUATION OF ELECTRONIC COMPONENTS FOR AEROSPACE APPLICATIONS

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Abstract

Nowadays, electronic devices characterization became more difficult due to the continued increase in complexity and miniaturization of integrated circuits (IC). Therefore, reliable techniques for evaluation of electronic devices becomes more important than ever. In this paper component qualification methods with NDT techniques is given in detail. During qualification process NDT techniques are used to identify defects. Further in industrial manufacturing of microelectronic components, non-destructive failure analysis methods are required for either quality control or for providing a rapid fault isolation and defect localization. Acoustic Microscopy is a powerful tool enabling the inspection of internal structures in optically opaque materials non-destructively such as de-laminations, mold compound voids and bond failures can be detected. X-Ray radiography is another non-destructive analysis method which is used for failure analysis such as assessment of internal damages, defects, and degradation in micro-electronic devices and in printed wiring boards. All metal joint failures such as solder voiding, wire bond sweep and wire bond breakages etc can be detected with X-ray analysis. There are many other methods of NDE techniques for failure analysis of electronic devices apart from Acoustic Microscopy and X-Ray analysis, however these two are most important analysis methods.

102-C

NON DESTRUCTIVE EVALUATION OF END PLUGS WELDS FOR ABSORBER PINS OF PFBR CONTROL AND SAFETY ROD AND DIVERSE SAFETY ROD SUBASSEMBLIES

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Abstract

Prototype Fast Breeder Reactor (PFBR) is a 500 MWe, sodium cooled nuclear reactor having mixed oxide viz. (Pu, U)O_2 as fuel. Control and safety rod (CSR) subassembly plays a vital role of controlling the chain reaction in PFBR. This sub assembly along with Diverse Safety Rod (DSR) sub-assembly together form essential safety features of PFBR. Nuclear Fuel complex, Hyderabad has successfully manufactured all structural components for these subassemblies and carried out final assembly of these critical sub assemblies.

The absorber pins consist of seamless stainless steel tubes which are loaded with natural and enriched boron carbide (B_4C) pellets. The ends of these tubes are sealed by TIG welding under Helium atmosphere. These welds have to meet stringent quality standards to withstand severe reactor operating conditions. The weld quality is ensured by carrying out various NDE techniques which are complimentary to each other. These include visual inspection, Helium leak test and radiographic testing. The radiographic testing was carried out by using Digital radiography. This involved developing shape correction blocks and fixtures. As the job was being carried out first time, it involved developing of reference radiographic images also. Special subroutines were developed which had facilitated evaluation of more than 2000 radiographic images in a very short span of time to enable meeting project schedule. The paper brings out various details of the above aspects.

Keywords: digital radiography, Helium leak testing , subroutines

103-C

NDE DURING FABRICATION OF BLANKET SUB ASSEMBLIES FOR PROTOTYPE FAST BREEDER REACTOR

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Abstract

Prototype Fast Breeder Reactor (PFBR) is a 500 MWe nuclear reactor which breeds its fuel apart from power generation. The reactor breeds its fuel viz. Plutonium through neutron absorption reaction with uranium -238 atoms. The PFBR core consists of 120 nos. of blanket sub assemblies.The blanket subassembly is an array of 61 pins which are enclosed in a hexcan. Each pin consist of depleted uranium oxide pellets loaded into a stainless steel tube. The ends of these tubes are sealed by TIG welding under inert atmosphere. The integrity of end plug welds are ensured by carrying out 100% visual testing, digital radiography and Helium leak testing.

During subassembly fabrication, verification of the pin number and its recording its location forms the first step of inspection. Subsequently hexcan with pre-welded head is lowered on to blanket pin array. Finally the bottom of hexcan is welded to the foot portion of subassembly. This weld evaluation is difficult due to its complex geometry. The weld quality is ensured by carrying out visual examination, liquid penetrant examination and ultrasonic testing. An ultrasonic testing procedure using shear waves and its required reference standards were developed for testing the weld. All the required 120 subassemblies have been made, tested and cleared for reactor use successfully. The paper brings out various details of the above aspects.

Keywords: digital radiography, Helium leak testing , ultrasonic testing.

104-C

NON-DESTRUCTIVE EVALUATION OF IRRADIATED NUCLEAR FUELS AND STRUCTURAL COMPONENTS FROM INDIAN REACTORS

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Abstract

Pressurise Heavy Water Reactors (PHWRs) have been operating in India for more than four decades and play a very important role in the nuclear power programme. The fuel and structural components used in nuclear reactors are subjected to stringent quality control during fabrication. These components suffer degradation during reactor operation under very hostile atmosphere of fast neutron flux, high temperature coolant corrosion and creep due to hoop stress. To evaluate the condition, many of the reactor components are brought to the hot cells for a detailed post irradiation examination (PIE).

The failed fuel bundle, which is highly radioactive, is brought to the hot cells for detailed investigation to find out the primary cause of failure. The liquid nitrogen-alcohol test is carried out on individual pins to segregate the leaky fuel pin. The region of interest is identified by non-destructive testing like profilometry, gamma scanning, eddy current and ultrasonic testing. The defects in the end cap welds were detected by immersion ultrasonic testing during post-irradiation examination. Ultrasonic velocity ratio technique has also been carried out on irradiated pressure tubes to detect hydride blisters. To evaluate creep in irradiated pressure tubes, internal diameter and wall thickness have been measured by UT, linear variable distance transducer and three point micrometer.

Gamma scanning measurement consists of gross, isotopic, and spectrometric gamma scanning. Gamma scanning has been carried out to generate information on axial burn-up distribution. Neutron radiography was carried out for detection of massive hydriding locations in zircaloy cladding and end caps, pellet cracking pattern and formation of central voids in fuel pellet. The important PIE results will be presented in this paper.

Keywords: PHWR, PIE, reactor fuels, coolant channels, NDE techniques, UT, diameter

105-C

EVALUATION OF YOUNG'S MODULUS OF METALS USING ACOUSTIC EMISSION TECHNIQUE

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Abstract

Young's modulus is an important characteristic of a material. In order to determine this parameter, tensile load test is carried out on samples up to yielding of the material. In this paper, an alternative non destructive approach is proposed to evaluate the Young's modulus of any given material, using Acoustic Emission technique. It works on the principle of release and transmission of acoustic waves within the material due to the growth of active flaws. For a simple 1-D rod, the wave velocity of an acoustic wave is related to the Young's modulus and density of the material. The velocity of propagation can be determined using Acoustic emission technique. In order to determine the velocity, pencil lead break is carried out on the surface of the material and the time delay in the response of two acoustic sensors is measured. If the density of the material is known apriori, then Young's modulus can be calculated using the measured wave velocity. This technique is very helpful to determine the Young's modulus of any material

in-situ without carrying out any destructive test on the material. This technique once established for metals, can be used to determine the elastic properties of composite materials too. In this paper, tests have been carried out to determine Young's modulus of different materials including Structural steel and Aluminum using Acoustic emission technique and the same have been compared with results from conventional tensile tests.

106-C

A FLASH X-RAY SYSTEM BASED ON FLAT PULSE MARX GENERATOR AND AN INDUSTRIAL PINCH DIODE FOR RADIOGRAPHIC APPLICATIONS

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Abstract

A compact flash X-Ray generation system using Folded Pulse Forming Line type Marx generator rated for 225kV, 5kA, 100ns; in conjunction with an industrial pinch diode has been developed at APPD, BARC. This Marx generator has the advantages of higher peak power rating, compactness, low cost and reliability and can deliver about 3 times more current than a conventional system made of discrete components. The pinch diode with pencil shaped tungsten anode placed at the centre of the circular SS cathode; is used to produce flash X-rays by Bremstrahlung process with the frequency in the region of hard X-rays. The electrodes are replaceable and tube life is almost unlimited. The flash X-rays produced are characterized using a FUJIFILM phosphor imaging plate BAS SR2025. PC controlled BAS5000 plate image scanner is used to obtain digitized images of the flash X-ray shots. The source size is determined using pinholes of size 50, 100 and 250μm kept in between the imaging plate and X-ray exit window of the system. The flash X-ray radiographs of various technological important objects like an aero engine turbine blade, INSAT cable cutter and 3/2 explosive manifold and Explosive Transfer Assembly used in space launch vehicles. To assess spatial resolution of the system a radiograph of an IC- processor chip is recorded to see the internal microstructure. The details of design, beam characterization and applications of the flash X-ray radiography system are presented in this paper.

Keywords: Marx generator, Pinch diode, Flash X-rays, Imaging plate, Pinhole, X-ray radiography

107-C

DETERMINATION OF SENSITIVITY AND SATURATION LIMIT OF PHOSPHOR IMAGING PLATES FOR PHOTON ENERGIES UP TO 1.25MEV

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Abstract

Sensitivity calibration of imaging plates (IP) is important for quantitative measurements of intensity data obtained in various X-ray and gamma radiography experiments. To test the sensitivity of the IP (BAS2025) with the scanner (BAS5000) for higher photon energies, we have performed gamma exposure experiments using radionuclides (Co-57, Ba-133, Cs-137, Na-22 and Co-60). This provides useful information in assessing the intensities and dose received on IP in radiography especially with flash X-rays in the range 250keV to 1MeV. The IP was exposed for prolonged time to determine the saturation dose limit. The observed photon sensitivity was measured as 1.310 x10^{-4} PSL/photon for 114 keV, 7.416 x 10^{-4} for 266 keV, 1.753 x 10^{-4} for 662 keV, 4.493 x 10^{-5} for 784 keV and 5.178 x 10^{-5} for 1250 keV. The PSL intensity increases linearly up to 8x10^{3} with dose received. With further increase in dose the intensity goes nonlinear till it gets saturated at ~9070 PSL. Both the sensitivity and the

saturation dose are dependent on the photon energy. The observed photon sensitivities were found to be consistent with a simulated model proposed by N. Izumi et al (2013).The calibration data of the SR2025 IP is used in assessing the dose in flash radiography experiments. The details of the experiment for performing exposure, calibration and the results will be presented.

Keywords: Photostimulated Luminescence, Phosphor imaging plate. SR2025, Radionuclide, Saturation dose

108-C

PHASED ARRAY ULTRASONIC TESTING OF DISSIMILAR METAL PIPE WELD JOINTS

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Abstract

Dissimilar metal weld (DMW) joints made of stainless steel and ferritic steel is used in nuclear industries as well as oil & gas industries. These joints are prone to frequent failures which makes the non-destructive testing of dissimilar metal weld joints utmost important for reliable and safe operation of nuclear power plants and oil & gas industries. Ultrasonic inspection of dissimilar metal weld joints is still challenging due to the inherent anisotropic and highly scattering nature. Phased array ultrasonic testing (PAUT) is an advanced technique and its capability has not been fully explored for the inspection of dissimilar metal welds.

In the present study, a mock up dissimilar pipe weld joint (194mm dia. and 8 mm thickness) made of stainless steel (316 SS) and ferritic steel (2.25 Cr 1 Mo) with inconel buttering layer is used. In-situ metallography of the dissimilar weld joint was carried out to precisely locate different zones at the weld region. Artificial notches of 5% and 10% wall thickness depth were made along the axial and circumferential directions at critical locations, namely weld, buttering layer and heat affected zones.

Comparative analysis of conventional ultrasonic and PAUT technique for detection of defects in the dissimilar pipe weld joint is carried out. PAUT technique was adapted to improve the inspection of the dissimilar pipe weld joints. 64 elements PA probes (2.25 MHz and 5 MHz) with shear and longitudinal wedges were used. Results of the study showed that the images of defects could be obtained using PAUT and simultaneous analysis of inner and outer surfaces of pipe is possible by optimization of the elements of PA transducer. The limitations and capabilities of the phased array ultrasonic testing will be discussed. Results of the CIVA simulation performed to understand the influence of buttering layer on the defect detection sensitivity using PAUT will also be discussed.

Keywords: Dissimilar weld joint, ultrasonic testing, Phased Array Ultrasonic Testing

109-C

SIMULATION, EVALUATION AND INTERPRETATION OF ULTRASONIC DEFECT AND GEOMETRICAL INDICATIONS IN SINGLE SIDE BUTT WELDED JOINTS BETWEEN HEADER STUBS TO FEEDER PIPE

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Abstract

The invention relates to Simulation, evaluation and interpretation of ultrasonic defect and geometrical indications in single side butt welded insert joints between nuclear reactor header stub/nozzle to feeder pipe. If we are getting

an indication from root of the weld joint, then we can prove and compare the indications signal detailed pattern with respect to indication signal achieved by simulation specimen. Based on indication pattern, an indication due to geometry or due to defect can be confirmed. Because of defect shown in UT equipment some time people go for repair of that defect but actually there is no defect at all. After detailed study of geometrical indications pattern and actual flaw pattern, total 24 nos. standard specimen has been developed with proper simulation of indications characteristics due to lack of penetration, un-fused inserts root concavity, excess penetration etc. After demonstration of simulation block, it has increase the effectiveness of the evaluation and interpretation. This method can be adopted for the salvaging of all UT indications which are not a defect actually. Rework due to improper evaluation has been reduced which is saving lot of time, man-hours, consumables and material. This invention not only saved valuable time, resources and avoided an unnecessary repair but also gave a high confidence in quality of the product and safety of important installation.

110-I

POTENTIAL APPLICATION OF ACOUSTIC EMISSION TECHNIQUE FOR WELD STRUCTURE INTEGRITY MONITORING UNDER DYNAMIC LOADING

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Abstract

Acoustic Emission (AE) has emerged as potential assessment technique for critical structural health monitoring and integrity inspection in nuclear components and weld structures during operation. As in the case of nuclear fusion reactor components like vacuum vessel, magnets, support structures comprising of extensive fabricated weld joints. The operational and long term reliable performance is important for these expensive and complex structures .The present paper gives the experimental results of Acoustic Emission monitoring technique applied to welded specimens made out of AISI SS 316L steel, under dynamic stress conditions roughly simulating the pre failure conditions in the welded structures. This is a preliminary step towards application of similar techniques in the structural health monitoring of reactor components under actual operational conditions with the prevailing thermo mechanical stresses. The weld samples (140 mm X16 mm X10 mm) are fabricated by deliberately implanting different types of defects like porosity, slag and inclusions in the welded zone. These samples are characterized by X-ray radiography tests for the defects confirmation profiling. By applying dynamic load within welded region of samples by specially designed mechanical jig with load cell. These samples were subjected to dynamic loading precisely converging on the welded zone, with the help of a specially fabricated mechanical jig with a load cell. AE parameters like the no. of counts, energy, amplitude, frequencies are monitored during loading of the samples (until the physical appearance of failure) and it is observed that samples with defective welds gave distinctly higher yield of AE signals/parameters compared to sample without defects. This distinctive differential behavior of the AE parameters between defective and defect free welds makes it a potential technique for the structural health inspection of the components with welded joints, quality evaluation during reactor operation conditions under heavier mechanical/structural loads like in the case of fusion reactors. By employing real time AE monitoring technique, the structural failures can be monitored in advance and help in preventing potential disasters in critical components of advanced reactors.

Keywords: stainless steels, nuclear reactor, acoustic emission, calibration, fracture

112-P

AUTOMATION OF PULSED THERMOGRAPHY USING COMPUTER NUMERICAL CONTROLLED MANIPULATOR FOR CFRP HONEYCOMB STRUCTURES

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Abstract

Compared to the other Non Destructive Evaluation (NDE) techniques, Pulsed Thermography(PT) is the fastest non-contact and reliable NDE whenever the couplants are not allowed for ultrasonic testing of large honeycomb structures. Reduction of NDE time, high Probability of Detection(POD), automatic recording of thermographic images, uniform heating at the curved regions, minimizing human errors, reducing the number of testing persons and safety of the Infrared(IR) thermography camera & operators are the advantages of using this method.

IR camera fixed on the 5 axis Computer Numerical Controlled (CNC) manipulator which has 3 linear axes (X, Y, Z) and 2 rotary axes (A & C). The precise movement of IR Camera is using SINUMERIC software. For generating separate CNC programs of the Carbon Fiber Reinforced Plastic (CFRP) honeycomb components, a generalized MATLAB code is generated in which length and width of flat components are fed as input. For circular components, input elements are sector radius, sector length and sector angle. The number of frames and time of capturing the image was verified by modeling and simulation done by COMSOL and also verified on the defect in-built specimen of HTS/M18.

Keywords: Infrared Thermography, Pulsed Thermography, Computer Numerical Control, Carbon Fiber Reinforced Plastic, Probability of Detection

113-P

DEVELOPMENT OF DATA ACQUISITION SOFTWARE FOR ULTRASONIC INSPECTION OF REACTOR PRESSURE VESSEL WELD JOINTS IN BOILING WATER REACTORS

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Abstract

Tarapur Atomic Power Station (TAPS-1&2) has completed 46 years of successful operation. It is mandatory to inspect the Reactor Pressure Vessel (RPV) welds of these two reactors at regular intervals for detection and characterization of flaws as per the regulatory requirements. Windows based system software has been developed at Electronics division, BARC for control & data acquisition from an indigenously developed 8-channel Ultrasonic Testing (UT) system for In-Service Inspection (ISI) of RPV weld joints at TAPS-1&2. The software controls various pulser/Receiver/Digitizer parameters of the 8-channel UT system, named ULTVIS, and acquires position encoded C-scan data from the system in either comb or meander pattern. It provides A-scan panel for calibration purpose & saving of channel related configuration data files, C-scan panel for configuring area scan parameters and display of each B-scan buildup while acquiring the C-scan data. It interfaces with two different mechanical scanners to cover different regions of RPV. The software was tested with a mock-up facility and then deployed successfully for ISI of RPV weld joints at TAPS. A file splitter utility to split the file, channel-wise or depth-wise, has been developed for easy analysis of the acquired C-scan data. Also a band pass filter with user programmable frequency bands has been implemented to facilitate removal of random noise from the acquired data when amplifier with very high gain is used. Due to high radiation environment inside the reactor, it is not possible to use potentiometer or encoder for position measurements. To overcome this issue, a UT based position sensing mechanism has been envisaged. This

software provides facility for position measurement using the UT technique while acquiring the C-scan data. This paper describes in detail various features of the control and data acquisition software developed at Electronics Division, BARC.

Keywords: Ultrasonic Testing, C-scan data acquisition software, Reactor Pressure Vessel, In-Service Inspection.

114-C

PROBABILITY OF DEFECT DETECTION IN CONVENTIONAL AND ADVANCED ULTRASONIC TESTING FOR DIFFERENT AUSTENITIC STAINLESS STEEL WELD JOINT CONFIGURATIONS

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Abstract

Ultrasonic testing is one of the nondestructive testing method used widely in manufacturing industries to detect & size defects originating either from primary or secondary processing of industrial components and also during pre-service (PSI) and in-service (ISI) Inspections. The method is widely preferred for weld inspection during fabrication, PSI and ISI since it is capable of detecting linear and volumetric defects. Compared to radiography, it offers the distinct advantage of greater probability of detection of linear defects and inspection of components with single sided access. Austenitic stainless material of 304L grade has been used as workhorse material due to its superior corrosion resistance and ease of fabricability in nuclear applications. In the present study, an attempt has been made to study the probability of detection of defects from different weld joint configurations such as butt welds (single V & double V), groove + fillet welds in set- in nozzle welds, open & closed corner joints and fillet welds using conventional pulse echo contact technique and Phased Array ultrasonic technique (PAUT).Weld pads are prepared with artificially created defects such as oxidation, lack of penetration, lack of fusion, root concavity, internal cracks etc., using 6 & 12 mm thickness plates conforming to ASTM A240 with different weld joint configurations. Side drilled holes (SDH) are prepared in each weld coupon as a reference to assess Probability Of Detection (POD). It has been demonstrated that the POD is much higher in phased array inspection compared to other techniques.

Keywords: Phased array, Austenitic stainless steel, Probability of detection.

115-C

WELD DEFECTS ANALYSIS OF 60 MM THICK SS316L MOCK-UPS OF TIG AND EB WELDS BY ULTRASONIC INSPECTION FOR FUSION REACTOR VACUUM VESSEL APPLICATIONS

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Abstract

The present paper reports the weld quality inspections carried with 60 mm thick AISI welds of SS316L. The high thickness steel plates requirement is due to the specific applications in case of advanced fusion reactor structural components like vacuum vessel and others. Different kind welds are proposed for the thick plate joints like Tungsten Inert Gas (TIG) welding, Electron beam welding as per stringent conditions (like very low distortions and residual stresses) for the vacuum vessel fabrication. Mock-ups of laboratory scale welds are fabricated by TIG (multi-pass) and EB (double pass) process techniques and different weld quality inspections are carried by different NDT tests. The welds are examined with Liquid penetrant examination to check sub surface cracks/discontinuities towards the

defects observation. X-ray radiography and Gamma ray examinations were carried for the thick section steels and the weld defects are not observed. Ultrasonic scan tests (A & B) have been carried out on all the TIG & EB welds. When compared with X-ray examination, ultrasonic has shown higher sensitivity for the detection of porosity. TIG sample was found having gas porosity [at the 28 mm depth with 0.5 mm size] which was not exposed by radiography observation. Also similarly in case of EB weld coupon, aligned porosity was noticed with ultrasonic examination. Defects (cracks/pores) generated in sample have been calibrated with different intensity level (dB) scans with two different probes (45 & 60 degree; 4 MHz and 10 mm dia) are employed and DAC(distance amplitude curve) are generated for known size defect measurements. Where in case of EB mockup welds, normal probe has been employed to detect the any scope of presence of defects. However by X-ray radiography analysis has not revealed the sub sized weld defects (porosity) in the test weld coupons. Hence Ultrasonic examination is very important for the weld inspection in case of thicker section steels welds where the application of X-ray/Gamma ray examinations pose limitations. Also in case of advanced fusion reactors where very high thick section welding is applied, the weld inspections with ultrasonic examinations are to be well established for quality assurance of structural components.

116-C

DAMAGE EVOLUTION STUDIES IN CARBON FIBER REINFORCED POLYMER COMPOSITES USING ACTIVE AND PASSIVE THERMOGRAPHY

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Abstract

The increasing demand for using advanced composite materials in critical load bearing components in a variety of structures under different loading conditions requires great efforts in various research areas such as development of methodologies for life prediction, characterization of damage evolution and mechanisms at multiple scales. These complicated issues are still long-term goals; however, in recent years research activity has been devoted to the application of non-destructive evaluation (NDE) techniques for the characterization of damage progress and failure mechanisms in composite materials. Among the NDE methods, infrared thermography is a non-invasive technique suited for real time monitoring and gives in-situ information regarding the onset and growth of damage.

The objective of this work is to use infrared thermography to predict the initiation of damage and their evolution of carbon fiber reinforced polymer (CFRP) composite specimens under static loading condition. To quantify the damage evolution under tensile loading, the load is applied in steps followed by dwell period at each load step. During the tensile testing, the thermal images are recorded through an infrared camera to measure the temperature evolution in CFRP composite specimen. Both active and passive thermography techniques are used to study the damage initiation and propagation under static loading condition. Post processing of the thermal images obtained using thermography techniques are used to quantify the damage in CFRP specimens of different layup configurations.

Keywords: Non-destructive evaluation, Active Thermography, Passive Thermograph

117-C

APPLICATION OF DIGITAL HOLOGRAPHY FOR NDE OF METALLIC TUBES USING THERMAL LOADING

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Abstract

Optical Non-Destructive Evaluation (NDE) techniques are attractive because of its diverse application and non hazardous nature. These techniques are widely used for measuring surface deformations of objects with and without load applied to the specimen. With the advance laser technology, Optical Holography and Speckle techniques are used as powerful inspection tools for NDE of specimens both in laboratory and industrial environments. Digital holography is a feasible tool to measure thermally induced deformation fields.

This paper demonstrates the application of wave front splitting holographic setup for evaluating thermally loaded metallic tube having holes drilled in it. Holographic interferograms are recorded at different stages of thermal loading using a CMOS camera with a pixel size of 220ì m.The present study employs H-Digital Holographic Software which supports Fresnel approximation technique for numerical reconstruction and processing of these digitally sampled holograms. Intensity and corresponding interference phase of the double exposure fringe patterns are acquired through subtraction of the reconstructed intensity and phases respectively of the unloaded and the loaded holographically recorded object wave fronts.

Keywords: digital holography, thermal loading, Fresnel approximation, numerical reconstruction

118

INDIRECT ERROR REPRESENTATION USING KANPUR THEOREM - 1

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Abstract

Computed Tomography is a vital tool in non-destructive imaging and evaluation. Various algorithms have been previously developed based on different mathematical approaches to perform tomographic reconstruction of a volume or a slice of an object under test. It has been established that out of the various algorithms Convolution Back-Projection stands out for its efficiency and speed. Other Developments in the field include identification and quantification of an inherent error in tomographic algorithms. This quantification called the Kanpur Theorem-1 can be used to extract information about the nature of reconstructions and can be used to represent error in the reconstructions indirectly. This work attempts at consolidating ways to represent error indirectly using Fractal Dimension computed using the Fractional Brownian motion approach and introduces another parameter as a measure of this indirect error. The analysis show that the inverse of sharpest change in the intensity of the reconstructed image shows healthy agreement with conventionally accepted error representatives like the Fractal Dimension of the reconstruction

Keywords: Computed Tomography, Fractal Dimension, Kanpur Theorem

119-C

CHALLENGES FOR RADIOGRAPHIC EXAMINATION OF CRITICAL DISSIMILAR METALS CIRCUMFERENTIAL BUTT WELD JOINT IN HEAVY THICKNESS TUBE BELOW 25 MM OD

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Abstract

Radiography is one of the most widely used volumetric NDT method , which is based on the principle of differential absorption of penetrating radiation in the material. SINGLE WALL SINGLE IMAGE is the best technique as compared to DOUBLE WALL DOUBLE IMAGE . DWDI (ellipse) is used whenever pipe outside diameter is less than 88 mm . DWDI (ellipse) is also not useful for smaller diameter and higher thickness than standard thickness. DWDI (superimposed) is useful but challenges still persist . According to ASME code minimum 3 DWDI (superimposed) exposures are suggested without fixing maximum exposures. Requirements like cost optimization, minimum no of exposures for full coverage, radiographic density, sensitivity and penetrameter placement are the challenges for tube less than 25 mm with higher thickness and length less than penetrameter length. NPCIL uses Radiography extensively for very critical nuclear components like channel venturi installed between reactor header & end fitting body. Other volumetric NDT method is also not useful due to space constraint.

Channel venturi is a critical equipment of INSTRUMENT CHANNEL MONITORING SYSTEM (ICMS) which measures thermal power of the nuclear reactor. 3 different materials are used for manufacturing of venturi. Low alloy carbon steel (SA 350 LF2), Inconel-82 & Austenitic stainless steel (304 L grade). Operating system requirement of material is SA 350 LF2. Measurement system requirement of material is SS 304 L because no wearing of material due to either erosion or corrosion is acceptable. Since low alloy C.S. material cannot be welded directly with austenitic stainless steel, Inconel—82 material acts as a buffer between C.S. & S.S. Coefficient of thermal expansion of austenitic stainless steel is similar to Inconel82 (ER NiCr 3).

This paper presents radiographic technique developed for complete volumetric examination of critical dissimilar metal circumferential butt weld joint by optimizing number of exposures technically & financially because 3 exposures for complete coverage were not adequate. Challenges like penetrameter placement, radiographic density and sensitivity were also complied.

120-P

PHASED ARRAY ULTRASONIC TESTING OF DISSIMILAR METAL PIPE WELD JOINTS

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Abstract

Dissimilar metal weld (DMW) joints made of stainless steel and ferritic steel is used in nuclear industries as well as oil & gas industries. These joints are prone to frequent failures which makes the non-destructive testing of dissimilar metal weld joints utmost important for reliable and safe operation of nuclear power plants and oil & gas industries. Ultrasonic inspection of dissimilar metal weld joints is still challenging due to the inherent anisotropic and highly scattering nature. Phased array ultrasonic testing (PAUT) is an advanced technique and its capability has not been fully explored for the inspection of dissimilar metal welds.

In the present study, a mock up dissimilar pipe weld joint (194mm dia. and 8 mm thickness) made of stainless steel (316 SS) and ferritic steel (2.25 Cr 1 Mo) with inconel buttering layer is used. In-situ metallography of the dissimilar

weld joint was carried out to precisely locate different zones at the weld region. Artificial notches of 5% and 10% wall thickness depth were made along the axial and circumferential directions at critical locations, namely weld, buttering layer and heat affected zones.

Comparative analysis of conventional ultrasonic and PAUT technique for detection of defects in the dissimilar pipe weld joint is carried out. PAUT technique was adapted to improve the inspection of the dissimilar pipe weld joints. 64 elements PA probes (2.25 MHz and 5 MHz) with shear and longitudinal wedges were used. Results of the study showed that the images of defects could be obtained using PAUT and simultaneous analysis of inner and outer surfaces of pipe is possible by optimization of the elements of PA transducer. The limitations and capabilities of the phased array ultrasonic testing will be discussed. Results of the CIVA simulation performed to understand the influence of buttering layer on the defect detection sensitivity using PAUT will also be discussed.

Keywords: Dissimilar weld joint, ultrasonic testing, Phased Array Ultrasonic Testing.

121-P

DEVELOPMENT OF MODULAR SOFTWARE IN LabVIEW FOR ULTRASONIC IMAGING WITH ADVANCED FEATURES

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Abstract

Detection of various types of defects with accurate sizing and location is one of the challenges in ultrasonic testing. With advancement in technology in the field of signal and image processing, ultrasonic testing deals with ultrasonic imaging today. Ultrasonic B-scan and C-scan imaging incorporating advanced features such as synthetic aperture focusing technique (SAFT), wavelet transforms, time of flight diffraction (TOFD) and 3D viewing enhances the defect detection sensitivity and their visibility in a material.

The work comprises of development of a modular software package for ultrasonic imaging. Being intuitive in nature, LabVIEW is an ideal tool for this purpose. The software mainly consists of two modes: an offline mode (for the creation of image from already acquired data) and an online mode (for creation of image while scanning the work piece). The software guides through a step-by-step approach for data acquisition or post analysis, depending upon the selected mode, in the sequence of analyzing the A-scan signal and its frequency spectrum, selecting gates in A-scan and B-scan images to generate C-scan images, using the C-scan slices to generate 3D images and automatic defect sizing based on amplitude drop methods, respectively. The software also showcase modules for generation of images incorporating advanced features such as SAFT, TOFD, wavelet transform, and 3D viewing. Various features are also present in the software, which can be incorporated by the user in any module of the program.

Keywords: Ultrasonic Imaging, modular software, LabVIEW

122-C

QUANTITATIVE ASSESSMENT OF IMPACT DAMAGE IN COMPOSITES BY IR THERMOGRAPHY

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Abstract

Thermography is an advanced NDE technique which is successfully applied for not only defect detection in composite but also for defect characterization. It is becoming popular due to its fast inspection rate and non-contact nature which also provides full field images of the defects. This paper reports the application of flash thermography technique for quantitative estimation of damage area in two composite laminates namely E-glass/epoxy and E-glass/phenolic of 5mm thickness. These laminates were subjected to low velocity impact tests using instrumented drop weight impact tester at three different impact energies viz. 50, 125 and 175J. Results showed that E-glass/phenolic composite absorbed more energy as compared to E-glass/epoxy composite. Absorbed energy was found increasing with impact energy up to threshold energy of perforation (125J), after that no significant increase in absorbed energy was observed with increase in impact energy. These impact tested laminates were subsequently inspected by flash thermography and the extent of delamination due to impact was assessed. Delamination area was estimated by sketching the polygon around the defective area and was found increasing with the impact energy. The three main inferences drawn from thermography inspection are: (1). E-glass/phenolic samples suffered higher extent of damage as compared to E-glass/epoxy samples, which corroborates well with the findings from drop weight impact test (2). Delaminated area was found increasing with the impact energy for both materials (3). Shallow plies in composites suffered less damage as compared to deeper plies.

This study has demonstrated the applicability of thermography for quantitative assessment of impact damages in composites, where most of the other NDT techniques like UT and radiography have limited scope of application.

Keywords: Composites, Delamination, Flash Thermography, Impact damage, Low velocity impact

123-C

NON DESTRUCTIVE EVALUATION TECHNIQUE IN REPAIR REHABILITATION AND STRENGTHENING OF CHLORINATION BUILDING – A CASE STUDY

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Abstract

The deterioration of concrete structures calls for an effective method of condition evaluation, life assessment and maintenance in its service life. The deterioration process and structure's present condition are essential for maintenance and repair which can be assessed through Non Destructive Evaluation (NDE).

The paper presents a case study, which includes use of various Non Destructive Tests (NDT), to evaluate chlorination building constructed in 1980's, suggest suitable repair, rehabilitation and strengthening technique. The building is a RCC portal framed structure with RC purlins and AC sheeting. The structure deteriorated over the years due to physical causes and aggressive chemical environment, showing signs of distress in the form of cracks in RC members and spalling of concrete, failing to meet the functional requirement of its designed service life, suspending the chlorination operations.

Visual inspection and NDT investigations such as Rebound hammer, Ultrasonic pulse velocity, half-cell potential, carbonation depth, resistivity tests, pH measurements, core sampling for chloride content and core compressive strength were done for life assessment, condition evaluation and categorization of distress. Based on the results of NDT field tests, laboratory analysis and visual observations it was concluded that the whole building can be repaired and rehabilitated for future use within its life span without demolishing. Detailed repair methodologies using Fiber Reinforced Polymer (FRP) Composites - glass fiber and carbon laminate system were proposed for repair and strengthening the structure. Periodical inspection and monitoring using NDE techniques were also proposed as structure evaluation is necessary for diagnosis of rehabilitation work.

Keywords: NDE, NDT, Fiber Reinforced Polymer Composite, Chlorination Building

124-P

NON-DESTRUCTIVE TESTING OF MACRO-BRUSH TYPE MOCK-UPS OF THE PLASMA FACING COMPONENT USING DIFFERENT INFRARED THERMOGRAPHY TECHNIQUES

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Abstract

The Plasma facing components (PFCs) inside a tokamak are typically exposed to extremely high heat flux of the order of MW/m^2. The brazing quality between the plasma facing materials (PFMs) and the heat sink will determine the structural integrity and hence the effective service life of these PFCs. Suitable non-destructive testing (NDT) technique for the pre-qualification of these components is thus essential to evaluate their structural integrity at various stages of their service life. Macro-brush type mockups of prototype PFCs with graphite as PFM have been inspected for their brazing quality using different active Infrared (IR) -Thermographic NDT (IR-TNDT) techniques. The results obtained from these different techniques are compared and discussed for their suitability. The quantification for the de-bonding is also attempted here by establishing a comparison between the experimental results and the Finite Element Analysis (FEA).

Key words: Infrared (IR) NDT & E, Non-destructive testing and examination, IR thermography techniques, Plasma Facing Components (PFCs), Finite Element Model (FEM) Analysis, defect quantification, Tone Burst Eddy Current Thermography, Induction heating, Thermal Imaging, Lock-in thermography, Pulse thermography

125-C

PHASED ARRAY ULTRASONIC INSPECTION OF HIGH STRENGTH STEEL SHEAR BOLTS USED IN LIGHT ALLOY STRUCTURES OF NEW GENERATION SATELLITE LAUNCH VEHICLE

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Abstract

High strength steel shear bolts made of maraging steel (M250 Grade) have been used in light alloy inter stage hardware for next generation satellite launch vehicle GSLV MKIII. On observing failures due to stress corrosion cracking on few bolts, phased array ultrasonic testing (PAUT) was carried out on all remaining bolts for the first time. Challenges in carrying out ultrasonic testing on finished bolts with complex shapes and reflecting surfaces, that too insitu on assembled hardware, were overcome by formulating novel procedures and techniques with near equivalent artificial reference defects. Health monitoring of the bolts were also carried out by doing tests before and after structural tests. Thus a novel and reliable NDT technique using PAUT was established for inspection of shear bolts

Keywords: Maraging steel, Phased Array Ultrasonic testing (PAUT), Shear bolt, Stress corrosion cracking, Ultrasonic testing

126-C

NON-DESTRUCTIVE EVALUATION OF IRRADIATED 240 MW PHWR FUEL ELEMENTS

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Abstract

The non-destructive evaluation (NDE) of six number of fuel bundles were carried out inside hotcell facility which had seen different burn up of around 10,000 to 22,000 MWD/T. The NDE technique includes visual examinations, leak testing, profilometry and gamma scanning. Four irradiated PHWR fuel bundles having burnup of 11272, 10109, 22263 and 10647 MWd/TeU respectively were taken for non-destructive evaluation. Two bundles had seen a power transient, 27% power increase for 13 minutes. Two MOX bundles having burnup of 20331 and 10788 MWd/TeU were also taken for the non-destructive evaluation.

Each bundle were visually examined through cell windows and radiation resistant cameras having tilt, rotation and zoom facility, installed in the front wall of hotcell. After dismantling and visual examinations of all the fuel elements individually, each fuel elements were subjected to liquid nitrogen – alcohol leak testing.

The fuel elements are expected to have dimensional changes after in reactor operation. Diameter profile measurement of 3 fuel elements (outer, inner and central) from selected bundles were carried out using Linear Variable Differential Transformer (LVDT) probe based profilometry system. The fuel element was placed in the fuel element holding grips and was translated from one end to another. The pin outer diameter data is recorded throughout the length of the pin. Increase in diameter at pellet interfaces due to hour glass effect of the fuel elements were clearly observed during profilometry.

Gamma-scanning was carried out for measuring the relative distributions of fission products in irradiated fuel elements that helps to generate information on axial burn-up distribution and distribution of specific fission products. An attempt was made to calculate the burnup of fuel bundle using fission product ratio method.

127-C

IMPROVING THE SENSITIVITY OF ULTRASONIC EXAMINATION OF NICKEL BASED SUPER ALLOY TUBES

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Abstract

Nickel based alloy cladding tubes with burn-up of nearly 1,00,000 MWd/T are being developed for light water reactors. These tubes require tubes with high integrity which is to be demonstrated by using a very sensitive non-destructive examination test. Conventionally, ultrasonic testing of fuel tubes is carried out using longitudinal and transverse notches made on the reference standard on OD and ID. With this reference standard reasonable sensitivity is achieved. However to improve the sensitivity of test further new type of standard is used with flat bottom hole of 0.3mm diameter and depth as 40 microns. Till now for immersion testing of tubes such a standard has not been used and there is no comparison available with the notch standard. For comparing the sensitivity of the notch and FBH standard CIVA simulation was carried out. It was observed that the sensitivity of FBH standard is much higher than the notch. For calibration using this standard, an additional spot focused probe is used for calibration. The details of the test parameters used are provided in the paper. Tests were carried out using the FBH standard and the defect indications were analyzed using metallography. At locations where FBH indications were obtained extremely fine surface defects were seen which were not detected with calibration with notches. Additionally, with this high sensitivity of calibration in some tubes due to coarse grain size.

128-C

ON EDDY CURRENT EXAMINATION (ECE) OF INCOLOY 800 SG TUBE USING OD ENCIRCLING AND ID BOBBIN COIL

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Abstract

The purpose of this paper is to present and compare the results of ECE carried out on steam generator tubes from OD side and ID side. During the manufacturing of the tubes eddy current testing is being carried out using OD encircling probe as per ASTM E 571. Here the purpose of the test is to capture the manufacturing defects. The parameters of the test are optimized to achieve best sensitivity to this requirement. These tubes are then installed in the steam generator and once again ECE is carried out during installation (pre-service inspection-PSI) and during in-service inspection (ISI) by using ID bobbin coil. These tests are carried out as per ASME section V article 8 appendix 1. Here the purpose of the test is to detect wall thinning, dent, pits etc due to operation and to locate these defects (OD side or ID side). Here the operating parameters are optimized for phase separation of defects from OD and ID. These parameters are quite different from those used during the manufacturing ECE. Interpretation of the signals detected in PSI/ISI in must be done with care to correlate with defect indications detected during manufacturing. In the present study, tubes with certain manufacturing defects, detected with OD encircling test were subjected to ID bobbin coil examination. Also certain tubes with signal picked up during test from ID were

examined by using the OD encircling probe. This comparison of the results provides a clear picture about the sensitivity and deficiency of the either type of test.

129-C

CONDITION MONITORING: A STUDY ON AGEING IN INCONEL 718

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Abstract

The development of contemporary high temperature materials is needed to enable the successful introduction of cleaner and more efficient next generation power plants. Due to inherent limitations in steels, new high temperature materials must be selected for a change in operating parameters. Inconel-718 is currently considered to be one of the leading materials for use in high temperature applications. Due to its excellent high-temperature mechanical properties, Inconel-718 is believed to be a contender for forged components of Advanced Ultra-Supercritical (A-USC) power plants. The A-USC power plant with steam conditions of 700°C / 35MPa, is expected to have greater efficiency. Thus the microstructural stability and its impact on the mechanical properties of this alloy at elevated temperatures will certainly be a crucial factor that influences the reliability of the power plants. Therefore it is of imminent importance to study the microstructural evolution of components made out of Inconel-718 preferably by Non-destructive methods.

Inconel-718 generally contains three phases: ã, ã′(Ni_3(Al,Ti)), and ã3 (Ni_3Nb) phase. ã3 phase is thermodynamically metastable and it tends to transform to the ä- Ni_3Nb phase at elevated temperatures. Thus, in the present study, Inconel-718 alloy was solutionized and aged at different temperatures for different times enabling the complete microstructural evolution on exposure at high temperatures. Four-probe electrical resistivity and Ultrasonic velocity measurements were carried to monitor the microstructural changes. The results show that the precipitation behavior in IN-718 can be studied using resistivity, ultrasonic testing. These results were further correlated with the hardness measurements and microscopy studies.

Keywords: Inconel 718, Ageing, Intermetallic Precipitation, NDE.

130-P

NON DESTRUCTIVE EVALUATION AND QUALIFICATION OF HIGH PURITY ALUMINA CORED BRICKS FOR STORAGE HEATER SYSTEMS

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Abstract

High purity Alumina cored bricks having high heat storage capacity, compressive and rupture strength and thermal shock resistance are used as the heat storage medium in the heater systems of Hypersonic Wind Tunnel (HWT), VSSC and are being developed indigenously. Cored bricks of heater II are designed to go up to a maximum operating temperature of 1550 K and are required to minimize the dust in test stream that the pebble bed Heaters are prone to.

Considering the extreme conditions to which the bricks are subjected to during the course of its operation, proper evaluation of its characteristics and qualification of the bricks are a must. The conventional evaluation and

qualification schemes involve the destructive tests such measurement of Cold Crushing Strength, Modulus of Rupture, Abradabilty index, Density measurements etc. However such tests are done on sample level, hence individual property variation cannot be captured. X ray cannot be used since property evaluation is not feasible. Inspection cannot be done in-situ because of X-ray hazard and Cost of film is also high. Hence a special non-destructive testing and evaluation scheme was developed for the qualification of the alumina cored bricks. The technique being a non destructive can be employed for the qualification of each and every individual brick, a definite advantage over the conventional destructive qualification techniques

The scheme has been successfully implemented for the evaluation and qualification of nearly 20000 nos. of heater bricks for the Hypersonic Wind Tunnels. The validity of the scheme has been established by comparing the measured velocities with the cold crushing strength of the samples. The details of the qualification scheme devised and the results obtained are covered in this paper.

131-C

FORESEEING THE HIDDEN DEFECTS IN ROCKET MOTOR HARDWARE THROUGH NDT- A CASE STUDY

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Abstract

Always, there lies an uncertainty when it comes to detect defects through non-destructible means like ultrasonic testing, radiography, dye penetrant testing etc. It is the result of cumulative result of machine, human error & human fatigue, machine limitations, human limitations, attitude towards detection, structure of the actual job and sometimes even the orientation of the defect. This paper gives the directions implemented in improving the certainty in defect detection in rocket motor M250 hardware.

Solid rocket motor case hardware of size 2.8m welded segments. The design is based on fracture mechanics and hence the presence of flaw and its growth potential have to be monitored till the hardware is used in flight. When a defect is detected after an year of storage in weldments in periodic Ultrasonic testing, it is often a debate as to whether defect was missed at an earlier stage or the defect has grown. Over the years quality improvement efforts have been put in place to improve defect detection and to analyse its growth. Such improvements are presented in the paper. This has led in reducing Uncertainty with increased probability of detection. Another interesting aspect is that overdoing & superfluous testing can be avoided.

Paper covers improvements in the area of Radiography, visual and Liquid penetrant testing and Ultrasonic testing. Radiography and ultrasonic testing being the mainstay in the detection of internal defects these are dealt in length. All the same when there is a defect growth, surface inspections have also revealed it. Such cases have been analysed for the root causes that have led to corrective actions in the process. Strengthening of inspection at the first stage has also been done to avoid missing of defect. Ultrasonic operator qualification was strictly implemented with training and exposure to the type of defects seen in the segments. Overall results show that defect detection and analysis are more certain which in turn reduce the time for decision making and eventually clearing the hardware for flight.

All the improvements are implemented in work centre industries strengthening our confidence to realize hardware through Indian sources.

132-C

TEMPERATURE EVALUATION IN FRICTION STIR WELDING THROUGH THERMOGRAPHIC TECHNIQUE

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Abstract

In this study, the temperature generated during the FSW process of AA2014 aluminum alloy was measured by using the Infrared thermography technique and also study the effect of tool pin shape on the thermal profile by using the Infrared thermography.

Experiments were conducted with different tool pin profiles (conical, triangular, square, pentagon and hexagon cross sections) maintaining the same swept volume during the tool rotation. The shoulder diameter was also kept constant for all tools at 12 mm. Tool pin profiles performance was evaluated through experiments under a constant set of input process parameters, viz., spindle speed: 1000 rev/min (rpm), travel speed: 600 mm/min and tilt angle: 2°. After welding, the FSW plates were sectioned perpendicular to the weld direction and samples are prepared for mechanical and metallographic analysis. The temperature profile of hexagonal tool pin showed maximum temperature of 364°C and having the minimum HAZ. The material flow during the FSW was also captured using IR thermography. Hexagonal tool pin profile showed best material flow during welding process.

Based on the experiments carried out, it was concluded that the hexagonal tool pin profile is best for friction stir welding of aluminum alloy AA2014. This is also supported by the tensile strength values of the welds for different tool pin profiles.

Keywords: FSW, IR, Thermography, Tool Pin shape.

133-C

IN-SERVICE INSPECTION FOR ASSESSMENT OF WELD DEGRADATION IN SS 310S REDUCTION RETORT

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Abstract

Austenitic stainless steel AISI 310S is used as the material of construction for Reduction retorts. SS 310S is selected for its ease of fabrication, corrosion and elevated temperature (around 850ÚC) properties. Matching welding consumables (E 310/ER 310) are used for welding of longitudinal and circumferential joints during fabrication of these retorts. The high temperatures applied during both welding and service, significantly affect the microstructure and properties of the weldment.

During operation, these retorts are subjected to highly corrosive chloride environment in addition to high temperature. The middle zone operating temperature is 600Ú C to 700Ú C and undergoes inter granular stress corrosion attack (IGSCC) from inside and oxidation on outside surface. The bottom zone operating temperature is 800Ú C to 850Ú C and undergoes IGSCC and weld degradation. The retort is operated at an internal pressure of 5 psig and carries a tensile load of around 6 tons at 850Ú C. Hence these reduction retorts are subjected to in-service inspection (visual inspection and radiography of hot zone welds) after 40 runs and thereafter at regular frequencies to assess the healthiness of the weld joints. During In-service inspection (ISI), in retorts which were welded with ER 310 filler

wire, many cracks were observed in the weld between shell and dished end. Inspection of welds during service was carried out using digital radiography by using a panoramic X-ray exposure.

In order to find out the cause for the weld degradation and linear defects formation and propagation, failure analysis of the retorts was taken up. The observations in the failure analysis were correlated with the fabrication history, operating data and in-service inspection data. With this the mechanisms of weld degradation were identified and recommendations were made to improve the life of the retorts. The use of E 310 Mo welding consumables, modification of process conditions and fabrication procedures resulted in improvement of the life of the reduction retort.

134-C

EVALUATION OF APS THERMAL BARRIER COATINGS USING INFRA RED THERMOGRAPHY TECHNIQUE

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Abstract

Application of thermal barrier coatings (TBCs) to the hot section components such as blades and vanes has enabled the use of higher turbine entry temperatures in the modern gas turbine engines. TBC is a bi-layer coating system having an insulating ceramic outer layer or topcoat and an inner metallic coating called bond coat (BC). During prolonged exposure at high service temperatures, the microstructure of the ceramic layer changes and it undergoes sintering. This can lead to an increase in its thermal conductivity during service. Such an increase in the conductivity is undesirable because it would reduce the ability of the ceramic coating to provide the required thermal insulation to the underlying substrate. Prolonged thermal exposure causesmicro-decohesion and delamination of TBC layer at TBC/BC interface.

Considering the critical dependence of the effectiveness of a TBC on the life of the ceramic top coat, it is imperative to develop a suitable NDE technique for life assessment and health monitoring of TBCs. Thermography has an advantage over all the other NDE techniques since it is a noncontact and comparatively fast technique. In the present study, we have explored the potential of thermography technique to monitor the changes in the thermal properties of air plasma sprayed (APS) 7YSZ TBC specimens under thermal cycling conditions and also to detect delamination of the ceramic layer during cycling process. A method has been devised to monitor the changes in the thermal diffusivity of the TBC coating. Lock-in thermography technique has been used to detect the delamination at the ceramic/bond coat interface. This study has shown that the thermography method can potentially be used for monitoring the health of a TBC in a non-destructive manner during its use.

Keywords: APS, TBC, Infrared thermography, Thermal diffusivity.

135-P

SMART PHONE BASED APPLICATION SOFTWARE FOR INDUSTRIAL GAMMA RADIOGRAPHY

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Abstract

The paper discusses a smart phone based application for performing calculations required in industrial film radiography using radioisotope sources. The application enables the user to find residual life of a radioactive

source, saving multiple source details in the phone memory, exposure time calculation required in gamma radiography and running multiple countdown clocks for accurate and convenient counting of exposure time. The application is also able to provide vibrating and audio alarms when the countdown finishes, automatic SMS facility to multiple users informing details of low activity sources in custody and cordon-off distances for open-source radiography. The application has been developed to work under Android, I-phone (Apple), Blackberry (RIM), Windows, Symbian operating systems and J2ME enabled feature phones. A simplified version of this application with limited features runs on java enabled low-cost mobile phones and tablets.

136-P

DEVELOPMENT OF A MACHINE BASED NON-CONTACT ID GAUGING SYSTEM FOR ZIRCALOY FUEL TUBES

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Abstract

Zircaloy 4 tube is used as fuel cladding material for Indian PHWR Nuclear reactors. The radial gap between cladding tube and uranium dioxide pellet is one of the major design parameter, and is maintained as 0.038 to 0.13 mm during manufacturing of fuel bundles. To maintain stringent radial gap, ground pellets with OD tolerance of +/ - 0.012 mm are inserted in tubes with ID tolerance of +/- 0.012 mm. However , owing to difficulty in manufacture the tubes with this tolerance, tubes, after cutting to the length of 500mm, are sorted to this tolerance based on ID measurement. Currently, ID sorting is being done manually. But with increasing production rate and to have better reliability, a machine based system for ID gauging and sorting was conceptualized. To fulfill this accuracy of sorting, a non-contact auto gauging system has been developed. The system works on the principle of air gauging i.e. back pressure is inversely proportional to clearance between the air jet nozzle and tube surface. A four jet air plug has been used to measure the internal diameter in two mutually orthogonal axis. During the controlled travel of the probe in the tube inside bore, more than 300 diameter measurements are made in length of 500 mm. Based on this measurement a database of all the measurements is available for minimum, maximum and average ID. A criterion of segregation of tubes is made on the basis of these measurements into 5 different categories. System can also measure the ovality at every point which is also used for sorting. Trials have been carried out at different probe insertion speeds. The cycle time is optimized at 15 secs for effective sorting of tubes. Based on these trials a machine based system is envisaged for ID gauging and sorting of these critical tubes in future.

137-C

AN APPROACH FOR SIZING OF FLAWS FROM 3D-GMR MAGNETIC FLUX LEAKAGE IMAGES

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Abstract

In magnetic flux leakage (MFL) technique, the object is magnetized and the magnetic flux that leaks out of the flaws is detected using field detection sensors. Flaw dimensions influence the MFL signals. Sizing of flaws from signals is important and essential for prediction of the remaining life of the components and also for life extension.

In this paper, we present an inversion method that uses iterative nonlinear least squares optimization to predict the flaw parameters from MFL images. 3D-GMR sensor has been used to obtain MFL images of all the three components

viz. tangential, B_x (along the measurement surface and perpendicular to the length of flaw), circumferential, B_y (along the measurement surface and parallel to the length of flaw) and normal, B_z (perpendicular to the measurement surface) of leakage magnetic fields from flaws (length 15.0 mm, width1.0 mm and depths 0.93, 1.72, 3.32, 5.76 and 8.90 mm) in 12 mm thick carbon steel plates. MFL images predicted from three dimensional-finite element (3D-FE) modeling have also been used to test the performance of the proposed method. Studies reveal that the approach is capable of fast estimation of the flaw parameters length, width and depth of surface-breaking flaws with relative errors less than 15%. The inversion method proposed and its results from the MFL images of flaws in carbon steel plates obtained by 3D-GMR sensor will be presented.

Keywords: Magnetic flux leakage, 3D-GMR, sizing, nonlinear least squares optimization

138-C

ANALYSIS OF SPATIOTEMPORAL EVOLUTION OF PORTEVIN –LE CHÂTELIER DEFORMATION BANDS USING INFRARED THERMOGRAPHY

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Abstract

Instability in plastic deformation due to dynamic strain aging is generally manifested as stress serrations during constant strain rate tests or strain bursts in the constant stress rate tests in the certain class of materials. Instabilities of this type are known as Portevin–Le Châtelier (PLC) effect. PLC is connected with localization of strain in deformation bands that some time propagates like a soliton along the specimen. In the present work, the nucleation and propagation of PLC bands in an Al-Mg alloy under constant strain rate have been studied using infrared thermal imaging technique (IRT). Infrared thermal imaging is capable of capturing information on the local heating due to plastic deformation in the deformation bands, and such information could be correlated to the conventional stress serration measurement. The spatio-temporal evolution of different types of deformation bands (e.g., types A, B, C) with the variation in strain rate has been captured using IRT technique. The use of IRT provides independent data on band propagation velocity, strain gradient inside bands as well as the width of the band. These experimental data have been used for analysis of the PLC effect in an Al-Mg alloy with variation in strain rate. An attempt has been made to capture the transition from A type to B and C type of bands. The effect of strain hardening on the nature of PLC effect is also examined.

Keywords: PLC effect, IRT, Al-Mg alloy.

139-C

A COMPARATIVE STUDY OF PULSED AND LOCK-IN THERMOGRAPHY TECHNIQUES FOR DEFECT DETECTABILITY IN AISI 316 L SS

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Abstract

Infrared Thermography (IRT) is one of the advanced NDE methods that is becoming attractive due to its ability to inspect non invasively large areas in short times and provide full field images in a non contact nature. The recent advances in active thermal techniques include Pulsed Thermography (PT) and Lock-in Thermography (LT). These techniques have found wide applications in the fields of materials characterization and quantitative defect detection. While extensive work has been done with these techniques for defect characterization in composites, very little has

been done for steels like AISI type 304 and 316 which find wide applications in nuclear industries as structural material. In this paper a comparative study of defect detectability and Signal to Noise Ratio (SNR) of PT and LT in AISI 316 L SS. Analysis of the results indicate that LT images have better Signal to Noise Ratio (SNR) compared to images from pulsed technique and accuracy of defect depth characterization is also higher. However, with the aid of signal processing techniques, like Thermal Signal Reconstruction (TSR), the defect detectability in PT can be improves and is comparable to LT.

Keywords: Pulsed thermography, Lock-in thermography, Defect detection, Stainless steel, Signal to Noise Ratio

140-P

EVALUATION OF GEAR FAILURES BY ULTRASONIC TESTING TECHNIQUE

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Abstract

Gears are one of the most vital moving parts in mechanical power transmission system. Gear failures are defined as the distress that occurred in the component, when allowable stress limits are exceeded. Basic type of gear failures are, lubrication failure and non lubrication failure, lubrication failures which are formed during service stage, show major effect on the gear component, where as non-lubrication failures are formed during manufacturing stage. Non-destructive testing techniques like magnetic particle test (MPT), liquid penetration tests (LPT), and ultrasonic tests (UT) which are proved to be more efficient techniques, in finding the lubrication failures in gear component are used for this investigation. Here UT is performed on the helical gear component to find the sub-surface level defects. The objective of the present work is to identify the defect and characterize it by using NDT method of ultrasonic test.

141-P

ESTIMATION OF SINGLE CRYSTAL ELASTIC CONSTANTS USING ULTRASONIC TESTING - A FEASIBILITY STUDY

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Abstract

Estimation of single crystal elastic constants (SCEC)of metallic materials is of paramount importance in the development of crystal plasticity based models as well as for studying the effect of microstructure on wave propagation. SCEC are usually determined destructively by tensile and shear loading a single crystal specimen. These constants can also be estimated non-destructively, using X-ray diffraction measurements on a polycrystalline specimen. However, the aforementioned procedures have a limitation of either the sample size (in case of X-ray diffraction) or, availability of single crystal (in case of destructive testing). Hence, in this study, an effort has been undertaken to estimate SCEC by subjecting polycrystalline specimens to ultrasonic testing. Ultrasonic longitudinal and shear velocities, longitudinal attenuation coefficient and ultrasonic backscattered grain noise will be measured on pure Cu specimen. Further, these parameterswill also be calculated analytically using existing relationshipsinvolving, elastic constants, grain size probability level, ultrasonic longitudinal and shear wave velocities, attenuation coefficient and backscattered grain noise. Byminimizing the difference between experimentally measured and analytically calculated ultrasonic parameters, an attempt will be made to estimate single crystal elastic constants.

Keywords: Single Crystal Elastic Constants, Immersion Ultrasonic Testing, Velocity, Attenuation Coefficient, Backscattered Grain Noise, Grain Size Probability Level.

142-C

CHALLENGES IN PROBABILITY OF DETECTION (POD) OF ULTRASONIC TESTING - A MODELLING APPROACH

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Abstract

Estimation of Probability of Detection of the NDT techniques used is important information under damage tolerance lifingphilosophy of aero-engines engines due to criticality of minimum detectable crack size.POD is a function of crack parameters such as size, shape and orientation along with type of material. POD of any NDT technique can be estimated by using the standard test procedure and methods mentioned in MIL-HDBK 1823A standard. However, as the experimental estimation of POD is both labour and cost intensive, numerical models to estimate POD are currently in vogue. Developing a model for POD estimation involves, a physics based model for the NDT technique as well as statistical analysis. In addition, information on the distribution of crack sizes identified for POD estimation is also very crucial. Hence, in this study, a numerical model based POD estimation on bulk defects has been carried out for ultrasonic inspection technique. A Ti-6Al-4V (Titanium alloy) cylindrical block (50 mm x15 mm) with a flat bottom hole (FBH) (0.5mm x 5 mm) was initially inspected with ultrasonic testing using 5MHz longitudinal transducer. Further, 2-D and 3-D FEM based numerical models were developed to simulate the interaction of ultrasonic waves with the FBH using COMSOL Multiphysics v4.3a software. These numerical models thus developed, have been validated by comparing the % full screen height of defect echo with that of experimentally observed. Random crack sizes (range: 0.2 – 2 mm) for POD estimation were generated using normal and Rayleigh distributions. By selecting a pre-defined threshold for signal intensity, POD curves were plotted using log normal distribution. From these studies, it has been observed that ultrasonic inspection of FBH for Ti-6Al-4V Titanium alloy has $a_{90/95}$(crack size with 90% probability and 95% confidence limit) POD of 0.5mm.

Keywords: Aero-engine, Damage Tolerance, Ultrasonic testing, Probability of Detection, flat bottom hole, finite element modelling, normal distribution, Rayleigh distribution.

143-P

INSPECTION OF REFORMER TUBES BY HIGHER ORDER MODE CLUSTER GUIDED WAVE (HOMC-GW) TECHNIQUE

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Abstract

Creep damage is the most prominent damage in the reformer tubes since the tubes are subjected to the differential pressure and temperature over a long period of time. After the service life of 11 years, the tubes experience creep voids/micro cracks which may lead to macro cracks and failure. This paper reports the potential of higher order mode cluster Guided Waves (HOMC-GW) for the inspection of macro-cracks in the reformer tubes. HOMC-GW

are highly non dispersive and occur when the frequency - thickness product is very high. 2D ABAQUS finite element simulations were used to decide the optimal wedge angle which facilitates the generation of the HOMC-GW in a pipe. Experiments were carried out on the centrifugally casted reformer tubes made of HK40 alloys, HP modified and micro alloy materials. The tubes were inspected in axially and circumferentially for the detection of cracks. The transducer was always placed at fixed circumferential position and moved axially along the length of the pipe. The defect position along the circumference was ascertained from the time of flight while the defect size was estimated using amplitude data obtained.

Keywords: High order mode cluster, Guided Waves, Creep, Macro-Cracks.

144-C

HELIBORNE TIME-DOMAIN ELECTROMAGNETIC (TEM) SURVEYS FOR URANIUM EXPLORATION

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Abstract

Airborne geophysical surveys have been used extensively in petroleum, mineral exploration, and environmental mapping.Of all the geophysical methods, Electromagnetic (EM) methods, both ground and airborne are used to map the conductive ore bodies buried in the resistive bed rock. Mapping resistivity variations can help unravel complex geological problems and identify areas of hidden potential. Besides the traditional applications to ground water investigations and other natural resource exploration and geological mapping, a number of new applications have been reported. These include hazardous-waste characterization studies, precision agriculture applications, archeological surveys etc. Airborne Electromagnetic (AEM) methods have undergone rapid improvements over the past few decades. Several new airborne Time Do-main EM (TDEM) systems appeared; ex-isting systems were updated and/or enhanced. The use of natural field (passive) EM surveys continued to increase, with new or im-proved systems becoming available for both airborne and ground surveys. The number of large airborne survey systems with combined EM, magnetic, gravimet-ric and gamma-ray spectrometric capa-bilities also increased.

Exploration of a mineral deposit is a multi-stage & multi-disciplinary approach that commences from regional investigations and concludes with establishing of a deposit. As economics play a major role in exploration, a proper integrated study is always beneficial in narrowing down the potential mineral target zones. Heliborne geophysical surveys are being conducted world-wide for exploration of base metals, gold, phosphorite, oil, uranium etc. that are very effective tool in identifying zones of interest accurately, economically and with less span of time. These surveys give a very good insight of surface and sub-surface geophysical signatures that can be attributed to geology with proper modeling. HeliborneTime- domain Electromagnetic (TEM) methods are well known for search of massive sulphides, shear zones

146-P

EFFECT OF PORE SIZE ON FATIGUE LIFE OF A CAST ALUMINIUM SAMPLE USING NDE & FEA

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Abstract

Non-destructive evaluation methods are generally employed to identify defects after a fabrication process is complete, thereby concluding whether the product is accepted or not (any repairs to be made). But this method proves

ineffective when it comes to evaluating the properties of a component like tensile strength, fatigue etc. There are many approaches made to predict / calculate the fatigue life of a defective component. This work explains the evaluation of fatigue life of a cast aluminium alloy specimen using Non-destructive evaluation and Finite Element Analysis (FEA) methods using the knowledge of stress concentration factor. This work also shows the relationship between fatigue life of the component with respect to the defect size (spherical) which has a crucial role to play in acceptance criteria.

147-C

COMPARISON OF WELDING INDUCED RESIDUAL STRESSES AUSTENITIC AND FERRITIC STEEL WELD JOINTS

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Abstract

X-ray diffraction (XRD) is a well established technique for measurement of residual stresses in components and is being widely used. In XRD technique, the distance between the crystallographic planes (d spacing) is measured from peak position (2è) at various ø angles, where ø is the angle between the normal to the sample and the bisector of the incident and diffracted beam. From the slope of sin2ø vs. d spacing plot, the residual stresses are arrived by assuming a plane stress model.

Welding induced residual stresses is of high importance as it is a major cause of failure in components. Surface compressive stresses improve the fatigue strength, whereas tensile residual stresses tend to decrease the fatigue strength. The present study compares the residual stresses that develop in 3 mm thick SS 316 and P91 TIG weld joints using the XRD technique. This study is aimed at understanding the influence of shrinkage during cooling and the effect of phase transformation induced volume changes on residual stress development in these two steels. While the first effect is predominant in the SS 316 weld, both the effects are present in the P91 welds.

Stress measurements on SS 316 and P91 were carried out using Cr Kâ (λ-2.0840 Å) and Cr Ká (λ-2.2896 Å) radiations respectively. Typical 'M' type stress profile was observed across the weld centre line in both the welds. The variation and similarities between the longitudinal stress profiles observed in these two weld joints would be discussed.

148-C

APPLICATION OF ELECTRICAL CONDUCTIVITY AS AN NDE TOOL FOR MICROSTRUCTURAL EVOLUTION DURING COLD ROLLING AND THERMAL AGEING

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Abstract

The application of electrical conductivity as a nondestructive tool for understanding the microstructural evolution during cold rolling and thermal ageing is demonstrated in this study. In general, electrical conductivity depends on

density of dislocations, precipitates, and crystal structure of the matrix and is influenced by changes in these microstructural features. Dislocations and precipitates are lattice imperfection in crystalline materials which decrease the electrical conductivity by scattering effect. Similarly, the electrical conductivity is more in a closed packed structure as compared to an open crystal structure .

In the present study, 316 stainless steel (SS) specimens are cold rolled up to 60 % reduction in thickness in steps of 5%. The 40 % cold worked (CW) steel is further annealed at different temperatures between 300 °C to 1200 °C. The two sets would enable in understanding the changes in dislocation structure. Electrical conductivity measurements are carried out on these two sets of specimens and results are compared with X-ray diffraction (XRD) measurements and hardness. The investigation showed decrease in electrical conductivity with increase in the cold work of 316 SS specimen. The XRD peak profiles (311) of these specimens were analyzed to estimate the microstrain. The observed variation of electrical conductivity, microstrain and changes in hardness are explained. Similarly, changes in electrical conductivity of Ti-alloy heat treated below â-transus temperature of 1155K is investigated. The phase transformation of β Ti-alloy (body centred cubic) to α Ti (hexagonal closed pack structure) on ageing is analyzed from the conductivity measurements and the conductivity is shown to be proportional to the volume fraction of α phase.

149-C

MODEL BASED OPTIMIZATION OF PULSED EDDY CURRENT TECHNIQUE FOR DETECTION OF DEFECTS IN STAINLESS STEEL PLATES

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Abstract

Pulsed eddy current (PEC) testing is one of the most widely used electromagnetic NDE techniques. As a pulse has continuum of frequencies, it enables different depths of interrogation in electrically conducting materials. Numerical modelling of PEC technique is useful to understand and optimize excitation parameters. This paper presents the results of finite element (FE) modeling of PEC technique using COMSOL Multiphysics software. For this study, the time dependent AC-DC module of the software has been used.

Typical FE model consists of a probe with exciter coil and receiver. The exciter is fed with a current pulse and the receiver senses the response due to the eddy currents produced in the metallic specimen. In this work, instead of a receiver coil, a Giant magneto-resistive (GMR) is used for detection of surface as well as sub-surface defects in an 8.0 mm thick AISI type 304 stainless steel plate. Time domain parameters i.e. the peak amplitude and time to peak are optimized for detection of defects.

150-C

3D SIMULATION AND UNDERWATER EXPERIMENTAL VALIDATION TOWARDS ULTRASONIC DETECTION OF PROTRUSION OF SUB-ASSEMBLIES IN PFBR

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Abstract

Prototype Fast Breeder Reactor (PFBR) is a sodium cooled pool-type fast breeder nuclear reactor, which has sodium-submerged 181 hexagonal shaped Fuel Sub Assemblies (FSAs). During normal operation of the reactor, the temperature of liquid sodium is 550 C. Due to high temperature and radiation, there is a possibility of protrusion of hexagonal shaped FSAs. Due to opaque nature of sodium, only ultrasonic testing is possible for detection of protrusion during shutdown. During the shutdown, the temperature of liquid sodium is about 180 C. Before starting fuel handling operation during the shutdown, under sodium ultrasonic imaging will be used to ensure that no subassembly is protruded beyond the allowable limit.

This work is associated with the simulation of detection of protrusions of fuel subassemblies using under-water ultrasonic testing. Towards this, a miniature core model (1/10th dimension of the real size core) is developed. Various simulations are carried out using the miniature core immersed in water, in the ray based ultrasonic NDE simulation software 'CIVA 11.1'. Ultrasonic parameters for the miniature model such as frequency and diameter of the transducer are optimized to obtain similar -6dB divergence at the distance of 500 mm in the miniature core as in the case of actual under sodium ultrasonic testing in PFBR at the distance of 5000 mm. By placing the transducer at a location corresponding to the in-vessel transfer port of PFBR, B-scan images of the peripheral subassemblies are obtained using CIVA. This serves as a reference for detection of protrusion in the fuel core. B-scan images are also obtained by placing random protrusions of different heights in the central region of the core. Experimental B-scan images are also acquired with the miniature core placed underwater with the same protrusions, as used for the simulation. Results will be discussed.

151-C

FATIGUE AND CREEP-FATIGUE DAMAGE ASSESSMENT IN TI-6AL-4V TITANIUM ALLOY USING IR-THERMOGRAPHY

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Abstract

Titanium alloys such as Ti-6Al-4V are susceptible for fatigue and creep-fatigue interaction induced damage both at ambient and high temperature conditions. These alloys are extensively used for various structural applications such as aero-engine components etc. Reliable operation of such components depends on effective damage assessment during service. For offline damage assessment, excellent NDT techniques such as eddy current, ultrasonics, radiography etc. are available. But for online damage assessment, IR-thermography is one of the most popular techniques worldwide due to its non-intrusive and non-contact nature. Hence in the present investigation, foe online damage assessment of creep-fatigue and fatigue damage, IR-thermography has been used. By holding the sample at peak stress, creep-fatigue interaction effect was introduced in the sample. Thermal profiles over fatigue and creep-fatigue samples were captured using online lock-in IR-thermography. Further, thermal modeling has

been performed on the experimentally evaluated IR-data using first and second laws of thermodynamics. Thermal modeling effectively captured the partitioning of hysteresis energy into thermal losses and damage energy. This damage energy is responsible for creation of damage features such as voids in these samples. The damage energy for the sample tested with hold time (creep-fatigue) was more than that without hold time (pure fatigue) sample. Microscopic investigation further validated the higher amount of damage in creep-fatigue sample than fatigue sample.

Keywords: Ti-6Al-4V; creep-fatigue damage; thermal modeling

153-C

A MICROWAVE ASSISTED IR THERMOGRAPHY BASED NON-INVASIVE TECHNIQUE FOR COMPOSITIONAL ANALYSIS OF MINERALS

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Abstract

?WIR-SORT- a microwave assisted IR thermography based technique for iron ore compositional analysis of Iron ore. In mineral industries, compositional analysis of ore plays crucial role at different stages of extraction process, from mining, beneficiation to blending and product dispatch. Standard industry practice is to collect samples, prepare and analyse either through conventional wet chemical methods or through instrumental analysis in XRF or ICP. From thecollection of the sample to the analysis cycle is time consuming and cumbersome. The time-lag between collecting the samples and receiving the chemical analysis data hobbles the plant operator from effective decision making and process optimization. Commercially available cross-belt analysers are capital intensive and their performance in iron ore applications particularly in terms of alumina determination is not adequately established. Henceforth need was felt to develop a relatively capital inexpensive, reliable non-invasive method for a faster and accurate determination of ore composition, in terms of alumina content, for real time application in mineral industries, particularly in iron ore. ?WIRSORT is an excellent breakthrough. It is a fast, cost effective and non-invasive technique to determine Alumina and Fe(t) content in iron ore. The technique relies on the conversion of microwave energy to heat energy based on the dielectric properties of the mineral constituents. Rise in temperature is sensed using IR camera and the average temperature is related with the alumina content of ore. The entire process from microwave heating till the display of alumina content is fully automated and takes only 30 secs. The technique has been implemented in a full swing since August, 2013 at Noamundi Mines of Tata Steel. This has helped in faster alumina feed analysis for more efficient process control resulting into a tangible saving of ₹ 3.23 Crores/ annum and reduction in 122390 Cubic Meter of water consumption in plant operation at Noamundi mines of Tata Steel.

Keywords: Microwave heating, IR thermography, Iron Ore, Alumina

154-C

X-RAY COMPUTED TOMOGRAPHY BASED DETECTION OF CASTING DEFECTS IN FATIGUE SAMPLES

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Abstract

Computed tomography imaging is widely used by various industries for characterization of defect features where a

three-dimensional image of an object is reconstructed from a large number of X-ray projection images taken around an axis of rotation. In the present paper, X-ray computed tomography (X-CT) is used to characterize the casting defects in the Nickel-aluminum bronze (NAB) alloy. The NAB alloys are extensively used in marine applications such as propellers, couplings and pump casings and impellers due to their good mechanical properties such as tensile strength, creep resistance, and corrosion resistance. However, there are several instances of in-service failure of these alloys due to high cycle fatigue (HCF). Before subjecting to HCF tests, the samples were subjected to X-CT for characterization of casting defects. CT was carried out using a 450kV Balteau constant potential X-ray tube and flash scan FS35 Thales flat panel X-ray detector with pixel size 127 μm. Modified filtered back-projection technique is adopted to reconstruct the cross-sections and Image J software tool is used for 3-dimensional visualization of the features. From the horizontal and vertical cross-sections reconstruction, the position and length of the feature is measured. The nature and size of the feature observed were categorized into four groups such as small (~1mm), intermediate (~2mm), large (~3mm) and surface breaking features. Some of the small and intermediate features were found at depths of about 2mm and 1.85 mm respectively. Analysis of the HCF data showed that the proximity of the defect features from the surface has significant influence over the size of the defects.

155-C

DEVELOPMENT OF EDDY CURRENT SENSORS FOR TURBINE BLADE TIP CLEARANCE MEASUREMENT

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Abstract

For aero-engines, the blade tip radial and circumferential positioning changes due to centrifugal forces experienced by them at high rotational speed. To avoid failures and for high efficiency operation, it is essential to ensure that the clearance between the blades of the engines and the casing are within specified limits. This study focuses on the development of coil based eddy current sensorand a permanent magnet based eddy current sensor for blade tip clearance measurement.

Permanent magnet based eddy current sensor uses static magnetic field produced by a permanent magnet as excitation. The receiver coil picks up the disturbances in the field created by the blade movement. The receiver signal amplitude and time of occurrence is proportional to the blade tip clearance and time of arrival of the blades at the probe location. At higher rotational speeds, the static field of the permanent magnet based eddy current sensor ensures higher sensitivity compared to conventional eddy current sensor having degradation in sensitivity with rotational speed. Details of the experimental set up, two types of sensors and their comparative performance for accurate detection of blade tip clearance are presented.

156-C

FINITE ELEMENT STUDY OF SCATTERING OF GUIDED WAVE MODES IN THICK AUSTENITIC STAINLESS STEEL WELDS

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Abstract

Scattering of longitudinal and shear waves by columnar grains of austenitic weldements has been extensively studied and reported in literature. However, scattering of guided waves by columnar grains has not been widely studied so far. The present study deals with scattering of guided wave modes by columnar grains of thick austenitic stainless steel weldements.

Towards this, a 2D- model of an austenitic stainless steel double V weld plate of 30 mm thickness is developed in finite element simulation software 'ABAQUS 6.13' to study the effect of scattering by columnar grains, on the guided wave modes. The angle of the weld is chosen to be 50 deg. The maximum and the minimum width of the weld are 16.48 mm at the top and 2.5 mm at the centre, respectively. First, the grains in the weld are simulated by arbitrarily drawn three-point spline curves. The total number of grains was 20. The size of each grain is approximately 1.2 mm and the weld is considered as transversely isotropic. The transformed stiffness coefficient matrices w.r.t the global specimen coordinates, based on grain orientations, were assigned to each of the grains to simulate inhomogeneity and anisotropy in the weld. The plate, containing the double V weld, is given boundary excitation (across 30 mm width) with a windowed toneburst of frequency 5 MHz. It is observed that the excitation generates symmetric S42 guided wave mode and additional modes. The generation of S42 mode is in agreement with the dispersion curves and mode shapes provided by Disperse. It is also observed that, as the guided mode S42 propagates through the weld, it is completely scattered by grains, in all directions. The simulation is also performed with excitation of different centre frequencies such as 100 kHz, 500 kHz and 1 MHz and 2.5 MHz, but there is no scattering observed in the weld. The onset of scattering was observed beyond 3 MHz. To extend the study to a real application, a real macrograph of double V weld is also considered. From the image, co-ordinates of the columnar grain features of real double V weld, are extracted and fed to the finite element model. The study shows the importance of choice of frequencies, when investigating thick weldements using guided waves, in real applications.

157-C

ULTRASONIC IMAGING FOR INTERFACE CHARACTERIZATION IN MULTI-LAYER SPECIMENS

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Abstract

Ultrasonic inspection is widely used for imaging discontinuities in various components during manufacturing as well as in-service. In recent years, ultrasonic imaging has also been exploited for characterization of interfaces joined by various processes such as diffusion bonding, adhesive bonding, mechanical bonding, welding process etc. for nondestructive evaluation of the interface bond quality. In order to obtain the best results, it is very important to judiciously select the characteristic parameters of the ultrasonic inspection (frequency, amplitude, focusing and inspection side) depending on the materials being inspected i.e. acoustic impedance of materials being bonded, thickness of various layers, and nature and size of defect being inspected.

In the present study, the criteria to be followed for the selection of various ultrasonic inspection parameters for ultrasonic C-scan imaging for evaluation of bond quality are described with suitable examples of different combination

of materials bonded by explosive welding (Al-Cu-SS plate type weld specimen, Al-Al-SS plate type weld specimen and Cu-Al ring type weld specimen) and mechanically bonded, ferritic steel tube to Zr liner tube specimen. Apart from the amplitude based imaging from the reflected waves from various interfaces, the concept of phase reversal has also been investigated for interface characterization of multi layer specimens in the present study. Using the C-scan imaging, the good bond and de-bond regions have been clearly identified. The amplitude of reflections at different interfaces are found to be in excellent agreement with the theoretically calculated values. Further, it is also demonstrated that the defect detection sensitivity can be improved substantially by using the ratio of reflection amplitudes from different interfaces. Results will be presented.

158-P

MASW ANALYSIS OF RAMAPPA TEMPLE

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Abstract

In this study, the findings of the seismic site characterization carried out at the Ramappa temple and the thousand pillar temple, Warangal, Telangana, are presented. The site characterization activity was divided into two categories. The first one was the geophysical testing, which included Multichannel Analysis of Surface Waves (MASW) tests. The second category was the conventional geotechnical testing, which included standard penetration test and laboratory testing. In the MASW test, shear wave velocity profiles are obtained based on Rayleigh wave dispersion curves.

159-C

APPLICATION OF NON-CONTACT ULTRASONIC TESTING FOR INTERFACE INSPECTION OF MULTI-LAYERED PRESSURE VESSELS

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Abstract

For non-destructive inspection of solid rocket propellant grains, RT and UT are the best suited techniques. RT of the propellant grains is a well established technique to investigate propellant as well as interfacial defects and UT is also used to detect similar flaws with modern equipments. In ACEM, all filled rocket propellant grains are inspected by RT, as conventionally done. Present work describes the application of non-contact ultrasonic through-transmission technique to investigate interface defects within the medium sized rocket motors of web thickness (150mm-250 mm) over the conventional tangential radiography. Complete inspection of propellant-insulation interface in a rocket motor is important considering its consequences; it is seen that these interfaces may get de-bonded over the period due to many reasons. Tangential radiography is generally carried to detect these defects however with through–transmission non-contact ultrasound testing technique complete multilayer-interfaces inspection is possible in cylindrical region in quick time. To study the application of non-contact UT, through-transmission technique was used and artificial defects were induced over the motor surface. For experiments, low frequency gas jet emitter probes were used for good SNR values and transmitted signals were detected using channel based piezoelectric detectors. Rocket motor scanning was carried out in automated mode. The suitability of the use of technique was arrived based on the results obtained.

160-C

ULTRASONIC BACKSCATTERED INSPECTION TECHNIQUE TO MONITOR PROGRESSIVE CREEP DAMAGE IN AN AERO-ENGINE COMPONENT

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Abstract

Aero-engine components undergo degradation during service due to severe loading conditions at high temperature in the form of low and high cycle fatigue, thermo-mechanical fatigue, creep, etc. Degradation in the aero-engine components is assessed using both destructive (DT) and non-destructive techniques (NDT) during overhaul. One of the major limitations of many existing NDT methodologies is that of identifying only already existing damage. However, ultrasonic backscattered inspection technique has a potential to virtually detect the variation in microstructure without sectioning the specimen/component. Further, the major advantage of this methodology lies in its scalability to inspect a component with intricate geometries. In present study, an attempt has been made to evaluate this technique by non-destructively monitoring progressive creep damage along with identifying damage locations in a specimen made out of directionally solidified DS CM 247 nickel based superalloy used for gas turbine blade applications. Specimens interrupted at different life fractions during creep test at 950°C /250 MPa were inspected using ultrasonic backscattering technique in an ultrasonic immersion testing equipment. The creep curve of the alloy exhibited predominant tertiary creep regime with limited primary and secondary creep regimes similar to most of the engineering alloys. A focused ultrasonic longitudinal probe of 10 MHz was used to capture "grain noise" emanating from different degraded crept samples. Further, area under the frequency spectrum of grain noise signals was evaluated to estimate the progressive damage during creep. In addition, C-scan images of grain noise were captured to identify damage locations. Validation of ultrasonic inspection results with microstructural observations of interrupted specimens in an effort to evaluate the ability of this technique to monitor progressive creep damage non-destructively will be discussed.

Keywords: Aero-engine, Creep, Ultrasonic Backscattering Inspection, Nickel Super Alloy, DS CM-247.

161-P

IMAGE QUALIFICATIONS TOOLS FOR DIGITAL RADIOGRAPHY AND COMPUTED RADIOLOGY

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Abstract

Image Quality is of paramount importance for all non-destructive/ diagnostic techniques, which enable superior probability of detection of defects/ features of interest. Periodic evaluation and monitoring of Image Quality parameters is important to ensure that system/ device generates consistent quality of image for meeting the needs of users, and their customers. American Society for Testing and Materials (ASTM) stipulates standards for evaluating the performance of Non-Destructive Inspection systems. Two of such standards for Digital Radiography and Computed Radiography are ASTM E 2737 – 10 (Standard Practice for Digital Detector Array Performance Evaluation and Long-Term Stability) and ASTM E2445 " 05 (Reapproved 2010) (Standard Practice for Qualification and Long-Term Stability of Computed Radiology Systems). The paper describes how software can help in estimating these parameters in a semi-automated manner. GE Inspection Technologies multimodality software "Rhythm" provides a set of image Quality Tools (IQT) for Computed Radiology (CR) and Digital Radiography (DR) based on CR Test Phantom and Duplex Test Phantom respectively. Tools for Digital Radiography include Spatial Resolution Basic,

Contrast Noise Ratio, Contrast Sensitivity and Signal Noise Ratio. Tools for Computed Radiography include Spatial Resolution, Contrast Sensitivity and shading correction. The software allows saving reports of these image-quality-parameters and thus enable performance monitoring of the systems.

Keywords: Digital Radiography, Computed Radiology, ASTM E 2737, ASTM E 2445

162-C

AN OVERVIEW OF NDE FOR THERMAL BARRIER COATINGS

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Abstract

Gas turbine engines depend on thermal barrier, oxidation and erosion resistant coatings to survive in increasingly adverse operating environments. In addition, turbine engines are being pushed beyond the use temperature of available metallic systems. Turbine engine coatings have the potential to significantly improve engine performance (through higher engine operating temperatures) and reduce life cycle costs (by reducing the frequency of engine overhauls). Thermal Barrier Coatings (TBCs) are typically ceramic structures that are designed to protect metal structural components from extreme elevated temperatures. This helps in increasing the lifespan of the part by reducing stress and fatigue. In particular, for gas turbine engines they provide thermal insulation to protect the underlying super alloy in engine parts etc. TBCs find extensive use in the Aviation, Power and Oil & Gas industries. The durability problems of TBCs are a cause for concern and a lot of studies have been done in order to improve their lifetime. Some of the common causes for failure include delamination at the interfaces, nucleation and propagation of micro-cracks within the different layers, topography changes at various interfaces due to compressive and residual stresses etc. It is important to identify the above mentioned failure modes in order to improve the quality of TBCs. Nondestructive Evaluation (NDE) of these coatings both during manufacture of new components as well as at regular intervals during in-service, repair and maintenance schedules becomes necessary in order to determine the extent of degradation and deterioration of its properties as well as the development of various kinds of defects. Several NDE techniques have been explored and many of them have become very attractive for inspection of the various failure modes of TBCs. Some of the commonly used NDE techniques for inspection of TBCs include Ultrasound, Electromagnetics, Optics etc. This paper presents an overview of these techniques as applied to TBC's and describe their capabilities, advantages and disadvantages. The paper will also highlight the current challenges encountered in the inspection of this important engineering material.

163-C

RAPID NON-CONTACT GUIDED ULTRASONIC METHOD FOR INSPECTION OF HIDDEN AND CURVED REGIONS IN COMPOSITE AEROSPACE STRUCTURES

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Abstract

The use of composites in stiffened aerospace air-frame structures introduces complex geometries and hidden regions that are vulnerable to defects during manufacturing and damage during service. Inspections of such structures are cumbersome and time consuming, but are of a great concern to aerospace industry since the criticality of defects/damage in these regions can lead to unexpected failures and downtime. This work presents a technique for rapid non-contact inspection of curved and hidden regions in stiffened composite components. Air-Coupled guided

wave ultrasonic inspection was employed. The probes were configured in order to excite Anti-symmetric plate mode(A_0). The direct A_0 modes as well as the mode converted S_0 modes were detected using a receiver probe. Different modes of reception i.e. in through transmission, in reflection, etc. as well as probe position configurations viz. both receiver and transmitter on the same side, receiver and transmitter on opposite side, etc. were explored. The technique was found to have the capability to detect and locate defects of the delamination type in the hidden and curved regions of such stiffened composite components. Additionally, finite element (FE) models were used to visualize guided wave propagation and its interaction with defects in such curved and hidden regions for improved interpretation of the as-received signals from the experiments. The technology has the potential to significantly improve the inspection capabilities for complex regions in aerospace components.

Keywords: Guided Waves, Composites, Rapid non contact inspection, hidden and curved regions

164-C

3D ELASTIC WAVE PROPAGATION AND HEAT DIFFUSION STUDIES USING POLYCRYSTALLINE MATERIAL MODELS

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Abstract

In a polycrystalline material, microstructural grain size, shape distribution, crystal anisotropy and grain misorientation play a significant role in deciding the thermo-mechanical properties. There is a need for developing quantitative nondestructive evaluation tool for assessing these properties of polycrystalline material. In the present effort, a three dimensional finite element based microstructural model is constructed using Voronoi tessellation for representing polycrystalline material. This representative volume generation is achieved using an open source software package Neper, and the geometry is imported into COMSOL MULTIPHYSICS™environment. This paper in particular addresses various issues during the development of accurate FEM model for studying the interaction of waves through polycrystalline material.

Keywords: Voronoi tessellation, 3D microstructure, Heat diffusion, Elastic Wave propagation, Finite element modeling

165-P

EXPERIMENTAL AND NUMERICAL STUDY OF NONLINEAR RAYLEIGH WAVES IN ALUMINUM 7075-T651

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Abstract

Nonlinear ultrasonic techniques can detect damage at the microstructure level in specimens undergoing variety of failureand plastic deformation mechanisms, including fatigue, cold work and thermal aging. However, such methods typically rely on assessing sample from both sides which may prove difficult for practical inspection. Rayleigh surface waves are ideally suited for inspection from a single access side. Moreover, they also have the potential to accumulate the nonlinear effect to a greater extent than bulk ultrasonic waves. Here, an ultrasonic piezoelectric transducer together with an acrylic wedge is used for experimental generation of Rayleigh surface waves. A robust non-contact detection technique is employed using heterodyne laser interferometer. Experiments are also performed

using air-coupled transducers for detection of Rayleigh waves, as it is reported that air-coupled detection is less susceptible to surface roughness of the specimen as compared to laser detection. In these measurements, a second harmonic wave is generated from a propagating monochromatic elastic wave, due to the anharmonicity of the crystal lattice, as well as the presence of microstructural features such as dislocations and precipitates. Finite Element simulations implemented in a commercial package are used to obtain physical insight into the measurements.

Keywords: Nonlinear Rayleigh waves, non-contact detection, laser ultrasonics, air-coupled ultrasonics

166-P

NON RELEVANT INDICATIONS IN SURFACE NDT METHODS

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Abstract

Whenever we discourse about non relevant indications in Non Destructive Examinations (NDE), the discussions remains limited to sub surface NDTs such as Ultrasonic Testing (UT) or Radiographic Testing (RT), whereas distinction between a relevant & Non relevant indications keeps an equal importance in surface NDT such as Liquid Penetrant Testing (LPT) or Magnetic Particle Testing (MPT).Same is useful in eliminating the possible cause of rework which leads to loosening of actual raw metal. At the same time; the challenge of validating the categorization of indication is required as to ensure that, relevant indications are not left to address. At L&T; we successfully demonstrated & validated the process of categorizing a continuous linear indication, appears to be crack on near surface of weld. During inspection of a production weld, we came across a continuous line on as polished surface of a weld. All indications were identical in nature and across the weld toe. Challenge was to ensure and validate, that the indication are not due to any imperfection, but the same is due to the permeability difference in Heat Affected Zone (HAZ) region of weld. With various exercise & demonstration, we concluded that the indication were non relevant, thus saved the entire joints of similar kind to get released further for production.

Keywords: Surface NDT, Magnetic Particle Testing, Non Relevant indications

167-C

DETECTION OF SENSITISATION IN AUSTENITIC STAINLESS STEELS THROUGH LOCK IN THERMOGRAPHY

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Abstract

Austenitic stainless steels are ductile, tough and most importantly easy to form and weld and hence are widely used as structural materials in strategic and core industries. One of the most widely used stainless steel is AISI type 304 and type 304L. The latter is preferred in more corrosive environment where welding is involved. Though these type of steels have high strength and excellent corrosion resistance, they are susceptible to Intergranular corrosion (IGC) due to sensitisation. When these steels are heated or slowly cooled in the temperature range of 450°C to about 950°C, chromium carbide can precipitate at the grain boundaries which in turn can lead to depletion of chromium in the vicinity of grain boundaries. This phenomenon is referred to as sensitisation. When sensitized austenitic stainless steel is exposed to a corrosive environment, the chromium depleted zones preferentially dissolve leading to inter granular corrosion (IGC). Sensitization is particularly important in welded metals. This is because the welding zone which also includes the heat affected zone (HAZ) can experience temperatures in the range that

can cause sensitization. Sensitised microstructure in the presence of tensile stresses and corrosive environment can lead to intergranular stress corrosion cracking. In nuclear fuel cycle facilities at Kalpakkam, tanks and pipes which are predominantly fabricated using AISI type 304 SS are likely to have corrosive fluids such as nitric acid. During welding especially in cases of tanks wherein the dished end to the shell is normally done under restraint is likely to have tensile stresses. Hence in such cases it is essential to ensure that sensitisation does not occur during welding or fabrication. While adeuateprecaustions are taken during welding, it is always preferable to have NDE methods to detect incipient sensitisation and / or localised corrosion before it can become a problem.

In this work, we explore the possibility of using an advanced technique like lock in thermal imaging to detect senitisation and hence IGC at an early stage. The main advantage of thermal imaging is its non contact nature and ability to inspect large engineering surfaces. Lock in thermography presents an added advantage of being invariant to surface emissivity variations. AISI Types 304 and 304L specimens of dimensions were subjected to sensitization heat treated at 675°C for 30min, 1hr, 10h and 100 hrs. The presence / absence of sensitization was ascertained through in-situ metallography. Lock in thermography was then carried out on these specimens. Analysis of the results clearly indicated a relation between the phase angle and thermal aging time. This paper dwells on the experimental approaches and the results obtained. Lock in thermography clearly indicates that it is a potential tool for early detection of sensitisation.

168-P

EDDY CURRENT THERMOGRAPHY FOR RAIL INSPECTION

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Abstract

With the tendency of the railway transportation into heavy haul, more frequent usage of rail tracks and increased axle load the problem of surface damage and fatigue is dominant on rails. Rolling contact fatigue (RCF), which leads to crack formation in rail track heads, is becoming a growing concern in the transportation industry. It occurs on or very close to the rail head surface, and is a significant cause of rail failure. The detection of cracks in RAILS is a critical requirement in the Railway industry. Cracks, if undetected will lead to rail fractures and consequently may lead to catastrophic accidents. Thus with the development and operation of high speed trains, condition based maintenance and monitoring becomes an important approach for the improvement of reliability and safety of rail transportation. Eddy Current Thermography (ECT) is an emerging NDT method especially for conductive material like rails which combines the advantages of eddy current testing and IR Thermography. Due to electro conductivity, thermal conductivity and high permeability of rails, ECT is very suitable for its damage detections. This technology describes an inspection methodology which utilizes induced scanning Thermography approach that employs two forms of excitation i.e. Eddy current and Stress, either independently or in combinations thereof for the detection of defects. The thermographic camera is arranged to capture data indicative of a thermal response resulting from the flow of electrical current through the copper coil which scans the rail track. A computer system is configured to process the data from the thermographic camera to generate an indication of a presence of a discontinuity in the rails

Keywords: Eddy Current, Thermography, Thermo-Mechanical, Induced Scanning.

169-P

NDT STUDIES OF LASER CLADDING DEFECTS OF PURE COPPER ON SS316L FOR IN VESSEL MATERIALS FOR FUSION REACTOR APPLICATIONS

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Abstract

The pure thick copper coatings of 1-3 mm are required for the in-vessel materials for the plasma facing components in fusion reactor systems to extract the very high heat flux in shorter durations (like VDEs) and to protect the in vessel components. Laser cladding technique is one of the potential technique for thick coatings on substrate materials. The present study reports the NDT characterization studies carried on samples of pure copper powder cladded on SS316L substrates of thickness 1 mm - 3 mm , fabricated by CO2 laser system. Process parameters optimization like laser power, laser travel speed, spot size, powder feed rate and shield gas flow show the effect on quality of final cladding on steel substrates. X-ray radiography and Ultrasonic testing has been carried out thoroughly on the fabricated samples and defects are analyzed. Ultrasonic scan tests using different probes are employed as the interface defects are not thoroughly revealed by radiography. The calibration has been carried out by the test sample plate with known defect size created and various process parameters like amplitude, gain and metal velocity, relevant to specimen are chosen for probes calibration. The interface defects of porosity, lack of penetration, cracks or group porosities are observed in few set of samples developed. Radiography examination revealed the porosity at extreme edges and distributed porosity in the middle for thick cladding. Ultrasonic manual A-scanning with TR probe provides qualitative information about flaw and broadly gives its location of the defects. Samples of 1 mm thick cladding have shown relatively less porosity defects at the interface compared to 3 mm thick samples.

170-P

A NEW APPROACH TO NON-DESTRUCTIVE EVALUATION OF THICK SECTION METALLIC MATERIALS THROUGH PORTABLE LOW INTRUSIVE MATERIAL SCOOPING TECHNIQUE

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Abstract

The boiler components of thermal power plants are subjected to high temperature & high pressure conditions are traditionally designedfor a service life of about 25–30 years. The critical components working at elevated temperature, pressure and environmental conditions undergo material degradation due to various damage mechanisms viz. creep, fatigue, corrosion, erosion, embrittlement etc. In this context, Residual Life Assessment (RLA) finds importance from the point of safety and reliability as the units approaching the design life. A new technology for degradation assessment & Remaining Life Estimation of in-service power plant components especially thick section components through in-situ miniature scooping / extracting of sample has been developed. The miniature sample extracted from the thick section components can be assessed through integrated approach by advanced material characterization techniques like small punch mechanical & metallurgical tests. This will help in assessing the present damage accumulation in the component and also helps to predict the remaining life of components for further safe usage.

The present papers deals with the extraction / scooping of miniature sample from thick section pipes of carbon steel (407 mm & 610 mm dia.) & low alloy steel (247 mm dia.) & evaluation of properties of scooped samples & parent materials for metallurgical comparison through optical microscopy, hardness measurement & XRD analysis. The microstructure of scooped & parent samples showed similar features and there is no change in phase due to any heating effect during scooping operation. The hardness measurements & XRD analysis confirmed the results obtained.

Keywords: Scooping device, thermal power components,Small punch test, carbon & low alloy steels, remaining life assessment.

171

FREQUENCY-SCANNING EDDY CURRENT TESTING (F-SECT) FOR CONDITION ASSESSMENT OF MULTIPLE LAYERS OF COATING ON GAS TURBINE BLADES

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Abstract

Gas based power stations are comparatively cleaner mode of thermal power generation and are used to meet base as well as peak load electricity demand. Gas Turbine is the most important component of such power stations. Operating temperature of gas based power station is higher in compare to coal fired or nuclear power stations. Inlet temperature at turbine is increased to improve the efficiency of the turbine. First stage blades of gas turbine in particular and other stages in general are subjected to very high temperature. To improve the high temperature sustainability of these blades made of nickel based super alloys, a specialized coating is applied on it. The coating generally comprises of a metallic bond coat, known as M-Cr-Al-Y (Metal-Chromium-Aluminum-Yttrium), over which, sometimes, a ceramic coat TBC (Thermal Barrier Coating) is also applied. During operation of these blades, the metallic bond coating degrades with high temperature exposure. The condition of this metallic bond coat plays major role in protecting the base metal from high temperature corrosion and oxidation. The key factors, which influence coating life cycles, are firing temperature and fuel/air contaminants, where corrosion and oxidation are the life limiting factors. Cyclic effects (start ups) that favour the formation of cracks may also reduce coating life. Earlier there were no other methods available for evaluating the condition of the coating non-destructively. Only, OEM (Original Equipment Manufacturers) prescribed guidelines, based on Equivalent/Valuated Operating Hours (EOH/VOH), are followed to refurbish these blades, where-in blades are recoated after evaluating condition and profile of base material. Estimation of coating degradation becomes complicated in view of partial loading of the gas turbine units now-a-days.

Frequency-Scanning Eddy Current Test (F-SECT) technique, characterizes different internal layers of the coating based on difference in electrical conductivity. Concentration of mono-beta alumina layer of the M-Cr-Al-Y coating is directly related to healthiness of coating and its approximate thickness can be estimated using inverse modeling software. The paper intends to present fundamental background of FSECT technology with few case studies and its application for assessment of gas turbine blades in NTPC.

Keywords: FSECT (Frequency-Scanning Eddy Current Technology), MCrAlY& TBC Coating, Degradation of Coating, Blade coating

172-P

CHALLENGES FACED IN SELECTION, MANUFACTURE, QUALITY ASSURANCE AND QUALIFICATION OF THE COMPONENTS FOR FBTR CRDM APPLICATIONS

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Abstract

Fast Breeder Test Reactor (FBTR) is a sodium cooled type experimental reactor. Six numbers of Control Rod Drive Mechanisms (CRDM) along with their B4C control rods perform reactor start up, controlled shutdown, reactivity

control for power changing & burn-up compensation and to shut down the reactor by SCRAM action during abnormal conditions. Lower part of the CRDM which consists of translation tube, outer sheath and gripper is partially immersed in sodium. Nested Ripple type Welded Disc Bellows (NRWDB) called translation bellows prevents entry of sodium in the space between the translation tube and outer sheath and acts as primary leak tight barrier. Silicone bellows which is near ground level elevation acts as secondary leak tight barrier. Non standard Aluminium bronze rod was used as raw material for various drive components in CRDM. These components were imported earlier from FRANCE. Indigenous development of these items and bellows was taken up due to difficulties in procurement. Extensive studies were carried out on selection of materials, establishment of manufacturing procedures and stringent Quality Assurance Program (QAP) to ensure defect free component during indigenous development. Suitable methodology was arrived for qualification of these components. Successful development of silicone bellows and Aluminium bronze rods were completed as per our requirements and selection, establishment of manufacturing procedure and QAP were completed for (NRWDB). Prototype development of NRWDB is in progress.

173-P

DEVELOPMENT OF MAGNETOSTRICTION BASED ULTRASONIC TRANSDUCER FOR IN-SITU HIGH TEMPERATURE INSPECTION

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Abstract

Ultrasonic transducersthat can work under in-situ high temperature are of much interest to the nuclear industry, in view of the possibility of on-line inspection without plant shut down. This paper describes a novel solution to address this problem, based on ultrasound generation through the magnetostriction phenomenon. Previous research by the authors led to the development of a novel material that supports significant magnetostriction even at elevated temperatures. Here, this material is incorporated into a waveguide sensor/actuator pair that forms the core of the proposed transducer, which is then tested under high temperature furnace conditions. Results show that the proposed concept can be used for high temperature defect characterization at 1 MHz. Advantages and challenges to practical realization of the technique are discussed.

Keywords: Ultrasonic transducer, high temperature, magnetostriction

174-P

SUBWAVELENGTH ULTRASONIC IMAGING WITH HOLEY STRUCTURED METAMATERIAL

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Abstract

The imaging resolution of conventional lenses is limited by diffraction. Artificially engineered metamaterials are capable of overcoming this limit. We report in this paper subwavelength resolution can be achieved while imaging with a periodic holey structured metamaterial as lens. We theoretically (through FE simulations) and experimentally demonstrate that the subwavelength resolution is achieved in ultrasonic regime. The evanescent components of a sub wavelength objects are efficiently transmitted through the holey structured metamaterial as a result image

resolution can be improved. This type of metamaterial lens may have wide range of applications for imaging in medical ultrasonography, under water sonar and non-destructive evaluation.

Keywords: Metamaterials, Holey structured metamaterials, ultrasonic imaging, evanescent waves and subwavelength imaging.

175-P

ULTRASONIC GUIDED WAVES FOR THE INSPECTION OF BOND QUALITY IN ADHESIVELY BONDED LAP JOINTS

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Abstract

Adhesive bonds are increasingly considered as an alternative to mechanical joints especially in aerospace and automotive structures. In addition toproviding advantages in weight reduction, increased stress bearing area and reduced vulnerability to corrosion, adhesives also allow design flexibility through possibility of joining substrates with different geometries, sizes and composition. However, occurrence of defects and degradation of material properties over time are common problems associated with adhesive joints. Here we study the feasibility of using ultrasonic guided waves for studying the characteristics of adhesively bonded lap-joint between a pair of Aluminium plate substrates.Ultrasoundis more effective as compared to other NDT modalities in extracting subsurface information.Guided waves are employed since they can interrogate the entire thickness and travel over a long distance when excited from a single location. The bond is assumed to have isotropic properties, while degradation is modelled by varying the ratio of Young's modulus (E) to material density ñ. The fundamental symmetric Lamb mode S0 is employed in our studies, and wave scattering characteristics from the bond are analysed in terms of the transmission and reflection coefficients plotted as a function of the bond E/ñ ratio. The studies are carried out using Finite Element(FE) simulations in time domain, cross-validated against analytical results obtained using the spectral finite element method (SFEM). Results show that bond quality has an impact on S0 mode transmission characteristics and measuring this provides a route to characterizing adhesive bonds. Limitations of the method and further work are also discussed.

Keywords: Ultrasonic Guided waves, bond quality ,lap joints, FE,SFE

176-P

INSPECTION OF FRICTION STIR WELDED (FSW) JOINTS USING EMAT GENERATED SH WAVES

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Abstract

Friction Stir Welding (FSW) is unique welding process in terms of the mechanical properties and metallurgical structure of the joint. Like any other weld joints, FSW joints also have its own characteristic defects generated during the joining process. These defects tend to reduce the overall quality of the weld and weaken the joint over time. This calls for the need of an inspection technique to find out the weld quality in FSW joints. In this paper, we present an inspection technique involving Shear Horizontal Ultrasonic waves to give a qualitative view of FSW joint of steel plates. SH waves offer the unique advantage of having a wave guided between the surfaces of the

plate with minimum amount of dispersion. Electro-Magnetic Acoustic Transducer (EMAT) is found to be a very efficient way to generate SH waves which is otherwise difficult to generate by conventional methods. Studies are conducted on an FSW welded 2mm steel plate using 500 kHz SH EMAT probes. Results are provided based on a scan along the weld in both through transmission and pitch catch mode. The methods were found to be effective in inspection, even though with different levels of sensitivity. Results from EMAT inspection are compared with radiographic images.

Keywords : EMAT, Friction Stir Weld, Ultrasonic scan, weld inspection

177-P

HEALTH MONITORING OF COMPOSITES USING EMBEDDED FIBER ACOUSTIC SENSORS

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Abstract

This paper explores the possibility of using embedded fiber acoustic sensors for health monitoring of composite structures using ultrasonic guided waves. A strip wave guide is assumed to be embedded in an epoxy substrate with a delamination-type material discontinuity(crack). The waveguide is provided with a notch feature at various locations. When excited using the fundamental symmetric Lamb mode S0, we show that such a mechanism allows us to detect, asses and monitor the growth of delamination/crack. Limitation of the method and direction for further work are discussed.

Keywords: Composite, Fiber Acoustic Sensors, Numerical Studies.

178-P

AUTOMATIC DETECTION OF DEFECTS AND PATTERN RECOGNITION IN TOFD SIGNAL/ IMAGE OF A THIN WELDMENT

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Abstract

The Time-of-Flight diffraction (TOFD) technique is widely used in automatic weld inspection to ensure the welding quality. Although it reaches the high speeds in the inspection, high sizing reliability and low rate of false indications. The classification of defect is still one of the relatively big troubles for the system because the detection defect signal accountability is only done by the knowledgeable and experience personal. The use of the computational tool for signal/ image processing and pattern recognition, such as the artificial neural network, improve the classification reliability of defect detected by this technique.

The paper describes the application of image/signal processing and neural networks(ANNs)to the task of completely automating the decision making process involved in the interpretation of TOFD scans. De-noising of signal help in determining the location with the feature vector extract (image processing)the two-dimensional information on defect/ component and non defect area. These inputs are then classified using an ANN trained with the back propagation algorithm. The major difficulty related to the inspection of thin section weld is the presence of defects in dead zone region. By the improvised effects like lateral wave straightning, lateral wave removal and synthetic aperture focusing technique (SAFT) deals the recovery of defect detected in the dead zone area.

Keywords: Ultrasound,TOFD, signal processing, image processing, pattern recognition, Artificial neural network.

179-P

AUTOMATIC DETECTION AND CHARACTERIZATION OF DEFECTS IN RADIOGRAPHIC IMAGES USING ARTIFICIAL NEURAL NETWORK

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Abstract

In this paper, we describe a MATLAB based virtual system to detect and classify the defects from radiographic images. The system has been used for detecting and discriminating discontinuities in the weld images that may correspond to false alarms or defects such as worm holes, porosity, linear slag inclusion, gas pores, burn through and lack of fusion or crack. The images are taken by using a computed radiography system (CRIS). In the first stage different image processing techniques, including noise reduction, contrast enhancement, thresholding and labeling were implemented to help in the recognition of weld regions and the detection of weld defects. After that a set of nine geometrical features which characterize the defect shape and orientation is proposed and extracted between defect candidates using image processing toolbox. In the next stage, an artificial neural network classifier is trained with the features extracted from different images.The classifier is trained to classify each of the objects into one of the defect classes or characterize it as non-defect. The performance of the proposed approach is evaluated using 50 radiographic images in the presence of various types of noise and blurring. After that outputs of the system is compared with interpretation data given by high skilled experts to check the efficiency of the software.

Keywords: Radiography, MATLAB, CRIS, Artificial neural network, Thresholding, Labeling.

180-P

NONDESTRUCTIVE EVALUATION OF THICK MULTILAYER PVC COMPOSITE AND TUBES USING ULTRASONIC C SCAN ALONG WITH THERMOGRAPHY

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Abstract

Non-destructive testing gains attention to get the quality products and longer life. Here we study Ultrasonic immersion C-scan and thermography to understand the bonding and de-bonding nature of polymer composites. These composites are made by attaching or gluing by gelatin and a pipe composed of these multilayer PVC are bonded together. The issue in ultrasonic NDT of composite fiber-reinforce PVC is the detection of flaw echoes due to the scattering of ultrasonic waves, high attenuation of ultrasonic signals and multiple reflections. The ultrasonic structural noise due to scattering by the small reflectors (fibers) is time invariant and slightly correlated with useful signal. Classical methods cannot overcome these effects.In this paper, we report an ultrasonic immersion c scan method for detection and location of defects in bonding or de-bonding between the multi-layer Polyvinyl chloride (*PVC*) thick films where each film has thickness of 2 mm and pipe compose of these bonded PVC layers. The data obtained directly by the ultrasonic c scan of these layered PVC while bonding or de-bonding of these layers and pipes are also analyzed to detect the strength of bonding. The results are compared using thermography method. The described method can be applied for post-production quality control and a distinct relationship among composites can be obtained.

Keywords: Ultrasonic immersion, Adhesive bonds, Thermography, PVC

181-C

NON-DESTRUCTIVE EVALUATION - A TOOL FOR ANALYSIS OF DEFECTS REVEALED IN PROOF TESTING

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Abstract

Non Destructive Evaluation is one of the best tool employed for detection and characterization of flaws in the component. Proof test popularly called as Hydro test is conducted for the verification of structural integrity of a component or assembly in which part under test is pressurized to 1.5 times the design pressure using water and then checked for leaks and pressure drop during testing. In one such test conducted for one of the assembly viz, 10 inch 1500 Class Gate valve, water leakage was observed from valve stem. The material of stem is of SA 182 F6Aand leakage was observed at a pressure of 100 bar whereas the final required testing pressure was 300 bar. The reason for leakage could not be visually identified at first instance and hence a systematic evaluation adopting series of non-destructive testing methods was performed for further analysis.

The Non-Destructive Testing methods such as Liquid Penetrant Testing, Magnetic Particle Testing and Ultrasonic examination were employed on the leaked stem in order to detect and study the nature of existing defects either on surface or subsurface which caused the leakage. From these examinations, the defect which caused leakage was observed as a sort of distorted form of piping in the hot rolled product. The defect was found to be present for full length of the stem covering a width of about 25mm on the cross sectional area. The defective stem was rejected. Then, it was also decided to ensure that such defects are not existing in the remaining finished or part finished or as supplied raw material stems. The same non-destructive testing methods were adopted and all tested items were confirmed as defect free.

Thus, by employing appropriate Non-destructive testing methods on any part at any stage of manufacture, staring from raw material to proof testing, it is possible to carry out analysis for drawing conclusions about the structural integrity of the material and this provides greater confidence to the manufacturer and customer as a Quality Assurance Measure for the product.

182-P

VIBRATION MEASUREMENT USING GUIDED WAVES OF PLATE IMMERSED IN WATER

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Abstract

Due to the difficulty in vibration measurement of immersed body the ultrasonic testing is mainly employed as a diagnostic tool. In order to facilitate vibration measurement, the development of guided waves is carried out. The ultrasonic signal is generated far from the hostile environment and transmitted to and fro using a waveguide. The principal advantage of this arrangement is that the source of sound is located in environment at one end of the waveguide and periodic maintenance can be done easily. 2D ABAQUS finite element simulations were used to decide the optimal wedge angle which facilitates the generation of waves. This article discusses the development of waveguide, vibration measurement using ultrasonic techniques, details of experiments carried out.

Keywords: ultrasonic technique, wave guide, vibration measurement

183-P

ULTRASONIC MEASUREMENTS OF THE ELASTIC MODULI OFNATURAL FIBER REINFORCED CELLULOSE COMPOSITES

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Abstract

Elastic moduli are very important properties of materials for engineering applications. Determination of elastic modulus by traditional methods (e.g.by tension test etc.) will destroy the material and the sample preparation for testing is very tedious process. We can also determine the elastic properties like Young's Modulus of elasticity, Shear Modulus and Poisson's Ratio by non-destructive testing (NDT) without destroying the material. This paper concentrates on How to determine Elastic properties of some Natural fibre Reinforced cellulose Composite material with Ultrasonic testing by measuring the longitudinal and shear velocity through the composite material. Cellulose composites are prepared by using hand layup technique with 5% and 10% cellulose and general purpose resin as matrix. Hibiscus Cannabinus fibers are used to prepare the cellulose.

Key words: Hybrid composites, Ultrasonic testing, elastic modulus, hand layup technique.

185-P

BOLT HOLE INSPECTION BY EDDY CURRENT TESTING

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Abstract

Bolt holes are critical areas where failure is prevalent. The rolling contact fatigue is a common phenomena in these bolt holes while the component is in-service. The fatigue results in shallow cracks that often lead to catastrophic failures in critical components. The bolt holes are difficult to inspect due to the small diameter of access. Nondestructive inspection of these complex features is of vital importance.Eddy current testing is one of the most extensively used nondestructive techniques for inspecting electrically conductive materials at very high speeds that does not require any contact or couplant between the test piece and the sensor, also this technique is effective, efficient, and commonly used technique for conducting fast and accurate inspection of bolt holes. Therefore, the development of an attractive life management procedure, based on Eddy Current NDT technologies would allow for the continued safe use of components beyond the safe life limit is of interest. In this work, defects are introduced in Aluminium samples with holes (in order to simulate bolt hole conditions) and introducing EDM notches in them in order to check the change in response of Eddy current coil parameters due to the flaws. An analysis of the same has been done using COMSOL Multiphysics.

Keywords: Non Destructive Evaluation, Eddy Current testing, Fatigue crack, Bolt hole.

186-C

EVALUATION OF DAMAGES ON CFRP-FOAM SANDWICH MATERIALS WITH INFRARED THERMAL IMAGING

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Abstract

Sandwich materials are increasingly used in aerospace, automotive industries and are recently being used in civil infrastructure and transportation applications. This sandwich material system shows high strength to weight ratio, high stiffness with improved mechanical strength and ease of fabrication along with better structural performance in in-plane load condition. Due to the limited strength in out of plane direction, damages are often reported in service. Prime causes being due to low velocity impact caused by hailstones, runway debris during ground run, accidental tool drop during servicing etc., in addition to concentrated static pay loads that are attached. These incidents generate damages such as barely visible impact damage, delamination, core crushing etc. Detection of damages on these materials with conventional NDT technique like ultrasonic etc., are extremely difficult due to the multi-layered sandwich construction.

Present study focuses on detection and evaluation of service damages on the CFRP foam sandwich materials used in construction of unmanned air vehicles (UAV) with advanced thermal imaging methods. Damages due to low velocity impact, concentrated mass etc., are simulated on sandwich panels of size 300 X 300 X 8 mm. Active transient thermography method has been adopted for the current study. The observation shows high merits of transient thermography for detection of damages in this material. Further, classification and quantification of damages such as delamination, debonds, core crush, depth, spread etc., have also been attempted with the thermal images using image processing tools developed in Matlab platform.

Keywords: CFRP Foam Sandwich, Service Damage, Thermography

187-C

LOCATING A DAMAGE IN AN ALUMINIUM PLATE USING LAMB WAVES

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Abstract

In the present study, Experiments are carried out on an Aluminium (Al) plate with a damage, using Lamb waves and an array of four Piezoelectric Wafer (PW) transducers bonded onto it. The PW transducers are used to actuate and sense Lamb waves. These transducers are small in sizes and cost effective. The data received from the experiments, is further processed using a new algorithm developed by the authors, in order to locate the damage. The damage location is obtained as a small enclosed area formed by the intersection of various curves generated by the algorithm using the data received from the experiments. The damage location is further refined in this enclosed area using the Lagrange optimization method. The results obtained are fairly well. Thus, the present method is capable of locating a damage in plate structures using minimal number of transducers.

188-C

DETERMINATION OF OPTIMUM X-RAY TUBE OUTPUT PARAMETERS KV AND MA FOR DIGITAL RADIOGRAPHY TESTING OF WELDED TUBES

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Abstract

Study of Image quality parameters like Contrast, SNR and MTF for Digital Radiography with FPD were carried out at different X-Ray tube variables like energy of X-Ray (kV) and tube current (mA) for different welded tube thicknesses. Experiments of Digital Radiography were carried out on butt welded tubes. Images of these welded tubes were taken with different kV and mA on actual working setup keeping other variables constant. Percentage contrast was calculated with ASTM hole type IQI, SNR values noted on welded area of interest and MTF curves were plotted by using Duplex IQI EN 462-5. This study has been done to determine optimum parameters (kV and mA) for Digital Radiography of different tube thicknesses which gives desired image quality with minimum exposure to FPD.

189-P

HEALTH MONITORING OF RAILWAY TRACK FRACTURES USING GUIDED WAVES

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Abstract

A lot of rail accidents have been happening throughout the world due to rail breaks. Even though only a small percent of rail breaks are causing the derailment, the cost it cause economically and in sense of human life is so heavy. As a remedial measure, health monitoring of railway tracks is been proposed. Guided wave inspection is found to be a reliable and effective method in this scenario.

My work is to analysis the various modes of guided waves in different frequency as it propagate through the railway tracks. Its propagation efficiency and reflective properties will also be studied in this section. As a preliminary study finite element analysis will be done to have an idea of displacement distribution and strain energy distribution.

Main causes of derailments are due to the transverse crack at the head of rails. So wave mode which shows high amount of displacement distribution in head portion will be considered for the application.

Reliability of guided wave inspection will be relieved in the practical demonstration on railway tracks.

190-P

TECHNIQUE FOR MEASURING CARBIDE LAYER THICKNESS IN HEATER TUBES

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Abstract

This paper explains how to measure the carbide layer thickness in heater tubes by non destructive method. The most occurring failure mechanism of the heater tubes is due to the action of carburization and creep ductility

exhaustion. Carburized material in the inner wall of the radiant tube has a higher thermal expansion coefficient and tends to increase in volume and place stresses on the tube. These thermal stresses make the tube more susceptible to creep failure. Also it leads to bulging, bending and ovalization of the tubes.

191-P

INSPECTION OF COMPOSITE STRUCTURES USING AIR COUPLED ULTRASONIC TESTING

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Abstract

Conventional ultrasonic tests are conducted using water or coupling gel as a transmitting medium. Conventional ultrasonic testing cannot be applied to certain water-sensitive or porous materials and is more difficult to use in the field. In contrast, air-coupled ultrasound is non-contact and has clear advantages over water-coupled testing. Air-coupled ultrasound has obvious advantages over conventional ultrasonic techniques. If contact-less, cheap and versatile transducers could be used, the inspection of structures would become much easier and the range of applications would become wider. The disadvantages of the technique include the limitation of the frequency of operation and the requirement of high voltage for excitation. Here, I have conducted several experiments to propagate Longitudinal, Shear, and Lamb wave modes on different composite samples that are excited and received by air coupled ultrasound transducers will be discussed. The technique is applied to aerospace components, composite pipes, adhesive bonded components, among others. The defects considered include delimitations characterization in composite structures, interfacial weakness in bonded components, etc. that are made with metals and or composites

192-C

MAGNETIC BARKHAUSEN EMISSION TECHNIQUE FOR EVALUATION OF RESIDUAL STRESSES IN P91 WELDMENTS

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Abstract

Evaluation of residual stresses is important for integrity and service performance of the welded components. Welding introduces high heat input to the material being welded and non-uniform distribution of heat develops residual stresses in the weldments. These stresses; if tensile affect the performance of welded structures and hence, need to be evaluated for their removal.During magnetization of ferromagnetic materials, the presence of stresses influences the alignment of magnetic domains; hence there exist the possibility of using magnetic Barkhausen emission (MBE) technique to evaluate the stresses nondestructively. Studies were carried out on two P91 weld pads of thickness 3.0 and 6.0 mm prepared using TIG welding. MBE measurements on these pads revealed variation in MBE RMS voltage parameter across the weldments due residual stresses. In order to confirm these finding, residual stress measurements were carried out using X-ray diffraction (XRD) technique. Very good correlation was observed between MBE parameter and the absolute residual stressobtained using the XRD. The study shows that nondestructive in-situ MBE measurements can be reliably used to evaluate the residual stresses on weldments.

193-C

METAL MAGNETIC MEMORY TECHNIQUE FOR EARLY DETECTION OF DAMAGE IN FERROMAGNETIC STEELS

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Abstract

Metal magnetic memory (MMM) technique is gaining considerable interest in the last decade among the magnetic NDT researchers, because of its potential for evaluation of early damage, micro-defects and stress states in ferromagnetic materials. In this technique, the distribution of self-magnetic leakage fields induced at the stress concentration zone in ferromagnetic materials during mechanical loading is measured using magnetic field sensors. Compared to traditional magnetic NDT techniques such as magnetic flux leakage and Barkhausen noise, MMM technique uses the earth's magnetic field as the magnetizing source instead of artificial magnets. This makes the MMM technique a potential NDE tool for on-line condition monitoring of engineering components. Also, it has the advantages of easy operation, low cost and high inspection speed.

Detailed investigations using numerical modelling and systematic experiments are necessary for enhanced understanding of the MMM technique and for its field implementation. In this direction, this paper discusses the MMM technique for early detection of damage and presents the preliminary results on carbon steel specimens during tensile deformation. It also discusses the details of the simulation studies carried out using three-dimensional finite element model for better understanding of the technique. Finally, the paper presents the challenges for field implementation of the MMM technique.

Keywords: Magnetic NDT, metal magnetic memory, finite element modeling, carbon steel, material characterisation

Acknowledgments

Dr. W. Sharatchandra Singh would like to thank Prof. Marc Kreutzbruck for encouragement and support during his Post-doctoral research stay at BAM Federal Institute for Materials Research and Testing, Berlin, Germany and also thank Mr. Robert Stegemannfor many fruitful discussions.

194-P

STUDY OF COMPLEX GEOMETRY COMPOSITE (T-JOINT) USING PHASED ARRAY ULTRASONIC TECHNIQUE (PAUT)

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Abstract

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other. As composites becomes more widely used for primary structural components in aerospace and other applications, the reliable detection of small defects in composite sections is increasingly important. Complex geometry composite structures have seen a substantial increase in application in the new generation airplanes due to their high specific strength, higher stiffness, high corrosion resistance and attractive thermal properties. Ultrasonic inspection of complex geometry composites suffers from loss of sensitivity, beam distortions, high attenuation of beams and coupling problem of transducers. Due to these reasons, ultrasonic inspection of curved composites is highly challenging. Ultrasonic phased arrays offer great advantages in scanning, sweeping, steering and focusing of beams for advanced imaging. There is an

increasing demand for phased array ultrasonic technique to inspect curved composites with in minimum time and with greater accuracy. This paper deals with the inspection of curved CFRP composites using phased array technique. So a better understanding of defects on composite can help making aerospace industry more safe and reliable. Ultrasound pulses are reflected by interfaces between materials of different properties. Mapping the time delay to reception of the reflected signal provides information about the depth of the damage. The information about defect depth can be used to view the ultrasound data as a pseudo-3D image which gives the information about kind of defects formed by the impact like delaminations, matrix crack, porosity, inclusions, fracture or buckling of fibers etc.

Keywords: Phased Array Ultrasonic Testing (PAUT), Composite material, T-Joint, CFRP, NDE(Non Destructive Evaluation).

195-I

NDE FOR CONDITION MONITORING AND STRUCTURAL HEALTH MONITORING: ADVANCES AND CHALLENGES

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Abstract

The presentation highlights the important role of non-destructive evaluation (NDE) techniques in condition monitoring and structural health monitoring (SHM) of engineering components and structures. NDE enables on-line as well as off-line monitoring and ensures early detection of anomalies, wear, deterioration, and other impending failures. NDE avoids unplanned shutdown and aids inventory management as well as life management programs. NDE has become an important module in SHM and integrated vehicle health management through implementation of diagnostic and prognostic methodologies using smart sensors, in-situ measurements, signal & image processing techniques, automated surveillance of accessible as well as inaccessible regions.

Visual, vibration monitoring, ultrasonic, acoustic emission, infrared thermography, eddy current and microwave techniques are gaining increased use in condition monitoring and SHM applications. The presentation covers the recent advances in these areas through example case studies including vibration monitoring of rotating machinery, guided ultrasonic wave based technique for rapid examination of critical welds in fuel tanks, eddy current technique for non-contact blade tip clearance measurements in turbines, fiber optic Raman distributed temperature sensor for in-situ leak detection in sodium circuits and combined use of acoustic emission and thermography techniques for damage monitoring. The presentation brings out how signal processing, artificial intelligence, and pattern recognition methods are able to handle noise enabling early detection of damage and quantification. It explains how wireless sensing systems are being deployed for condition monitoring applications, especially on concrete structures. Finally, it enlists the challenges, especially concerning the sensor location, miniaturization, sensitivity, stability, embedding, packaging etc.

196-C

A DIGITAL HOLOGRAPHIC NDT SYSTEM FOR TYRE TESTING AND PROTOTYPE OPTIMIZATION

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Abstract

Recent decades witnessed several developments in automobile engineering, right from engine design to body streamlining. This contributed a lot in fuel efficiency and wide spread use of high speed vehicles on express highways. On the other side, it is important to note that a majority of accidents on express highways are due to tyre bursting. This throws light to the fact that it is essential to have improved tyre designs by optimizing tread patterns, tyre cross section and material composition so that tyre scan endure prolonged stress under high speed operations. Mapping of stress at the foot print of tyres is very critical in tyre design and optimization. Foot print is hidden in between the ground and the tyre and it is difficult to image the region by traditional means. Hence, colour sensitive dyes and sensor arrays are being generally applied by the global tyre industry. These methods are not sensitive and have several drawbacks. Holography is an effective method for precision Non Destructive Testing. It is non-contact and yields information at a stretch on a specific area. Earlier, we introduced a method to map stress at the foot print of tyres[1,2] by applying analogue holographic interferometry.

Stress distribution at the footprint of a car tyre recorded by analogue holography

Nevertheless, conventional holography demands costly high resolution photographic films and plates that require complex and time consuming chemical processing and stringent vibration isolation conditions. High resolution CCD and CMOS cameras and high speed computers havefacilitated emergence ofdigital holography which, in several ways, is more versatile and convenient than analogue holography. The technology is applied for a variety of NDT applications in fields ranging from aerospace, marine, off shore and biomedical engineering, material testing, stress measurement etc. We have developed commercial level Digital Holographic Non Destructive Testing (DHNDT) systems for various applications. The original software was developed by the VSSC for aerospace applications and licensed to Light Logics for system development and commercialization. This paper reports development of a very compact and flexible DHNDT system and the study conducted by us in mapping stress at the footprint of car tyres and its applicability in precision tyre design testing and prototype optimization.

197-C

NDE DURING MANUFACTURE AND MAINTENANCE OF AIRCRAFTS, AND HELICOPTERS

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Abstract

From a small beginning in 1940, The growth of Indian Aeronautical industry is phenomenal, presently it has engaged in all aspects of Aircraft and Helicopter design, production and service.

Non destructive evaluation (NDE) plays a multifaceted role in product cycle of an Aircraft / Helicopter. It is a vital tool of inspection in the manufacture and maintenance of Aircrafts/Helicopters.

NDE contributes reliability & safety, through implementing design stipulated acceptable norms , during Manufacturing process, prevention of service failures by in service inspection and Failure Investigation of failed components for further improvement. Also NDE has a vital role in life extension of Aircrafts & Helicopters.

Conventional non-destructive testing methods, namely, radiography, ultrasonics, magnetic particle, dye penetrant and eddy current have undergone similar growth and are in position to cater to the requirements of the Aerospace Industry. More advanced NDE techniques are also being introduced.

This paper attempts in covering Aerospace NDE topics related to personnel Certification , Approvals of various Government regulatory bodies, National and International Accreditation like, NABL NADCAP, approval of materials and equipment. Process control, Calibration, MRO (Maintenance Repair & Overhaul) of Aircraft / Helicopter, and failure analysis of Aircraft / Helicopter components.

Keywords: Aerospace NDE, NADCAP, Aircraft Helicopter, MRO In In-service Inspection.

198-P

ULTRASONIC C SCANANDTHERMOGRAPHY BASED NONDESTRUCTIVE EVALUATION FOR METAL-POLYMER ADHESION

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Abstract

Metal-Polymer composites are used in industries like automotive, household appliances manufacturing, also in home and garden, etc. Metal/polymer composites have been used in automotive parts to control and reduce the interior noise and vibration in passenger compartment. Apart from that these composites also used as a passive dampers to control and eliminate noise and vibration in the appliance industry. In the present work we report bonding and debonding nature of the metal and polymer adhesions and its debonding natures through immersion C scan and Thermography methods. In the present case metal we used is Aluminium and the polymer Acrylic is used. We include the purposeful debonding and also increased the concentration of debonding and studied the quality of flaw deduction using above mentioned methods. Apart from that we also explored multi-layered composites like Polymer-Metal –Polymer through the same methods.

199-P

A STUDY ON THE EFFECT OF DIFFERENT RECORDING MEDIUMS (FILMS) USING CONVENTIONAL X RAY SYSTEM ON THIN WEBBED PYROGEN IGNITERS OF SRM'S

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Abstract

Historically, non-destructive techniques (NDT) were used widely for defect detection in metallic as well as non-metallic components/structures. Film based conventional X-ray radiography is indispensable for the inspection of launch vehicle components, particularly composite products like propellants to ensure their quality and reliability. The defect detection in film radiography is influenced by many factors out of which the resolution of the recording medium plays an important role in addition to absorption speed and grain size of the film. Defect detection by X-ray radiography films becomes important, where no other methodology can be used to assess the criticality of defects. The detection of any size of defect is most important in NDE of critical launch vehicles systems like thin webbed pyrogen igniters, pyro devices, etc. Critical film interpretation is very difficult due to the thin webbed propellant grain with star shaped port in the assessment. This paper deals in detail about the defects in propellant systems, different recording mediums, and a case study on the effect of using different films on defect detection.

200-P

STUDY ON LASER-ULTRASONICS WAVE GENERATION AND PROPAGATION IN STEEL SPECIMEN USING FINITE ELEMENT SIMULATION

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Abstract

In non-destructive testing using laser ultrasonics, the development of models thatidentify the propagation paths of the ultrasonicwaves is necessary to establish criteria that allowthe defects identification especially in materialswith complex geometries. The objective of this research is to study the interaction of laser generated ultrasonic waves and their propagation in steel. Numerical models of laser generated ultrasonic waves are created to gain a deeper understanding of the Physics.A 2D finite element model is considered in order to evaluate the propagationpaths of the ultrasonic waves generated inside a steel specimen. The regime considered is the thermo-elastic regime. An attempt is made to understand the directivity patterns for the longitudinal, transverse and surface waves.

Keywords: Non-Destructive Testing, Laser Ultrasonics.

201-P

INTERACTION OF GUIDED WAVES WITH DELAMINATIONS IN COMPOSITE PLATE STRUCTURES

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Abstract

A thorough understanding of wave scattering characteristics is essential when characterizing composite structures using guided ultrasound. This poster describes finite element simulation studies to understand the scattering of the

fundamental symmetric Lamb mode S_o from square shaped delaminations in a - ply CFRP composite plate with 0/0/0/0 degree orientation. Scattering coefficients are plotted in the far field as a function of circumferential position around the delamination. The impact of delamination size and through-thickness position is studied. The results show that the anisotropy of the composite plate, size and position of delamination, all have an influence on wave scattering. This work will be useful for practical Lamb wave based inspection of composite plate structures.

Keywords: Composites, Lamb Wave, Finite Element Analysis.

202-I

SIMULATION-ASSISTED DETERMINATION OF PROBABILITY OF DETECTION (POD) CURVES: A SHORT REVIEW

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Abstract

The Probability of Detection (PoD) curves are considered as an important metric to assess the reliability of NDE techniques and systems. The limitations associated with the cost and time of empirical means of determining PoD curves means have led to the use of simulation and physics based models to assist the process. Focus groups on Model-Assisted PoD (MAPoD) worldwide have studied the capability of physics-based models in PoD curve determination over the last two decades. More recently, numerical modeling has also emerged as an attractive alternative which complements the empirical limitations and can also provide results on a wide range of parametric conditions. Statistical approaches were incorporated in the numerical models and data fusion techniques were used to make the PoD curves more realistic. This paper reviews the state of simulation-assisted PoD curve generation in the recent past.

Keywords : NDE, Probability of Detection (PoD), Numerical simulation

203-C

A TRANSFER FUCNTION APPROACH BASED ON SIGNAL NOISE FOR POD CURVE DETERMINATION

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Abstract

Probability of Detection (PoD) curve estimation requires large data sets which are obtained through expensive and time consuming experimentations. In recent years, reducing the time and cost of experimental trials is of greater concern. One approach is to transfer the PoD curve obtained for specific application to predict the PoD curves for the other related application. The classical transfer function approach is based on the hypothesis that the ratio of signals in simulation and experiment is equal in both the applications. Hence it requires the numerical data of both the applications. However the proposed approach here directly deals with the signal to noise ratio instead of ratio of signals which in turn requires the simulation and experimental data of only the parent application. The new approach is illustrated through an example case of PoD curve generation for ultrasonic inspection on Aluminium plate. The available PoD data of Austenitic Stainless Steel plate is used.

Keywords: Transfer Function, Ultrasonic testing, Probability of Detection (PoD)

204-C

CLASSIFICATION OF FLAW IN TOFD IMAGES OF AUSTENITIC STAINLESS STEEL WELD BASED ON WAVELET DESCRIPTORS

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Abstract

Grain structure of austenitic stainless steel (ASS) weld causes difficulty in defect detection and classification while inspecting using Time of flight diffraction (TOFD) method. This study aims at classification of defects based on the wavelet descriptors extracted. This study makes use of TOFD images of ASS weld pads fabricated with defined linear and volumetric defects. Feature vectors are extracted for each type of defect. Each feature vector includes five different wavelet descriptors. 75% of the total vector set is used for training and remaining vectors are used for testing of neural network. During training and testing the feature vectors are given as the input to Neural Networks architecture. Four different neural network architectures are considered in this research. The efficiency of the network was analyzed by comparing their overall classification accuracy. For the utilized data base Cascade Feed forward Neural Network(CFFNN) was found to highly efficient network for defect classification in TOFD images for the given data base. The classification algorithm enables enhanced defect detection at earlier stage. It reduces error caused by human fatigueness of the operator when the volume of examination data increases. The future direction is to identify the optimized feature vector and to reduce time required for classifications.

205-C

A STUDY ON THE APPLICATION OF CONVENTIONAL AND DIGITAL RADIOGRAPHY SYSTEMS ON NDE OF CRITICAL LAUNCH VEHICLE COMPONENTS

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Abstract

Film based conventional X-ray radiography is indispensable for the inspection of launch vehicle components, particularly composite products like polyimide pipeline used for critical functions in the cryogenic stages to ensure their quality and reliability. The defect detection in film radiography is influenced by many factors out of which the resolution of the recording medium plays an important role. Defect detection by X-ray radiography by using films becomes important where no other methodology can be used to assess the native and criticality of defects. It is very difficult to assess the nature and severity of different type of defects in mission critical cryogenic sub-systems like polyimide pipelines. These pipelines are made of Polyimide-Fluoropolymer film wound layer by layer over the collapsible mandrel with metallic adapters at both ends and cured to obtain required profile of the pipeline. Polyimide-Fluoropolymer film is a composite material composed of polyimide tape with 25 micron thickness and single side coating of 12.5 micron thick FEP. This paper deals in detail about the radiographic inspection of these pipelines using film based conventional radiography and digital radiography systems and the effect on the defect detection.

Keywords: X ray radiography, films, digital radiography, polyimide pipelines and defects.

206-C

SIMPLIFICATION OF AUT VALIDATION PROCESS IN LINE WITH ASME

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Abstract

Advanced Ultrasonic techniques like TOFD and PAUT are now rapidly taking over RT for the volumetric inspection of welds in Process Plant Industry. The ability of the technique in detecting the flaws for different scan plans prepared has to be validated. ASME also calls for this validation of the AUT procedure, with the help of Qualification Blocks prepared with known size of flaws. This validation process enables to evaluate the NDT method adopted in terms of its Probability of detection, flaw size and flaw location measurements. Bringing accuracy in the data–image collected within the acceptable limit is a challenge. The flaws need to be carefully embedded so that the location and size of flaws can be precisely set. These accuracy measurements also validate the software used for sizing. This paper describes in detail about the requirements of Qualification block and the simplification of the validation process in line with ASME. This paper also discusses about the Signal response for various types of induced defects and their effect on probability of detection and sizing accuracy

Keywords: TOFD, PAUT, ASMe, Qualification

207-C

DETECTION AND SIZING ACCURACY OF FLAWS IN BLIND ZONES OF TOFD

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Abstract

Blind zones in TOFD are still a challenging area where it requires further development. This paper concentrates more on enabling the TOFD technique to work with limited aid of supplementary method for the blind zones. The indications in both the top and bottom zones get submerged with lateral wave & back wall signal respectively and thus affecting the Probability of Detection. The inability to have the phase reversal information, which is required for the height measurement results in inaccurate sizing. The above points were taken into account while deciding the scan plan, selection of frequency, diameter of the probe and angle of probe. The aid of software was also used in bringing the accuracy. Moreover the supplementary method A-scan ultrasonic testing used for sizing accuracy and locating the indication with respect to the weld center was also made to undergo heavy validation process with known size of slits.

Keywords: TOFD, Blind zone, Sizing accuracy

208-C

A NOVEL METHOD FOR REVERBERATION CANCELLATION OF SYSTEMS BASED ON PULSE ECHO METHOD WHICH USES SINGLE ULTRASONIC TRANSDUCER

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Abstract

Blanking zone refers to distance between the surface of the transducer to the target specimen where measurements cannot be made due to ringing of the transducer. Ringing is the continued vibration of the piezoelectric transducer element beyond the electrical excitation pulse. All piezo electric transducers show this phenomenon irrespective of their design. The blanking zone caused by the reverberation of transducer, even after the excitation signal ceases, is a menace in single transducer based measurements, where the echo's presence can be detected only if it occurs after the blanking zone. This has the implication that targets closer to the sensor cannot be subjected to ultrasonic measurements using single sensor. Conventional noise removal techniques cannot be employed for removal of reverberation.

Digital signal processing techniques are employed for the removal of reverberation, without affecting the echo present in the blanking zone. A novel method is found out, which ensures that the echo signal can be detected even if the signal falls inside this Blanking zone. This technique ensures that the ringing signal is attenuated to a large extend (50dB for 1.8 degree phase matching) without affecting the echo strength, thus enabling detection of the echo. The method employed has successfully detected the presence of echo in the blanking zone by effectively removing the reverberation without affecting the echo. This method, if employed effectively can result in building non destructive test systems where the distance between transducer and target is not constrained by the presence of blanking zone.

209-P

SPLIT DOMAIN APPROACH FOR THE FINITE ELEMENT SIMULATION OF GUIDED WAVE PROPAGATION IN PIPES

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Abstract

Guided wave Ultrasonic Testing (UT) is an extensively used Non-destructive testing (NDT) technique for the long range inspection of pipes in various industries such as petrochemical, oil and power plants. In the recent years, Finite Element (FE) simulations are widely used to predict the performance of any ultrasonic inspection before taking it into the field. However, the 3D FE simulations which can be used for the detailed study of the interaction of guided waves inside the material with complex geometries are limited because of the computation resources required.Advances in computing processor speed and memory may allow them to solve, but it may cost more and every time high performance systems may not be accessible. To address these limitations, a new technique called Split Approach has been developed for simulating long-range guided wave propagation in complex structures with limited computation resources. This method involves splitting the larger FE model into smaller sub-models and analyzing them individually. The feasibility of this approach is illustrated by an example case of 3D FE simulation of guided wave propagation in a sufficiently long pipe.The results obtained through split approach are compared with the conventional simulation method.

210-P

PHASED ARRAY ULTRASONIC CHARACTERIZATION ON INCOLOY STEAM GENERATOR TUBING

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Abstract

Phased array ultrasonic testing on tubes offers several advantages over conventional single element tests such as improved resolution, imaging of defects, better focusing and increased inspection area. Thus phased array testing has been applied for testing of thin-walled Incoloy tubes of dimensions of outer diameter 19 mm and wall thickness 1.1 mm. They are used in nuclear steam generators due to their inherent stress corrosion resistance and high temperature strength properties. Experimentation was carried out using cylindrically focused phased array probe and immersion setup was made in house. The focal laws were optimized for circumferential beam scanning in tube using M2M experimental software. With this setup in addition to the detection of longitudinal defects we were able to distinguish them with reference to wall thickness. Multi-Salvo testing of the tubes was demonstrated to achieve interlaced scanning and as well as wall thickness monitoring using single probe. This technique is very useful in automatic ultrasonic testing. To validate experimental results, metallography was performed on tube defects and it was conformed that both were good agreement.

211-C

AUTOMATIC RECOGNITION OF VOIDS IN DIGITAL RADIOGRAPHS OF TUBULAR SOLID ROCKET PROPELLANT GRAIN

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Abstract

Flaws such as voids, porosities, cracks and debonds are detrimental to the performance of the solid rocket motor. Radiographic NDE method is widely used for detection of such kind of flaws in the solid rocket propellant grains / motors. In recent past, digital radiography has been widely accepted as the preferred technique of inspection due to many advantages such as reduction in exposure time, comparable image quality with film, better dynamic range, ease of archiving and digital image processing capabilities. Faster inspection with digital radiography method leads to generation of large number of radiographs in short duration of time. Interpretation of such large numbers of digital radiographs by human being is not only a tedious task but also unreliable because of fatigue. Hence Automatic Defect Recognition (ADR) of flaws in the digital radiograph is becoming a necessary part of inspection process.

Automatic Defect Recognition (ADR) for rocket motors / propellants is always a difficult task because of the geometry of the solid rocket motors / propellant. Voids being most dominated flaws that appear in the solid propellant grains; at the initial stage, ADR algorithm was developed to detect presence of voids in the tubular propellant grains. Simulated digital radiographs with void were generated without noise, with noise and with different positions of voids in the grain. The developed algorithm was utilised initially with the simulated radiographs, which could successfully detect and identify the void. Further, few actual radiographs of tubular propellant grains were scanned by the algorithm and could successfully detect the presence of voids of different sizes. This paper discusses about the algorithm and its application on the simulated and actual digital radiograph of grains for automatic recognition of voids in the tubular solid rocket propellant grains.

Keywords: Solid Rocket Propellant, Tubular geometry, Radiography, ADR, Voids, Image processing

212-I

FINITE ELEMENT MODELING OF ULTRASONIC GUIDED WAVE PROPAGATION IN VISCO-ELASTIC MEDIA WITH FREQUENCY DOMAIN ANALYSIS

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Abstract

Ultrasonic Testing (UT) is an important Non Destructive Evaluation (NDE) method for inspection of structural materials and components for presence of various kinds of flaws. Ultrasonic guided wave is utilised for inspection of material over a long range because of its capability to travel a longer distance without much attenuation. However the propagation of ultrasonic guided wave over a long range in the visco-elastic media like composites gets affected by the attenuation offered by the material.

To understand the distance of propagation of ultrasonic guided wave, their interaction with flaws in visco-elastic media, it is essential to model the guided wave propagation considering the visco-elastic material properties. The frequency domain analysis is appropriate for modelling the wave propagation in attenuating material by considering the complex material properties.

This paper describes the two dimensional Finite Element Method (FEM) model for simulation of guided wave propagation in visco-elastic media using frequency domain analysis. The visco-elasticity in the material is incorporated by considering the complex material properties. The complex material properties cannot be modelled in time domain whereas modelling with complex material properties in frequency domain is the natural process. This paper describes in detail regarding the effect of visco-elasticity of a unidirectional composite material on propagation of guided wave.

Keywords: FEM, Frequency Domain Modeling, Unidirectional Composite, Ultrasonic guided wave

213-C

ULTRASONIC GUIDED WAVE PROPAGATION IN STEEL-RUBBER STRUCTURE – SIMULATION AND EXPERIMENTAL STUDY

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Abstract

This paper describes about the investigation for feasibility of generation and propagation of ultrasonic guided wave within steel-rubber double layer structure for rocket motor application. It also describes the possibility of detection of debonds present at the interface of the structure. A straight beam probe was used to generate the guide wave within the structure. Another straight beam probe was used to receive the guided wave signal on and around the debonded region. The guided wave was generated by exciting the specimen from both sides and wave is also detected from both sides of the specimen. It was found that rubber layer does not support the guided wave mode and guided wave does not propagate through rubber layer. However, point-wise inspection of the specimen is possible and that can detect presence of debond in the specimen.

Keywords: FEM, Frequency Domain Modelling, Steel-Rubber, Ultrasonic Guided Wave, Visco-elastic

214-C

ADVANCES IN DETECTION AND CHARACTERIZATION OF METAL LOSS IN PIPELINES USING GUIDED WAVE ULTRASONIC TESTING

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Abstract

Guided wave ultrasonic testing is gaining widespread acceptance as a non-destructive testing tool for rapid screening of pipelines and process piping for metal loss – corrosion and erosion. As an externally applied tool, it finds application in testing unpiggable pipelines and with pipelines in service.

Current commercial guided wave systems detect changes in cross-sectional area and are not currently capable of measuring remaining wall thickness. As a result, anomalies identified by guided wave ultrasonic must be quantified by a secondary non-destructive testing technique, to provide data suitable for use in fitness-for-service assessments and integrity management decision making.

This paper gives an introduction to guided wave testing for pipelines, highlights relevant international standards and presents the current state of the art in terms of test data.

Recent advances in guided wave testing technology which allow estimates of remaining wall thickness and maximum extent of metal loss flaws to be made directly from guided wave tests are presented. TWI's research programme aimed at developing flaw sizing for guided wave testing will be described in terms of numerical modelling, laboratory testing

Flaw sizing for guided wave testing will find application for 'standard' mobile testing as well as online monitoring and metal loss trending using permanently installed tools.

A selection of new and future developments in guided wave testing are briefly introduced, such as high temperature applications, non-intrusive in-service monitoring of atmospheric storage tank bottoms, measurement and reduction of internal fouling in piping/pipelines, wireless remote monitoring using permanently installed sensors, ship hull testing, marinised system for subsea pipelines.

Keywords: Guided wave ultrasonic testing, long range ultrasonic testing, pipeline inspection, condition monitoring

215-P

INSPECTION OF BASALT FIBER COMPOSITES BY MECHANICAL STRESSING USING THERMOGRAPHY TESTING

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Abstract

Advanced composite materials are finding increasing application in aerospace, marine, automotive and many other industries due to their higher stiffness to mass ratio and structural efficiency. Adhesive bonding is useful for bonding sandwich materials, which are playing an increasing role in reducing structure weight. Defects in these engineering structures are unacceptable as it affects the strength and durability of the structures. Defects such as interfacial debonding, delamination and buckling may occur under mechanical stress depending on the direction of applied load. This work aims to present the identification and quantification of defects using pulsed thermography when the sandwich materials are stressed. In our present work we have prepared Basalt fiber samples and we have studied the quality of bonding and type of defect induced by stressing the samples.

Keywords: Adhesive bonding, sandwich materials, interfacial debonding, delamination, Basalt fiber.

216-C

NOVEL MEMBERSHIP FUNCTION FOR THE FUZZY BASED SEGMENTATION TO EXTRACT HOTSPOT FROM PCB THERMOGRAPH

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Abstract

Of the various NDT techniques for condition monitoring of electronic circuits, Infrared thermograph gains importance owing to its non invasive, non hazardous, non contact nature .Heat pattern of the circuit board is measured with an IR camera and is converted into thermal map called thermograph. Anomaly in the circuit board appears either as hotspot or cold spot depending on flow of current. Various techniques are proposed for extracting the hotspot from the thermographs. Various image segmentation techniques namely edge detection, region growing, region split and merge and thersholding cited in the literature. Conventionally image processing techniques follow a standard procedure which does not allow the expert knowledge to fine tune the results. Hence in this paper work fuzzy based image segmentation technique is proposed for extraction of hotspot. The proposed membership function is symmetrical in nature. The hotspot pixel are assigned the higher probability and background pixelsare assigned with lower probability. In each case the proposed membership function works satisfactorily better than the conventional function. In this work 30 realtime thermograph are acquired by varying the distance and emissivities.

217-C

THE EFFECT OF SURFACE BREAKING CRACK ORIENTATION IN DETECTION CAPABILITY: A LASER THERMOGRAPHY NUMERICAL MODELING APPROACH

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Abstract

The detection and characterization of cracks prior to damage is a technologically and economically highly significant task and is critical when it comes to safety-relevant structures. The evaluation of a component's structural health is closely related to the presence of surface cracks. One of the more promising techniques among NDT techniques is thermography. In the present work a laser spot excitation for surface crack detection is simulated using the finite element method (FEM). Here a CW laser is used to scan over the steel surface and the presence of surface breaking discontinuities are detected by the variation in the thermal distribution over the metal surface. The developed FEM 3D model helped us to study the effect of orientation of the surface breaking crack with respect to metal surface (such as oriented at an angel 45^0 towards the scanning direction , normal to the scanning direction, and 45^0 against the scanning direction) in heat distribution phenomena. CW Gaussian laser wave interaction with crack also modeled successfully. A dedicated tracking algorithm use to identify the crack signature. The same notch parameters and orientations are studied for different surface temperature to understand the capability of the laser scanning thermography at elevated temperature to detect the surface breaking cracks in steel. The developed FEM model shows a good correlation with the experimental measurements.

Keywords: NDT, Laser Thermography, FEM, Surface breaking cracks, Elevated temperature.

218-C

BIOLOGICALLY INSPIRED AUTONOMOUS UNDERWATER VEHICLE (AUV) FOR STRUCTURAL INSPECTION AND SURVEY IN COASTAL REGIONS

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Abstract

Coastal and littoral assets need to be inspected for structural faults periodically, but this process is affected by difficult wave conditions close to the shore line. Typically manual inspection using boats is challenging closer to the shore where the draft is lesser. Automated robotic inspection using conventional propulsion techniques is also difficult as the power and manoeuvrability required to operate against rough wave action can be considerable. However, marine organisms are able to navigate and swim through such conditions and here we aim to learn from such natural mechanisms to improve the performance of robotic underwater vehicles for inspection and survey. This paper describes research on the development of a biologically inspired autonomous underwater vehicle for operation in near-shore marine locations. The design incorporates biomimetic biologically inspired propeller together with conventional rotary thrusters. The biologically inspired propelleris used for efficient long range navigation, while rotary propellers provide manoeuvrability, thus making the vehicle both efficient and more manoeuvrable for the overall mission. Key parameters such as propulsive efficiency, cost of transport, manoeuvrability and the overall performance of the hybrid design are studied.Further development and suitability of such designs for on-field observatory missions is also discussed.

Keywords: Aautonomous underwater vehicle (AUV), bioinspired biomimetic design

219-C

REMOTELY OPERATED VEHICLE (ROV) FOR INSPECTION OF UNDERWATER PIPELINES USING BULK AND GUIDED ULTRASONIC WAVES

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Abstract

Underwater pipeline assets need to be inspected at periodic intervals to ensure operation without leaks or other structural failures. However such structures may typically be located in difficult immersed conditions where divers may struggle to reach, operate and perform inspection with good reliability. This paper describes the development and features of a robotic remotely operated vehicle (ROV) for inspection of underwater pipes. The single-hull four-thruster differential configuration ROV developed can navigate steadily and reach remote underwater locations with design depths up to 100 m. The four thrusters provide 4 degree of freedom manoeuvrability through proportional-integral-derivative (PID) controllerand Inertial Measurement Unit (IMU) assisted navigation. A novel feature of the design includes the allowance for customized pipe gripper actuators that allow the ROV to hold on to and navigate along the pipe even during cross-currents. Unlimited power and communication with the ROV are through a tether, while on-board electronics allow local control and manoeuvring. Inspection data and visual feedback from onboard HD cameras is streamed live and can be viewed from a safe on-shore station. Results of inspection of immersed pipe using bulk & guided ultrasound through transducers mounted on the ROV in controlled water conditions are presented. The use of guided wave technique allows the ROV to use one transducer to detect flaws in any given cross section of the pipe. Extension of the technology for other NDT methods is also discussed.

Keywords: Remotely operated vehicle (ROV), underwater pipes, Ultrasonic NDE

220-C

MIKE: A REMOTELY OPERATED VEHICLE (ROV) FOR VISUAL INSPECTION OF UNDERWATER STRUCTURES

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Abstract

Underwater assets such as off-shore platforms, jetties and piles need to be inspected periodically for detecting any structural damage and initiating maintenance activities. However, reliable manual diver based inspection may be challenging due to difficult environmental conditions, while also putting the operator at risk. Planys Technologies, an IIT Madras incubated company, is developing robotic remotely operated and autonomous vehicles (ROV and AUV) for marine and immersed structure inspection. This paper describes the development and features of MIKE, a single-hull 6-thruster differential configuration ROV built by Planys for visual inspection of off-shore structures. Addressing on-field conditions such as mild waves and currents, and designed for reaching 100 m depth with 6 degrees of freedom, Mike has unlimited endurance through custom-built tether system. Advanced stability algorithms use data from on-board inertial navigation sensors to provide high degree of manoeuvrability and control. High definition video streams from multiple on-board cameras and powerful illumination sources assist the pilot to perform challenging missions. Example results from field trials at Port and Harbour locations, reaching depths of up to 20 m are presented and further work is discussed.

Keywords : Remotely operated vehicle (ROV), underwater structure, visual inspection

221-P

DIAGNOSTIC TECHNIQUES FOR DETERMINING PLASMA DISRUPTION SIGNALS IN TOKAMAKS

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Abstract

Tokamak uses controlled thermo nuclear fusion for power generation. The output current in depented on the time duration for which the plasma is confined within the toroidal chamber. However due to unprecedented reasons, ions in the outer circumference of the plasma disrupts. It may affect the temperature of the plasma, thereby resulting in continuous plasma disruptions. The disrupted ions hits the in vessel component leading to the emission of carbon from the limiters. These carbon ions enhances the disruption of plasma. It not only leads to collapse of plasma, but alsocauses damage to in-vessel components. Such disruption are called hard disruption. Hence it is necessary to study the different types of disruption and identify the suitable techniques for classifying the plasma disruption. This paper provides detailed information about various diagnostic techniques that can be used for plasma disruption identification. This paper also suggest suitable signal processing techniques for relating the plasma disruption with the signal parameter. Various signal that describe the plasma disruption includes the plasma current, loop voltage, pre-filled gas pressure, Additional gas-stuff, APPS power supply parameters, hard x-ray signal, Radial and vertical plasma position, Magnetic probe signals, density signal, Soft X-ray signal, electron temperature information, Há, O-I, C-III, Visible Continuum impurity line radiation signal, In-out spectroscopic position signal, Total Power radiated from plasma (Bolometer signal), Ohmic current, VF current, Fault, current,

vessel current signal for some of the hardware fault, Langmuir probe signal, Electrode Biasing voltage and Bias current signal, Edge safety factor (q) information and Fast Feedback Plasma position control current. Performance of spectral domain feature disruption is compared with that of time domain technique.

Keywords:Bolometer signal, PHA System, ECH, ECCD

222-P

NDE AND METROLOGICAL PERSPECTIVES FOR CRITICAL PARTS OF A SMALL AERO ENGINE—A CASE STUDY

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Abstract

The parts of an aero engine are undergo various metrological and Non-destructive evaluation methods before being put to the testing or service. These methods are playing an important role for verifying the configuration and integrity of the parts of the engine. The methodical approach adopted is very essential for the evaluation of the parts and arriving at the accurate results of the examinations and tests carried out. Combustor casing is a critical part if the aero engine. Being critical in nature in terms of functionality and safety, integrity and closeness to design intent is important. Current case study discusses about various methods of metrological and non-destructive methods adopted for the evaluation of the combustor casing of a small aero engine.

223-C

HELIUM MASS SPECTROMETRIC LEAK DETECTION IN VACUUM SYSTEMS WITH VERY SMALL PUMPING TIME CONSTANTS

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Abstract

Helium Mass Spectrometric Leak Detection is an important, essential, reliable and highly sensitive technique for the detection of leaks in R&D vacuum systems, Analytical Instruments and many industrial process plants. The application of this technique in conventional vacuum systems is proven and established. Pumping time constant, which is given by the ratio of volume of system to effective pumping speed present in the system, is an important factor in the leak detection sensitivity and accuracy. Application of Helium Leak Detection technique to systems which has very low pumping time constant, faces many difficulties due to low sensitivity and large response time. This paper addresses the problems that are present in such practical systems and methods to improve the sensitivity of detection. A specific example of application in a Lyophilizer system is presented and discussed. The work has immense potential for application to Leak detection in many process plants in Pharmaceutical, Chemical, Petrochemical, Nuclear and Energy fields

Keywords: Leak Detection, He-MSLD, Helium Leak Detection.

224-C

WIRE ROPES CONDITION MONITORING: CONCEPTION AND EMBODIMENT

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Abstract

Non-destructive inspection of steel wire ropes becomes quite common for onshore and offshore operations, and relevant equipment is now available on the market. The reason for growing interest to this inspection is increasing in prices for wire ropes, especially for ropes of large diameter, which may not considered as consumable product anymore, but as assets, and thus should be discarded for reason, i.e. according to discard criteria and their actual technical condition. The key issues for wire rope non-destructive inspection are prompt equipment and correct data interpretation. Rugged and reliable equipment capable to make data interpretation with computer without human intervention is of interest of many customers. INTRON PLUS LTD. has developed INTROS-AUTO, that is a successor of widely used wire rope tester INTROS. It is designed for non-destructive inspection of wire ropes with automatic data interpretation. Following criteria are used to discard rope – number of broken wires along lay length and loss of metallic cross section area in percentage. Discard criteria can be adjusted according to agreement with the customer. INTROS-AUTO stores detailed data, which can be downloaded and interpreted in regular manner. The instrument is ready for inspection of ropes as large as 135 mm in diameter and can be used for periodical or permanent wire rope monitoring onshore and offshore.

225-C

IN-SERVICE APPLICATION OF EMAT IN BOILER WATER WALL TUBES AND HIGH TEMPERATURE PIPELINES

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Abstract

This article describes the application of electromagnetic acoustic transducer for thickness mapping of boiler water wall tubes and high temperature pipelines used in various industries. Although conventional UT spot thickness gauging is widely used in industries such as oil and gas, power, petrochemical, Pharmaceutical plants etc., this paper will give an idea about the importance of mapping entire tubes/pipes and its advantages .This article also describes the use of Medium Range Ultrasonic Testing (MRUT) by EMAT for quick detection of wall loss for later verification by thickness mapping to find out the integrity of the pipelines

226-I

ADVANCED VOLUMETRIC CT SYSTEM FOR NON-DESTRUCTIVE EVALUATION

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Abstract

Volumetric CT system has evolved over a period of time for industrial inspection applications. Demand for speed, ease of use and highest level of image quality was a good technical challenge for technologists and engineers. While the journey towards an ideal system is yet to complete, decades of research has resulted in next generation system with a lot of improvement.

This talk will emphasize a few of those breakthrough innovations for industrial VCT system and discuss applications which have benefitted from it.

227-C

APPLICATIONS OF VISUAL TESTING IN NDE OF AERO ENGINE COMPONENTS –CASE STUDIES

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Abstract

Visual Testing has evolved from being a simple naked eye examination to advanced Remote Visual Testing using articulated Videoscopes fitted with CCD camera for image storage and retrieval facilities. Visual Testing plays a significant role in quality assurance of aero engine hardware. The applications range throughout the product life cycle starting from inspection of newly manufactured components to condition monitoring during service. Usage of visual testing aids for examining the critical aero engine components like turbine shafts, blades, intermediate casing, oil tank etc. have been presented in detail.

Keywords: Visual Testing, Industrial Videoscope, Aero Engine, Shaft, Blade, Oil tank

228-C

TRAINING AND CERTIFICATION IN NON-DESTRUCTIVE TESTING:

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Abstract

NDT education and training has evolved from a simpler time with less requirements, fewer educational providers, and an abundance of willing participants. Today there are many formal certification requirements with many options for education and training. This era of sophisticated technology demands more education and training for NDT practitioners to succeed in the advanced NDT methods.

ASNT offers a number of refreshers courses designed to help NDT professionals review and expand their knowledge of important concepts in each NDT topic. The proposed wording in the Recommended Practice No. SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing states that personnel being considered for initial certification should complete sufficient organized training. The organized training in accordance with ASNT and ISNT may include instructor-led training, self-study, virtual instructor-led training, computer-based training or web-based training. The British Institute of NDT had offered training programs and certification based on BS-ES-ISO. They provide PCN Level 1, 2, and 3 certification. They also conduct audits for the approval of AQB and ATO and also a periodical audit to check the quality of the training programs.

Keywords: Training, Certification, PCN, ASNT, AQB, ATO, ISNT

229-I

EXTENDED MAJOR TURN AROUND AT HEAVY WATER PLANT (KOTA) - A GREAT CHALLENGE

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Abstract

India through Heavy Water Board (HWB) is world's largest producer of heavy water and one of the heavy water exporting countries. Starting from a scarcity in 1970s, self-sufficiency in 1990s, indigenous development of heavy water technology has gone through various phases of transformation. All operating plants are subjected to appropriate health assessment strategies including In Service Inspection and Condition Monitoring techniques.

Heavy Water Plant, Kota, a constituent unit of Heavy Water Board under Department of Atomic Energy, employs bi thermal Water- Hydrogen Sulphide Chemical Exchange Process for production of Heavy Water. The plant has been in safe, sustained operation during the past twenty seven years due to the best Operation & Maintenance practices including regular condition monitoring & In-service Inspection. The plant has crossed its intended design life and opportunities were not available to inspect entire quantum of weld joints, wetted surface areasof all equipment and extensive inspection of piping network under insulation during regular ISI campaigns.

Hence, Heavy Water Plant, Kota conducted an Extended Major Turn Around after removal of entire trays from all exchange towers & protective pyrite film near welds to identify any incipient, hidden degradation. Since the criteria and jobs for health assessment vary with the changing age and operating conditions of the components, several conventional and advanced techniques such as Phased Array UT, Remote Visual Inspection etc, were adopted with qualified professionals. NDE examinations and mechanical testing of specimens of aged materials have established the integrity of equipment and piping. We have acquired a broad spectrum of inputs which has improved the confidence, assured components reliability & strong optimism for sustained future operation. This paper discusses the scope including planning, identification of techniques for assessment of ageing related degradation, challenges encountered, measures adopted for timely execution and salient highlights of the campaign.

*Keywords***:** Ageing, Health Management, Degradation, Techniques

230-I

ADVANCES IN INFRARED THERMOGRAPHICTECHNIQUES FOR NON-DESTRUCTIVE TESTING AND EVALUATION OF MATERIALS

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Abstract

Thermal infrared non-destructive testing is potentially a very useful technique for rapidly inspecting defects in large structures without any physical contact. This talk focuses on the fundamental factors limiting the usage of conventional thermal non-destructive testing techniques followed by recommendations for achieving high-contrast thermograms based on usage of various aperiodic thermal excitation schemes. Further emphasis is given to the feasibility of various aperiodic pulse compression favourable coded excitation schemes for thermal non-destructive testing and evaluation. Advantages and limitations of each technique are presented by taking the defect detection sensitivity and resolution as a figure of merit.

Keywords: aperiodic signals, pulse compression, non-destructive testing, thermograms

231-C

ROLE OF NON DESTRUCTIVE TECHNIQUES FOR MONITORING STRUCTURAL INTEGRITY OF PRIMARY CIRCUIT OF PRESSURIZED WATER REACTOR NUCLEAR POWER PLANT

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Abstract

The safety of nuclear installations is ensured by assessing status of primary equipment for performing the intended function reliably and maintaining the integrity of pressure boundaries. The pressure boundary materials undergo material degradation during the plant operation. Pressure boundary materials are subjected to operating stresses and material degradation that results in material properties changes, discontinuities initiation and increase in size of existing discontinuities. Pre-Service Inspection (PSI) is performed to generate reference base line data of initial condition of the pressure boundary. In-Service Inspections (ISI) are performed periodically to confirm integrity of pressure boundaries through comparison with respect to base line data. The non destructive techniques are deployed considering nature of the discontinuities expected to be generated through operating conditions & degradation mechanisms. The paper is prepared considering Pressurized Water reactor (PWR) Nuclear Power Plant. The paper describes the degradation mechanisms observed in the PWR nuclear power plants & salient aspect of PSI & ISI and considerations in selecting non destructive testing. The paper also emphasises on application of acoustic emission (AE) based condition monitoring systems that can supplement in-service inspections for detecting and locating discontinuities in pressure boundaries. Criticality of flaws can be quantitatively evaluated by determining their size through in-service inspection. Challenges anticipated in deployment of AE based monitoring system and solutions to cater those challenges are also discussed

232-C

GOLAY CODED THERMAL WAVE IMAGING FOR NON-DESTRUCTIVE TESTING AND EVALUATION OF MATERIALS

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Abstract

Infrared Thermography (IRT)has emerged as a valuable technique for non-destructive testing and evaluation of various solid materials due to its full-field, remote, fast and quantitative inspection capabilities to characterize their surface and sub-surface details. Among the widely used active IRT techniques, recently proposed pulse compression favourable aperiodic thermal excitation schemes gained a significant importance in thermal NDT community due to their improved test resolution and sensitivity. The attainable resolution and sensitivity are comparable with the results obtained from narrow duration high peak power thermal stimulus. This present work highlights the defect detection capabilities of recently proposed aperiodic pulse compression favourable Golay coded thermal wave imaging technique by considering the signal to noise ratio as a figure of merit.

Keywords: aperiodic signals, pulse compression, non-destructive testing, Golay codes

233-C

FREQUENCY MODULATED THERMAL WAVE IMAGING FOR NON-DESTRUCTIVE TESTING AND EVALUATION OF REINFORCED CONCRETE STRUCTURES

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Abstract

Reinforced concrete structures have a very long tradition as a building material mostly due to their low cost, availability of raw materials along with its high strength, robustness, sustainability makes them to use for construction of buildings, flyovers, nuclear power plants. However reinforced concrete has also some drawbacks with their poor tensile strength and ductility, which leads to formation of cracks in the structure. This creaks may cause penetration of chlorides which may lead to corrosion in the reinforcement. Among the various widely used non-destructive testing methods for testing reinforced concrete, Infrared Thermography (IRT)has emerged as a valuable technique for non-destructive testing and evaluation of reinforced concrete structures due to its full-field, remote, fast inspection capabilities to monitor the sub-surface rebar corrosion. This present work highlights the corrosion detection capabilities frequency modulated thermal wave imaging technique for health monitoring of reinforced rebar.

Keywords: frequency modulation, pulse compression, rebar corrosion, infrared thermography

234-I

TRENDS IN X-, GAMMA AND NEUTRON RADIOGRAPHIC IMAGING AT IGCAR KALPAKKAM

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Abstract

NDE plays a significant role in ensuring the quality, reliability and safety of components in strategic and core industries. In the nuclear fuel cycle, right from raw material stage through fabrication and in service inspection upto the retirement of the component, NDE is an indispensable tool. Conventionally, X- and gamma radiography have been widely used during component fabrication and also at preservice inspection stage. With the development of digital techniques digital industrial radiography using flat panel detectors and computed radiography are being used increasingly. In DAE, Indira Gandhi Centre for Atomic Research has pioneered the applications of digital radiography. Right from early 1990's X-ray sensitive vidicons and real time image inetnsifier based systems have been used for a variety of industrial and R & D applications. Today digital radiography using flat panel detectors and computed radiography for evaluation of welds and components is a regular affair. Extensive R & D has also being undertaken to study the effect of scattered radiation on contrast response of these systems.

While X- and gamma radiography is quite common, neutron radiography is a very efficient and complementary tool which can enhance investigations in the field of non-destructive testing as well as in many fundamental research applications. The main advantage of neutrons compared to X-rays is its ability to penetrate heavy elements and also image light elements (i.e. with low atomic numbers) such as hydrogen, water, carbon etc. This is because, neutrons interact with the nucleus rather than with the outer electron in the shell. This also makes it possible to distinguish between different isotopes of the same element by neutron radiography. The KAMINI reactor at IGCAR is a versatile and unique facility wherein extensive work has been undertaken on neutron radiography and activation analysis. Apart from conventional neutron radiography using transfer technique, real time neutron imaging of fuel pins and other objects have also been carried out. Using Beam purity indicator and sensitivity indicator, the neutron beam from KAMINI has also been characterized.

This paper focuses on the developments and applications of digital imaging NDE using X-, gamma and neutrons at IGCAR. Both 2-dimensional imaging and #D tomography has been undertaken. Case studies undertaken for strategic and core industries including societal applications such as in cultural heritage is also highlighted. Advanced image processing and analysis has also been applied for enhancing the sensitivity and better defect quantification.

235-I

INDIGENOUS PULSED X-RAY AND NEUTRON SOURCES FOR NON-DESTRUCTIVE MATERIAL CHARACTERIZATION

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Abstract

The pinch plasma devices such as plasma focus, x-pinches and z-pinches can serve as an intense, and powerful pulsed radiation sources. When used with deuterium with or without tritium, these devices can produce burst of neutrons of 14.1 or 2.45 MeV energy respectively. The advantage of such sources over conventional ones such as x-ray/ neutron tubes and isotope based systems is that they can be indigenously prepared in compact versions which are portable, cost effective and may be used for applications like x-ray lithography in microelectronics, x-ray back lighter for dynamics of moving objects and radiography of biological samples or non-destructive material interrogation if used with neutrons. These sources can be highly intense with short pulse width and also emit wide energy range of x-ray energies from soft to extremely hard.

Plasma focus device produces radiation by magnetic compression of hot dense column of plasma formed at the end of coaxial electrodes. By using suitable gas such as deuterium, nitrogen and argon, radiation of several types and different yields can be produced. The x-rays produced in the process are of tens of ns width and range up to hundreds of keV. When used as a fusion neutron source, it can be used to activate and characterize materials especially fissiles. The latter process has been utilized by us to assay fissile material like U-235 through delayed neutron and gamma emissions [1-2].

Using Fujifilm x-ray image plates as detectors for x-ray imaging, due to its sensitivity over wide range of energies up to hundreds of keV, a 11.5kJ plasma focus device with 24kV capacitor bank has also been used for radiography of objects of varying thickness. We have characterized the radiographic system in terms of important imaging parameters related to contrast, resolution and x-ray energy. The imaging parameters estimated are x-ray emission profile, spatial resolution of detection system and energy range by step wedge method and spot size using pinhole camera. The spatial resolution of the radiographic system has been estimated by analyzing the line and edge spread function of a thin (25 ì m thick) lead strip and resolution strip. The spatial resolution is found to be 147±10ì m.

Energy profile of x-rays has been estimated by filter transmission method. Aluminum and copper step wedges of step size 2 mm and 170 μm pasted at image plate were used for energy dispersed x-ray profile estimated from 8 keV to 34 keV and 8 keV to 50 keV coming through 2mm to 14 mm and 170um to 1.2mm Cu. The lower limit of 8 keV arises from 5 mm Perspex window used in the set up.

The x-ray spot size of plasma focus device has been measured by pin-hole camera of magnification ~1. The pinhole image of the source shows that a bright spot is formed at the centre, which could be the pinch region. Different samples of varying thickness such as BNC connectors, computer RAMs, and copper studs have been radiographed as also some samples placed inside metallic boxes.

The energy information of the source could be helpful for choosing the windows and filters to get better contrasts for samples of variable thickness. Under properly chosen diagnostics these devices can be used for radiography of fast moving objects.

Recently, other plasma pinch sources such as X-Pinch have gained significant attention as a source for radiography of low density plasma and thin biological samples because of its small source size (~μm), short pulse width (ns) [3]. Source size can besufficiently small underproperly chosen conditions so that it can be usedas an x-ray source for point-projectionradiography. A feasibility study has been carried out with the copper wire x-pinch using image plates. Radiographs have been generated using different thin foils of variable thicknesses to study the x-ray transmission.

All the above works with their prospective application shall be presented and discussed.

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236-C

ENHANCED INSPECTION CAPABILITY FOR SPECIFIC APPLICATIONS USING ULTRASONIC PHASED ARRAY

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Abstract

The advent of ultrasonic phased array equipment has revolutionised ultrasonic testing in many ways. This paper presents four specific applications where the development has enabled inspections that were difficult or impossible without this technology. In the first example the inspection of welds in polyethylene pipes and structures is shown. The second application shows a method for inspection of welded clad overlay of corrosion resistant alloys in pipes, the third shows the difficult inspection of aluminothermic welds in rail track, and finally the imaging of fatigue crack growth to produce parameters for crack growth calculations is given.

Keywords: phased array ultrasonic, polyethylene welds, clad overlay, fatigue cracks

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ULTRASONIC INSPECTION OF MOORING CHAIN FOR FATIGUE CRACKS

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Abstract

TWI assisted BP to confirm the integrity of a mooring chain of an FPSO in the chain stopper location which had been in service a number of years, and required an inspection technique that would give quantitative information. It was agreed that in order to be conservative the detectable flaw size with 90% probability of detection should be 20mm through wall and 100mm long.

The restrictions for the inspection were that it had to be carried out in 15m depth of water inside the turret structure, with no demanding tasks on the diver such as probe scanning because of the difficult water conditions.

This paper describes the development of the inspection technique and equipment, from concept to mobilisation on site, and some of the results of the inspection. It also describes the expected future challenges for mooring chain inspection and some recent results using phased array ultrasonic.

Keywords: mooring chain, FPSO, ultrasonic, probability of detection

238-P

DEVELOPMENT OF A PULSED EDDY CURRENT METHOD FOR CORROSION DETECTION IN PIPEWORK

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Abstract

Corrosion under Insulation and Scab corrosion are perennial risks of failure in the oil and gas industries. Pulsed Eddy Current methods in various forms have been investigated for inspection for these flaws. This paper describes the development, from concept, modelling and equipment development of a pulsed eddy current method using an encircling coil to enable a more rapid inspection of pipework. Some results from laboratory tests are included.

Keywords: scab corrosion, pulse eddy current

239-C

REVIEW ON STRUCTURE PROPERTY CO-RELATION IN BIOCOMPOSITES / BIONANOCMPOSITES MATERIALS BY NON-DESTRUCTIVE EVALUATION.

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Abstract

Abstract: Polymer composites/Nanocomposites especially bio composites have an increased stiffness and increased strength to weight ratio compared to traditional materials like metal and ceramics. The commercial importance of polymers has derived intense applications in the form of composites in various fields viz. in packaging, aerospace, automotive, marine, infrastructure, military etc. [1-6]. A composite consists of two or more physically distinct and mechanically separable constituents. When one of these constituents is dispersed in the other, the new material achieves superior properties compared with the individual components. Conventional composites are typically reinforced by fillers with dimensions at the ì m or mm scale. Biocomposites or bionanocomposites are composite materials comprising one or more phase(s) derived from a biological origin and also one dimension in nanometric level. Biocomposites materials present specific features, mainly due to their very high interfacial area, and a very short distance between reinforcing particles surface. For polymer based bicomposites, reinforcing fiber/agricultural resources most of the time much stiffer than the matrix. In that case, the percolation of those particles which occurs at a threshold fraction which depends on their shape factor (and on their dispersion characteristics) is shown to play a drastic role, especially if they form a rigid network. Such a network may result from strong interactions between the surfaces of the dispersed filler, but softer network may appear if the filler are bound together through the interactions of their surface with polymer chains. This review paper will clearly explained the interfacial behavior of the bionanocmposites by nondestructive way to give an idea about structure property relationship as well as failure mechanism.

Keywords: Biocomposites, Nanocomposites, filler

240-I

HIGH TEMPERATURE CHALLENGES IN INFRARED THERMOGRAPHY

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Abstract

Industry is increasingly deploying Infrared thermography as a reliable non-destructive technique thanks to advances in technology and improved understanding. Two central issues that continue to be challenging for quantitative assessment, particularly at high temperatures, are the determination of temperature and the emissivity of the surface under investigation. At high temperatures, specimen's emissivity data is either unavailable, or difficult to measure. Changes in the specimen's thermodynamic state/phase, changes in specimen's surface conditions such as oxidation, harsh environments make the task more difficult. We present recent developments to tackle these twin issues with specific references to availability of high temperature black bodies, approaches involving multi-wavelength radiometry and attempts to model emissivity.

241-C

MICROSTRUCTURAL CHARACTERIZATION OF TI-6AL-4V USING ULTRASONIC ATTENUATION AND ITS CORRELATION WITH MECHANICAL BEHAVIOR

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Abstract

Various microstructures namely lamellar, bimodal and equiaxed can be obtained in titanium alloys as a result of different heat treatment procedures. The mechanical properties of titanium alloys are mostly dependent on its different microstructural features. Bimodal microstructure of titanium alloys is generally exploited in making almost every industrial parts or components used for the aerospace and automobile industries. Ultrasonic examinations have been carried out at room temperature to correlate the microstructural variation of Ti-6Al-4V alloy with that of ultrasonic parameters. Microstructural variation in terms of different volume fraction of primary alpha phase of Ti-6Al-4V alloy has been introduced as a result of solution annealing at different temperatures followed by thermal ageing. Attenuation coefficient has been found to decrease from the content of 10% primary alpha phase to 20% primary alpha phase and then the same is increasing from the content of 20% primary alpha phase to 30% primary alpha phase. Ultrasonic attenuation coefficient strongly depends on both beta grain size effect and alloy element partitioning effect; which has been found to be the lowest at the content of 20% primary alpha phase. Tensile test for various samples of Ti-6Al-4V alloy containing different volume fractions of primary alpha phase has been carried out and the results of tensile test are also correlated with the parameters of ultrasonic measurement. Results indicate that ultrasonic measurement could be successfully used to assess the microstructural variation of Ti-6Al-4V alloy resulted due to solution annealing at different temperatures followed by thermal ageing.

242-C

SORTING OF ID AND OD FLAWS DURINGTHE ULTRASONIC TESTING OF PRESSURE TUBES OF PHWR

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Abstract

Nuclear Fuel complex (NFC) Hyderabad is only organization for manufacturing and supply of pressure tubesfor Pressurized Heavy Water Reactors (PHWR) in India. The integrity of pressure tube is critical throughout its design life of 30 years since it operates under high temperature, high pressure and also are subjected to fast neutron fluence. . Pressure tubes for 700 MWe PHWR of dimensions 112.70 (OD) X 4.30 (WT) were manufactured from extruded blanks of size 119mm (OD) x 6.0 mm (WT) by cold pilgering process. The inspection of pressure tubes is very critical during every stage of manufacturing and in order to meet the stringent requirements, various quality control and NDE techniques were employed such as eddy current testing, visual inspection and Ultrasonic testing.

The blanks are ultrasonic tested to ensure freedom from defects before pilgering and the 20% cold worked pilgered tubes are again ultrasonic tested to ensure soundness requirements of the finished product. In both the cases, ultrasonic testing is done by immersion technique by passing each blank / tube through six channel examination for detecting longitudinal flaws(2 channels), transverse flaws (2 channels), Normal beam channel for lamination flaw (1 channel) and continuous wall thickness measurement (1channel) the output being recorded on strip chart recorder. In case of L &T defects, chart records the indications irrespective of defect location, i.e ID or OD. In order to condition the defects, extensive visual inspection has to be carried out on OD which is laborious and the visual defects were conditioned. ID defect conditioning was carried out based on Chart records. In the absence of clear visual indications it was difficult to assess location of defect (OD/ID). This resulted in number of retesting followed by reworks.

In order to reduce the iterations of testing and reworks a novel method was introduced to separate OD & ID flaws which can be recorded on the chart. Here ,the probes were realigned to increase the angle of incidence and water path distances to sort both OD and ID flaws signals. The repeatability of flaws with modified method was validated by testing number of tubes in standard method also. The modified method, resulted in substantial reduction in iterations of testing and reworks thereby increasing the output. This paper brings out the details of novel method for testing tubes.

Keywords: PHWR, Pressure Tubes, Calibration, ID flaws, OD flaws and Ultrasonic Testing.

243-I

NDE SENSORS: ADVANCES, CHALLENGES & SOLUTIONS

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Abstract

The industrial world continues to demand greater efficiency and effectiveness from the inspection processes using Nondestructive Evaluation (NDE) techniques. NDE sensors form the heart of any inspection system and could be one of the most important contributors to effective and reliable inspections in the industrial world. One important and frequently adopted approach by researchers in the NDE community is to innovate in the NDE sensors area.

The industrial world of engineering structures and components is reasonably complex and extremely broad in terms of materials used, shapes, designs, defects to be detected, operating conditions, etc. The reasons for focusing on the sensors side is multifold; most important being the fact that in the entire system, it is the closest in proximity to the object being inspected and thus can contribute significantly. In addition many of the advances taking place in a host of enabling technologies such as electronics, communication, signal processing, computers, manufacturing, modeling/simulation tools, etc, have accelerated and motivated the design and development of new NDE sensors which can meet today's tough demands. A snapshot view of sensor advancements and requirements in NDE indicate that some of the big trends in today's world include arrays, miniaturization, harsh environment, flexible, embedded, wireless, new materials, hybrid and multi-sensor systems, self-calibration, sensor networks and many others. This desire in NDE sensor innovation is primarily driven by the increasing demand for improved sensitivity, ability to reach difficult to access places, faster inspection throughput, retain / improve inspection reliability, ability to do remote monitoring and their longevity in extreme environments.

This paper discusses some of the evolutionary traits and advances in the world of NDE sensors for some of the important modalities such as ultrasound, electromagnetic, x-ray, visual/optical etc, its current status and the direction it is proceeding in the future. Examples of practical utilization and deployment of some new and advanced sensors will be illustrated to spell out the upcoming scenarios in this area. The paper will also highlight the important challenges lying ahead for the world of NDE sensors.

244-C

MICROWAVE NDE : AN EMERGING TECHNIQUE FOR INSPECTION

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Abstract

The search for newer and more advanced Nondestructive Evaluation (NDE) techniques is a constant endeavor in the industrial world due to a variety of reasons including introduction of newer materials, design complexities, stringent and more demanding defect detection and characterization requirements. In the world of electromagnetic NDE, having matured the eddy current NDE technique, the move is towards exploring the higher frequencies in the electromagnetic spectrum (GHz and THz). Microwave NDE has been gaining a lot of attention in the last decade as a potential tool for inspection of various materials especially dielectrics like plastics, ceramics, composites, etc. Some of the characteristics of this technique such as non-contact, portable, fast, imaging capability, etc, make this an attractive option to be explored seriously as an advanced NDE tool.

This paper will discuss the physics of this technique followed by some of its practical applications including the challenges to make it a widely used methodology in the industry. Preliminary results obtained with studies on composites using different types of sensors will also be discussed.

245-P

MULTI-FREQUENCY APPROACH FOR ACCURATE THICKNESS MEASUREMENT OF STEAM GENERATOR TUBES AT GROOVES USING REMOTE FIELD EDDY CURRENT TECHNIQUE

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Abstract

Steam Generators (SG) are an integral part of the Prototype Fast Breeder Reactor (PFBR). The NDE in-service inspection (ISI) of SG tubes is a particularly challenging task due to time and space constraints. Earlier, robust technique has been established where Radial Basis Function Neural Network (RBFNN) based scheme that predicted the thickness of the tube. However, this approach is insufficient in estimating wall thinning at grooves which are much smaller than probe spread as the RFEC phase is non-linearly influenced by other factors of the groove.

In the present work, the influence of length of the grooves on estimating the depth has been studied in detail. Based on the studies a new non-linear parametric model for estimation of groove depth has been proposed. The non-linear model is developed with the aid of a data set (training set) of RFEC phase signatures from a number of grooves whose length and depth are known. The non-linear parametric model is validated by an evaluation set which is non-redundant and independent with respect to the training set. The training and evaluation data sets have been generated by extensive FE modeling. The proposed nonlinear parametric approach provides accurate estimation of the depth of grooves with a maximum absolute error of $\pm$**0.03** mm. In addition, it also resulted in the simultaneous estimation of groove length. Further work is planned to extend this approach for sizing three dimensional volumetric defects in ferromagnetic SG tubes.

Keywords: RFEC, SG tubes, thickness, RBFNN, non-linear parametric, FE modeling.

246-C

DETERMINATION OF SENSITIVITY AND SATURATION LIMIT OF PHOSPHOR IMAGING PLATES FOR PHOTON ENERGIES UP TO 1.25MEV

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Abstract

Image plates (IP) based on Photostimulable x-ray storage phosphor BaFBr:Eu^{2+} are an alternative to conventional 2-dimensional detectors such as X-ray film. The incident ionizing radiations get absorbed in the phosphor and electron-hole pairs are generated. A fraction of the e-h pairs are trapped separately, holes at divalent Europium sites, electrons at F^{+} and Br^{+1} vacancy sites. The concentration of trapped centers is proportional to the absorbed X-ray energy and forms the latent image. The latent image stored on the IP can be read out by irradiating the IP with He-Ne laser (ë=633 nm). The laser excites trapped electrons to recombine with Eu^{3+}. The decay of Eu^{3+} to Eu^{2+} causes the emission of photons ë=400 nm). The process is called photostimulated luminescence (PSL). A photomultiplier tube collects the PSL intensities. The resulting signal is converted and stored as a digital image and displayed on a monitor. After reading, the IP is exposed to strong visible light to erase the residual image and it can be reused. Sensitivity calibration of imaging plates (IP) is important for quantitative measurements of intensity data obtained in various X-ray and gamma radiography experiments. To test the sensitivity of the IP (BAS2025) with the scanner (BAS5000) for higher photon energies, we have performed gamma exposure experiments using radionuclides (Co-57, Ba-133, Cs-137, Na-22 and Co-60). This provides useful information in assessing the intensities and dose received on IP in radiography especially with flash X-rays in the range 250keV to 1MeV. The IP was

exposed for prolonged time to determine the saturation dose limit. The observed photon sensitivity was measured as 1.310 x10^{-4} PSL/photon for 114 keV, 7.416 x 10^{-4} for 266 keV, 1.753 x 10^{-4} for 662 keV, 4.493 x 10^{-5} for 784 keV and 5.178 x 10^{-5} for 1250 keV. The PSL intensity increases linearly up to 8x10^{3} with dose received. With further increase in dose the intensity goes nonlinear till it gets saturated at ~9070 PSL. Both the sensitivity and the saturation dose are dependent on the photon energy. The observed photon sensitivities were found to be consistent with a simulated model proposed by N. Izumi et al (2013).The information deduced from the calibration of the SR2025 IP is used in assessing the dose from flash X-ray sources designed and commissioned at our centre using the industrial pinch diode and accelerator based high voltage pulse power systems. The details of the experiment for performing exposure, calibration and the results are given in this paper.

Key words: Photostimulated Luminescence, Phosphor imaging plate. SR2025, Radionuclide, Saturation dose, Flash X-rays

247-C

ROLE OF NDE IN REGULATORY OVERSIGHT OF NUCLEAR POWER PLANTS

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Abstract

Atomic Energy Regulatory Board (AERB) was constituted in 1983 to carry out regulatory and safety functions for independent assessment of safety status in all the stages of nuclear and radiation facilities. Quality of safety related systems, structures and components (SSCs) of nuclear power plants (NPPs) plays crucial role in achieving the specified safety objectives. Non-destructive examinations (NDE) of the NPP components is one of the important means to determine their quality.

AERB carry out safety review of pre-service inspection and in-service inspection (PSI/ ISI) program of NPPs to check adequacy of coverage of SSCs for inspection, suitability of specified NDE technique, inspection procedures, frequency and competence of inspection personnel. AERB ensures implementation of PSI/ISI programme by conducting safety review and regulatory inspections, prior to issuance/ renewal of regulatory consent.

NDE of safety related SSCs of NPPs is carried out during different stages of manufacturing in accordance with approved Quality Assurance Plan (QAP) and complying with the specified requirements given in applicable Codes/ Standards. Baseline data is generated for all the safety related SSCs by implementing the PSI programme. During operation stage of NPPs, status of the safety related components is monitored by carrying out in-service inspection (ISI) using the same NDE methods as those of PSI and results are compared with the baseline data for assessment of service induced degradation.

This paper also covers certain challenges faced during review and assessment of the adopted NDE approach for SSCs of different NPPs

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CAREER PROSPECTS IN QA AND NDE INCLUDING CERTIFICATION SCHEMES FOR STUDENTS AND RESEARCHERS

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Abstract

Non-destructive Examination (NDE) plays an important role in deciding the acceptability of a component, whether new or in use. Different NDE Methods / Techniques are evolved over a period of time and they are getting more and more refined to give the ultimate reliability of the product and systems. It also assists in ensuring a safe and reliable operation of plants and machinery. NDE, Quality Control (QC) and Quality Assurance (QA) measures are critical to the daily functions of many companies. These tests and analytical procedures are necessary to ensure safety and reliability for a company, its people and its products. Motor vehicles, aircraft, bridges, power stations, trains, pipelines, oil platforms and refineries, Nuclear Plants, Space launching vehicles are all inspected using Non-destructive Examinations. The different methods generally used in NDE are Visual Testing (VT), Liquid Penetrant Testing (PT), Magnetic Particle Testing (MT), Radiographic Testing (RT), Ultrasonic Testing (UT), Eddy Current Testing (ECT), Leak Testing (LT). The more sophisticated methods like Thermography, Vibration Analysis, Neutron Radiography, Laser Testing are also increasingly used.

Qualified Manpower, Calibrated Machines and Correct Procedures are the basic parameters for any ND Examination to be effective. The qualification of manpower is based on the 5 basic steps namely, Education, Experience, Vision Test, Training and Certification Examination. Once qualified and certified, the individual can enter in the NDE career and can progress. As NDE technology areas are fast growing and continuously developing, one has to keep himself updated and keep on learning continuously.

NDE is an old profession. QA/QC and manufacturing are two sides of the same coin. NDE is an inseparable part of QA as decisions of QA are based on information gathered from NDE and other such methods. Especially, in-service inspection is fully dependent on NDE. Thousands of engineers, technicians, consultants and supervisors have been working for years in this field as their main profession. This career offers a new challenge daily, due to its dynamic nature. It always keeps us on toes due to the ever changing technology and increasing scope and requirements. Needless to say, as a main career, it is also a financially rewarding profession.This paper is taking a stock of different NDE methods and techniques, various certification schemes with their specialities and the Career opportunities in QA and NDE.

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RADIATION PROTECTION IN INDUSTRIAL RADIOGRAPHY APPLICATIONS

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Abstract

The application of industrial radiography has grown tremendously in the last few decades in the country. The method utilises radioactive sources such as ^{60}Co, ^{192}Ir, ^{75}Se of activity typically in the range of 2 TBq to 4 TBq housing in industrial radiography exposure devices (IREDs) as well as electrically operated devices such as X-ray machines, linear accelerators (LINAC) and Betatron. In industrial radiography practice, there is always high probability of occurrence of unusual incidents leading to the potential human exposures, if IREDs are not handled as per the Standard Operating Procedures (SOP) and stored securely when not in use.

In late 1960s, radiography devices were designed in such a way that sources were operated manually by radiography personnel using remote tongs. Subsequently, the shutter operated type devices using a collimated radiation beam were developed. A series of these exposure devices namely IRC-1, IRC-2 and IRC-4 with a source capacity of 8-20 Ci were supplied to industries until the year 1990. In view of the several reported incidents such as of theft, excessive exposures, radiation injuries, these exposure devices were discontinued in 1994. The first indigenous remotely operated radiography exposure device model ROLI-1 was designed, manufactured and introduced in the market in1992. After the introduction of remotely operated radiography devices in the country (indigenous or imported), the dose to radiography personnel was substantially reduced.

For ensuring trained and certified personnel, adequate number of training courses are being conducted based on the minimum qualifications and syllabus prescribed by Atomic Energy Regulatory Board (AERB). About 15-20 courses for radiographers (Radiography Testing (RT)-1) and 5-6 courses (RT-2) for Safety Site-In-Charges / Radiation Safety Officers are conducted every year, which generates about 300 trained and certified radiography personnel annually.

The overall radiation protection in industrial radiography practices has been significantly improved due to the evaluation in the design of IREDs which is compact and inherently safe, availability of adequate number of trained radiography personnel, withdrawal of AERB non-type approved radiography devices and also the effective regulatory control over this widespread industrial application.

250-C

ACOUSTIC EMISSION MONITORING DURING PROOF PRESSURE TESTING OF A SOLID ROCKET MOTORS

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Abstract

In Indian Space research organization, Solid rocket motor cases such as S139 and S200 is being used for Polar Satellite Launch Vehicles and Geosynchronous Satellite Launch VehiclesMKII and MKIII asa coreand boosterstage respectively. These motor cases are realized from high strength high alloy (HSHA) steel. After completion of fabrication, ageing, and machining of motor-casing, a Proof Pressure Testing(PPT) using oil mediumis used to qualify the structural integrity as well welding of the hardware at supplier's site. During proof pressure test, Acoustic Emission (AE) monitoring was being carried out. Due to welding/repair welding during the fabrication process, the presence of flaws that can grow during PPT pressurization cannot be ruled out. Online acoustic emission monitoring as a NDE tool is being used to identify the presence of any active defects and its location.

To eliminate the extraneous noise during pressurization, hydraulic pumps are kept away from the hardware.

During PPT, step wise increase in pressure was monitored from near 0 to 66 ksc (atmospheric)in the steps of 10-20-10-20-30-40-50-63-66 with 1 min. hold at each pressure hold from 10 to 63 ksc and 2 min. hold at 66 ksc (proof pressure). After this, motor case was suddenly depressurizedwithin 5 seconds(max.) from 66 to 40 ksc to arrest the micro cracks. Acoustic signals were recorded during each pressurization and hold period also.

A Disploc AE system with AE win software was used to carry out the test. 20 nos. typical R15D type acoustic sensors(range 0 to 100dB max.) were used to pick up the acoustic signals during the PPT. The sensors were mounted on the hardware with the help of the magnetic clamps and acoustically coupled to the job using high vacuum silicon based grease. The sensors were connected to the preamplifiers having 40dB gain, which in turn provided input to the Disploc system. Transient data was also recorded to the differentiate and eliminate spurious

signals and also for AE parameter settings. Before carrying out the actual test, background noise analysis was done and 40 dB threshold was applied in software.

Presence of the active flaws, if any, was observed during the pressurization and holding cycles of the test. The population of the hits, events and counts from alllocation/regions was monitored and compared with set acceptance criteria for any violation. As a result of the acoustic emission activity observed during the PPT, acceptance of the hardware is subject to subsequent UT examination for flaw detection and sizing.

The paper describes details of the acoustic emission monitoring carried out during proof pressure test of S139/ S200 solid motors.

251-C

ELECTROMAGNETIC NON-DESTRUCTIVE EVALUATION OF RESIDUAL STRESS IN ULTRA LOW CARBON STEEL SUBJECTED TO FATIGUE

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Abstract

Residual stress in steels plays a vital role in the service life of engineering components. During industrial processing of materials through machining, grinding etc, residual stresses are generated which have to be annihilated through suitable heat treatment to avoid catastrophic failures during fatigue, stress corrosion cracking etc. However, there are applications wherein compressive residual stresses are induced in materials which are exposed to fatigue cycles during their service life. In many engineering components residual stress is induced in steels through shot peening so as to enhance the fatigue life of the component in service. Assessing the influence of fatigue on residual stress is of paramount importance for structural health monitoring (SHM) of industrial components. Various non-destructive evaluation (NDE) methodologies are being adopted for the evaluation of residual stress in steel subjected to fatigue.

The present investigation addresses the effect of residual stress on high cycle fatigue behavior of ultra low carbon steel as observed using electromagnetic non-destructive technique. The steel was subjected to industrial shot peening process at selected Almen intensities. Non-destructive evaluation of shot peened steel was carried out by magnetic Barkhausen emission (MBE) technique using an electromagnetic sensing device *MagStar* developed by CSIR-National Metallurgical Laboratory, Jamshedpur in collaboration with M/s. Technofour, Pune. MBE studies using *MagStar* revealed compressive nature of residual stress induced in the steel. This was also validated by x-ray diffraction technique. An interesting transition of compressive to tensile stress is observed through depth profiling of shot peened steel with respect to MBE and XRD signals. The different span of shot peening time induced various levels of compressive stresses which also affected the mechanical hardness. Interrupted fatigue test was carried out on shot peened samples at a constant load of 12KN with subsequent x-ray diffraction and MBE measurements. Three distinct stages of residual stress variation with fatigue life were observed from the variation in these signals. Transition from stress relaxation stage to generation of cell structure through dislocation tangles were revealed from changes in the *MagStar* sensor output at different stages of fatigue life till failure. The study indicates the potentiality of magnetic sensing device for periodic assessment of engineering components with designed compressive stresses and the consequent change in the sensor output during fatigue life.

Keywords: Residual stress, Shot peening, Fatigue, Magnetic Barkhausen emission, X-ray diffraction.

252-I

IMPROVED INSPECTION OF CRA-CLAD PIPE WELDS WITH OFF-THE-SHELF ULTRASONIC PHASED-ARRAY TECHNOLOGY

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Abstract

CRA-clad pipes are increasingly used for the transport of hot and corrosive materials, as cladding provides a higher resistance to degradation caused by corrosion. Because of the nature of the corrosion resistant alloys (CRA) used for clad pipes, the inspection of the resulting dissimilar girth weld poses a particular challenge, to which the petrochemical industry has been searching for a simple and reliable solution.

Olympus has developed tools to increase the capacity for detection and sizing of flaws located at the root, in the volume, and on the surface of the dissimilar weld. These tools include dual matrix and dual linear array probes combined with off-the-shelf ultrasonic phased array instruments and software, all packaged in a friendly and accessible manner.

This paper presents how accessible advanced ultrasonic phased array technology contributes to the improved integrity of CRA-clad pipes used in infrastructures as pipelines, LNG and refineries.

253-I

APPLICATIONS OF ULTRASONIC PHASED ARRAY TECHNIQUE DURING FABRICATION OF NUCLEAR TUBING AND OTHER COMPONENTS FOR THE INDIAN NUCLEAR POWER PROGRAM

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Abstract

Ultrasonic phased array technique has been applied in fabrication of nuclear fuel and structurals at NFC. The integrity of the nuclear fuel and structural components is most crucial as they are exposed to severe environment during operation leading to rapid degradation of its properties during its lifecycle. Nuclear Fuel Complex has mandate for the fabrication of the nuclear fuel and core structurals for Indian PHWRs/BWR, sub-assemblies for the PFBR and steam generator tubing for PFBR and PHWRs which are the most critical materials for the Indian Nuclear Power program. NDE during fabrication of these materials is thus most crucial as it provides the confidence to the designer for safe operation during its lifetime. Many of these techniques have to be developed in-house to meet unique requirements of high sensitivity, resolution and shape of the components. Some of the advancements in the NDE during the fabrication include use of ultrasonic phased array which is detailed in this paper. Following applications have been explored

- Integration of phased array system in high speed ultrasonic testing (tube rotating) system. With this system test speeds upto 4m/min has been demonstrated on stream generator and D9 clad tubes.
- Use of ultrasonic phased array for defect detection and visualization in thin wall stainless steel tubes of D9 material. For establishing of the source of defect, the visualization of defect location using curved phased array probe is extremely helpful.
- Use of ultrasonic phased array for characterization of defects in the Zircaloy rods close to OD surface. Such defects result in the helium leak during plug welding.
- Use of ultrasonic phased array for testing of tubes by replacing 3 conventional probe with single phased array using multi salvo technique.

- Ultrasonic testing of PHWR end cap welds using ultrasonic phased array. This has an advantage of defect sizing which is highly difficult in the conventional single element system.
- Improving the sensitively of immersion ultrasonic testing of small diameter thin wall clad tubes by use of phased array with a FBH in place of conventional notch.

In addition to the above, the conventional ultrasonic tube testing techniques have been improved in test speed with automation, better repeatability by improvements in mechanical design and vibration corrections, real time digital data acquisition and recording systems etc. An overview of this is provided in this paper.

254-I

NON-LINEAR ULTRASONIC FOR DAMAGE ASSESSMENT OF IN-SERVICE COMPONENTS: AN APPROACH AT CSIR-NATIONAL METALLURGICAL LABORATORY

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Abstract

CSIR-NML has been active for the last two decades on structural health monitoring and remaining life assessment of materials in the power plant, petrochemicals and steel industries through both microstructure and mechanical property evaluation as well as non-destructive evaluation (NDE). Over the years, CSIR-NML is pursuing focused application oriented research in NDE for diverse components like aerospace, defence, power and steel sectors. Need based development of NDE sensors and techniques for specialised applications are also the integral part of the activities.

In recent years, realising the potential of Non-linear ultrasonic (NLU) for the assessment of progression of damage in structural materials, CSIR-NML has initiated activities in the area of NLU from 2006 onwards. Applications of NLU to assess the most prominent damages in industrial components like fatigue, corrosion and creep are one of the niche research areas of CSIR-NML. An attempt has also been initiated to develop damage predictive model based on NLU parameter.

NML has developed a portable, site worthy NLU device (**Ultra?**) that can be used to monitor the damage of in-service structural components. Moreover the device comes with a software cal? that can measure NLU parameter online after calibration.

This presentation will highlight our activities on fatigue and creep damage evaluation using non-linear ultrasonic.

255-P

A STUDY ON RESIDUAL STRESS DISTRIBUTION IN THE DISSIMILAR METAL ELECTRON BEAM WELDMENTS OF ULTRAHIGH STRENGTH STEELS

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Abstract

Ultrahigh strength steels are now being extensively used in many high technology applications in aerospace and defence arenas. Ultrahigh strength coupled with excellent toughness, high reliability and high performance with minimum weight makes these steels an excellent choice for many of the applications. Maraging steel and medium

alloy medium carbon steels are among such class of ultrahigh strength steels which are employed in the present work. Many of the applications demand use of dissimilar combinations so that the specific properties of the individual materials can be utilized efficiently.

One of the major fabrication routes of these steels is welding process in general and fusion welding process in particular. In the present work, electron beam welding process is employed as it is characterized by short interaction time with intense energy density, greater control and higher joint completion rates.

The problems generally associated with fusion welding of dissimilar metal welds are compositional variations in the welds leading to large residual stresses and inadvertent changes in mechanical properties. Welding residual stresses come into existence due to the non-uniform expansion and shrinkage during the thermal transient of the welding process. An attempt is made in the present work to study and understand the residual stress distribution in dissimilar metal electron beam weldments. As the steels employed in this work exhibit their best properties in their respective heat treated condition, an attempt is also made to study the influence of post-weld heat treatment on the residual stress distribution.

It is revealed that in the dissimilar welds the nature of residual stresses in the weld varied from compressive in maraging steel to tensile in medium alloy medium carbon steel. The magnitude of residual stresses decreased when the maraging steel is taken in soft solutionised condition in dissimilar welds. Post-weld aging resulted in lowering of the residual stresses.

256-I

FULL MATRIX CAPTURE, TOTAL FOCUSING METHOD AND PHASED ARRAY TECHNOLOGY

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&

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Abstract

Total Focusing Method is known for about 10 years. This technique uses Full Matrix Captured ultrasonic data which is transmitted and received from several incidence points within the same phased array probe. This data yields an ultrasonic image of very high resolution. This technique has been recently made available in portable Phased-Array Ultrasonic Instrument. Portable industrial equipment with full-parallel capabilities are now handling of matrix-array probes, 3D imaging and advanced techniques for optimal focusing. Total Focusing Method, a reconstruction based technique, is discussed: it allows better sizing of the defects during inspections, a clear detection of small defects and defect characterization using mode conversion or corner effect modes. Moreover, real-time adaptive inspections associated to Total Focusing Method have been implemented to take into account the variability of the examination surface. During the presentation, results of inspections are presented for industrial relevant applications (Corrosion, HTHA, Porosity detection, crack detection and sizing in welds, blades examinations…). The advantages, drawbacks and the complementarity of different techniques (TFM, Electronic scanning, sectorial scanning…) will be discussed.

257-I

DEVELOPMENTS IN ULTRASONIC IMAGING FOR NDE

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Abstract

Ultrasonic inspection has migrated from point measurements to area scanning and the results are now often presented in form of images rather than raw A-scan signals. Various ultrasonic methodologies developed by the author towards ultrasonic imaging incorporating advanced techniques such as synthetic aperture focusing technique, phased array ultrasonics, time-frequency based analysis, and 3D visualization of objects are presented in the paper. In sodium cooled fast breeder reactors, ultrasonic imaging is the only possible mean of viewing the components submerged in opaque sodium. The methodology developed and results obtained for 3D imaging of objects submerged in sodium will be presented. Specific methodologies and signal analysis approach developed for under sodium ultrasonic imaging for detection of protrusion of subassemblies in Prototype Fast Breeder Reactor (PFBR) will be discussed. Development of a one tenth model of PFBR core for experimental simulation of, under sodium ultrasonic imaging based on a detailed CIVA simulation will also be presented. The orientation of ultrasonic transducer is crucial in deciding the quality and significance of the image generated. An innovative methodology developed for the assessment of misorientation of an immersion ultrasonic transducer by imaging of a retro-reflector will also be presented. Additionally, imaging of microstructure, deformation and damage in metallic materials using ultrasonic techniques will be discussed. Ultrasonic based imaging of elastic stiffness and damping at submicron scales using atomic force acoustic microscopy will also be presented.

258-P

ANALYSIS OF REPORTED EXCESSIVE RADIATION EXPOSURE IN INDUSTRIAL RADIOGRAPHY PRACTICE – MEASURES FOR MINIMIZING GENUINE AND NON-GENUINE CASES

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Abstract

Introduction: The Atomic Energy Regulatory Board (AERB) has issued the Directive dated April 27, 2011 prescribed for the cumulative effective dose for radiation worker over a successive five years shall not exceed 100 mSv (i.e. average 20 mSv in a year) and shall not exceed 30 mSv dose in any calendar year. The equivalent dose to the extremities shall not exceed 500 mSv in a calendar year. To review the work procedure and to ensure that radiation dose to the workers do not exceed the dose limit, dose constraint of 10 mSv in a given monitoring period (i.e monthly for industrial radiography) is recommended. If the dose recorded by the personnel monitoring badge of the personnel exceeds any of the level mentioned above, the Radiological Safety Officer (RSO) of the institute need to submit an investigation report with a statement from the personnel reported to be excessively exposed, to AERB. The investigation report is further reviewed & evaluated at Radiological Safety Division (RSD), Atomic Energy Regulatory Board (AERB) and the genuineness of the dose received by the personnel is decided based on the report submitted, inspection at the site, interview with the individual exposed etc. Most of the cases, it is tried to reconstruct the situation and assessment of dose is carried out based on the information gathered. In case the reported dose is greater than 100mSv, the biological dosimetry i.e. chromosomal aberration (CA) test report of the individual is also considered to determine the genuineness of the dose.

Materials and Methods: Industrial radiography involves handling of sources in open field and always sources have to drive out from the device during radiation exposure. Therefore, industrial radiography has potential to

cause excessive exposure (EE) for radiography personnel. Based on the experience gained by reviewing reported excessive exposure of industrial radiography personnel handling radiography exposure devices, the common reason for excessive radiation exposure to radiography personnel as well as non-genuine cases where only the personnel monitoring badge got exposed has been brought out in this paper.

Results and Discussion: Following are the main reasons observed for exposure to radiography personnel

- Radiography work carried out at height with temporary scaffolding with minimal clearances available. Due to this, operators couldn't provide the necessary distances to avoid unnecessary exposure. Additionally, if the exposure time is less, operator remains in the scaffolding where the radiography exposure device is placed until the exposure is over.
- Handling of un-usual incident involving radiography sources. Such incident involves the source stuck in the guide tube due to sharp bending, fall of radiography device in exposed condition from a height, detachment of the source pencil or pig tail from the control cable etc. due to improper maintenance of exposure devices.
- Non utilization of collimators wherever feasible
- Work pressure on the radiography personnel. Sometime carrying out radiography work in adverse climatic condition.
- Non-use of radiation survey meter after radiography work or use of faulty survey meter
- Accidental entry to the radiography enclosure during radiography work
- Handling of radiography devices by trainee independently without the surveillance of certified radiographer or RSO.

Following are the reasons observed for non-genuine case where the Personnel Monitoring Badges only got exposed.

- TLD fell down in the work area during the preparation of radiography procedure.
- The kit containing TLDs mistakenly placed in the work area.
- Shirt on which TLD clipped has forgotten in the work area.
- Deliberate exposure of the TLD due to personnel rivalry.
- Improper storage of TLDs after its use like inside enclosure, in the tool kit etc.
- Use of TLD badges continuously for few months due to financial constraints of the institution.

Conclusion:

Undue exposure to radiography personnel increases probabilistic risks to them and on the other hand, non-genuine reported exposure cases waste the time and effort of the RSO, licencee and the Regulator for investigating the cases. Following are the some of the points may be considered by the users of radiography exposure devices to minimize the excessive exposure cases

- Standard operating procedure of each radiography devices should be provided to the operator.
- Awareness among the Radiography Personnel regarding handling of Personnel Monitoring badge should be provided by the RSO.
- Site specific emergency handling procedure should be established and the same should be implemented while handling any kind of un-usual incident involving radiation source.
- Handling of radiography exposure devices by trainee radiography personnel in radiation safety shall be avoided.
- Use of safety tools and monitoring instruments while handling radiography devices should be ensured.
- The storage of Personnel Monitoring badge in radiation free area should be ensured by the RSO. A standard operating procedure (SOP) for use and storage of TLD badges need to be developed in the institution.
- The working status and calibration of radiation monitoring instruments should be ensured by the RSO.
- Rotation of radiography personnel for the radiography jobs where exposures are likely due to critical nature of job. Appointment of adequate radiography personnel.

Industrial radiography practice is very safe and safety of radiography personnel can be ensured if a good safety culture is established in the institution. The average annual exposure to radiography personnel is below 1mSv in the country. It can be concluded that the main cause of excessive exposure reported is the lack of safety culture among the radiography personnel and in the radiography institution.

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259-I

SOUND BEAM FOCUSING TECHNIQUES USING PHASED ARRAYS

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Abstract

Sound beam focusing has been a subject of interest in ultrasonic non-destructive evaluation. The focusing of sound beam not only helps to achieve higher sensitivity, good lateral resolution and improved signal to noise ratio, but also in precisely locating the flaw extremities of crack-like flaws for their accurate depth estimation. Many 'hardware' and 'software' based approaches aimed at focusing the sound beam has been developed over the years. The most common method involves the use of an acoustic lens that is fitted in front of the crystal. Such transducers are primarily used during immersion testing. Another approach of focusing the sound beam is by Synthetic Aperture Focusing Technique (SAFT). With SAFT, the raw data is acquired by using a divergent sound beam. This data is then processed by an algorithm, which involves time-shifting and averaging of the A-scan signals. The constructive and destructive interference during the processing leads to focusing effect at the flaw location.

In recent years, phased array has found many applications for detection and characterization of flaws in engineering components. Phased array ultrasonic testing offers several advantages, including the possibility of sound beam focusing using contact transducers. Using phased array one can vary the focusing depth and direction by using appropriate 'focal laws'. One of the limitations of sound beam focusing using phased array is that the sound beam can be focused only within the 'near-field', which is decided by the active aperture and the frequency of sound. To achieve focusing at large depth, one needs a linear array with large number of elements and high-end phased array instrumentation capable of exciting these elements simultaneously.

A new set of methods using linear arrays have been developed in recent times, which can achieve sound beam focusing at higher depth by using very less number of active elements. These methods are based on acquiring the raw data using a divergent sound beam, which is then processed by algorithms like SAFT of Total Focusing Method (TFM), to achieve sound beam focusing through-out the thickness of the component. Such methods include Full Matrix Capture – Total Focusing Method (FMC-TFM), Synthetic Focusing using Linear Arrays (SFLA), Phased Array-Synthetic Aperture Focusing Technique, Virtual Source Aperture, etc.

This paper deals with the sound beam focusing using linear arrays by conventional and advanced approaches. The comparison of sound beam focusing achieved by these approaches is brought out in this paper.

Keywords **:** Sound beam focusing**,** TOFD**,** Phased Array, SAFT, Flaw Characterization.