

## 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 Ascertain 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.

**Key words:** Eddy current array, multiplexing, topology, cartography, CRA-Liner

## **INTRODUCTION:**

Eddy current technique is one of the main technique in that are used for the non- destructive examination of metallic plates and pipes to detect various kind of anomalies. Eddy currents are fields of alternating magnetic current that are created when an alternating electric current is passed through one or more coils in a probe assembly. Conventional 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. This electromagnetic technique can reliably detect surface-breaking flaws and subsurface defects. Unfortunately, inspecting large surface areas such as pipes, large area plates using a single-coil probe and recording data is extremely impractical as the process would be too time consuming and the probability for missed flaws too great.

However in those situations involving inspection of pipes or sheets materials, an alternating inspection method utilizing Eddy current Array (ECA) technique may be more suitable. Eddy current array (ECA) technology provides the ability to electronically drive multiple eddy current coils placed side by side in the same probe assembly. Data acquisition is performed by multiplexing the eddy current coils in a special pattern to avoid mutual inductance between the individual coils and it will provide the enhanced signal to noise ratio.

Eddy current Array technology applied on the Inconel (625) material of 3.3mm CRA liner pipes to detect the multi directional surface and sub-surface discontinuities and established the setup with central frequency. Acknowledged feasibility of detecting discontinuities and compared the effectiveness and efficiency of results with conventional eddy current testing.

## **EDDY CURRENT ARRAY PROBE AND SCANNER:**

The probe used for this inspection is more flexible and suitable for job configuration. Coils are excited in sequence to eliminate the interference from the mutual inductance. It will help to minimize the cross talk between to coils and increase Signal to Noise Ratio (SNR). In the circumferential channel one coil exciter and one coil act as receiver located in axial direction and it is ideal for longitudinal discontinuities. In the axial channel two coils are in the excitation mode and one coil act as receiver located in transverse directions and it is ideal for axial direction discontinuities. The diagrammatic view of these channels is as shown in the fig. 1. The scanner used for this experiment is flexible with spring arrangement and wheels. It will be idealized for above 6"- 12" ID liner pipes. Figure 2 a) and b) shows the probe and scanner.

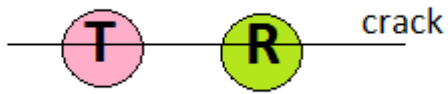


Fig: 1 a) Circumferential Channel



1. Axial Channel



Fig: 2 a) Eddy current array probe

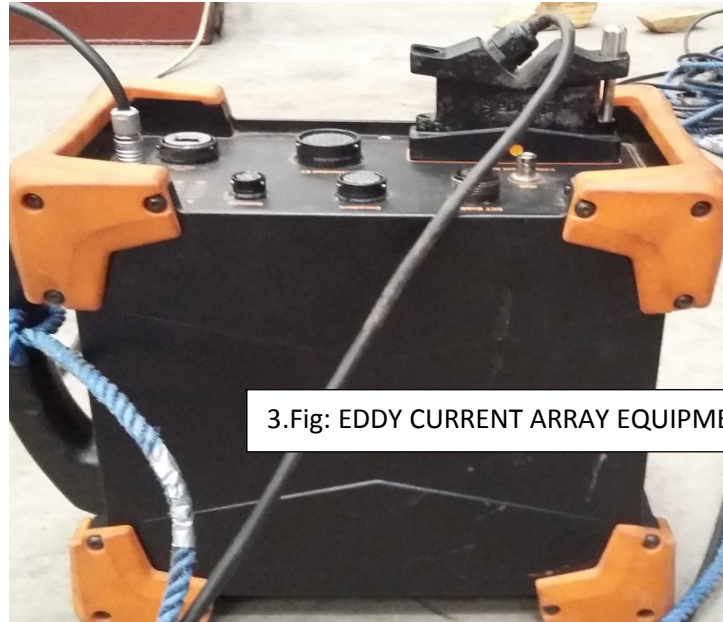


1.

b) flexible scanner

**EQUIPMENT CAPABILITY:**

Equipment used for this inspection was compatible with the frequency range of 5Hz to 10MHz and generating coil output/ coil drive up to 20Vpp. Eddy current array channels existing in the machine are 64, 128, 256. The photograph of the Eddy current array machine shown in the figure.3



3.Fig: EDDY CURRENT ARRAY EQUIPMENT

**OPTIMUM EXCITATION FREQUENCY:** frequency has been calculated by using the following formulae and calculated as 26.42 KHz. By considering this frequency and after the trials optimized the test frequency as 30 KHz.

$$f = \frac{661^2}{\delta^2 * \sigma}$$

Where  $\delta$  = Standard depth of penetration = 3.5mm

$\sigma$  = conductivity of the Alloy 625 = 1.34 %IACS

### **CHANNEL CALIBRATION:**

Calibration block is needed in order to normalize the individual coils of the eddy current array and setup a comparison of known flaw sizes. The material from which the block is fabricated shall be same material specification, product form, and heat treatment condition, as the material to be tested. Basic Calibration block selected material Inconel alloy 625 and equipped with two notches, one is for calibrating the circumferential channel mentioned as circumferential notch and second one is for calibrating the axial channel called axial notch. EDM Notches are prepared with uniform depth of 1mm in overall length of the notch to sensing the entire channel with

uniform

response.

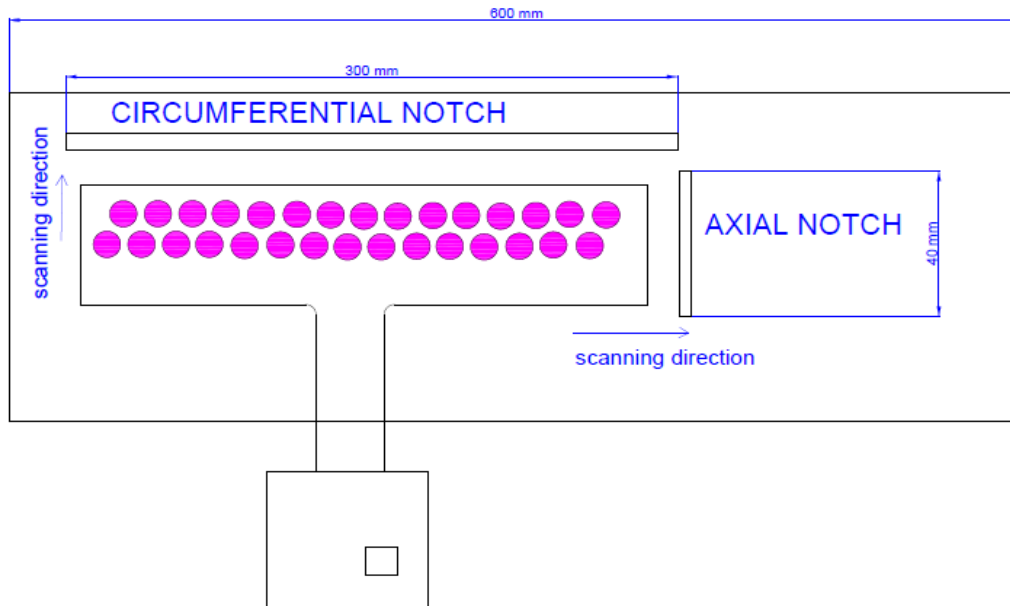


Fig:3) Model drawing of calibration block and probe.

The purpose of the performing Calibration is to standardize the sensitivity for an ECA probe. First scanning has done on the circumferential notch with uniform speed by sensing the coils uniformly on the plate. Second scan performed on the axial notch as shown in the figure 3). Calibration has been done on true depth basis.

Select the circumferential notch signal after the scanning and given instruction to the software with reference signal as circumference and applied the constant voltage for the signal as 6.6V with the orientation angle  $30^\circ$ . Median filter is applied to eliminate the low frequency liftoff signals.

### EXPERIMENTAL RESULTS:

The eddy current array and array acquisition system described above have been used on different samples having various kinds of flaws in different locations to collect experimental data. C scan pallet with 3D view have been used for the data collection and viewing the flaws. The C-Scan palette should be set to the voltage level at the threshold distance. When measuring any voltage values in the channel data a lissajous applies a measurement process to the data. The most common measurement process is the peak-to-peak process ( $V_{pp}$ ). This takes the start and end cursor positions, and determines a voltage value that reads the largest peak-to-peak change in

voltage. C-Scan data gets a color associated to a voltage value based on a single point of voltage to a single point in the color scale. The exclusion map channels are calibrated with the lift-off response moving down, or rotated to 270°, rather than the usual 0°. Since the lift-off is almost exclusively a horizontal variation, the correlation between the horizontal distance and the Vpp from null to each point of data is very high.

Application of this Inconel 625 pipes are used as corrosion resistive liner (CRA) for Carbon Steel (CS) pipes forming in the process called hydroforming. It will highly resist the formation of corrosion on the CS pipes from the sea water and different kind of processing chemicals. Intension of this experiment is to find the cracks which may develop, while doing hydroforming and manufacturing flaws.

The experiment was carried on Inconel 625 seam welded pipes of thickness 3.3mm with outer diameter 149.1mm and 700mm length. Block sketch as shown below.

### **1. Experimental Results of Inconel 625 with Flat Bottom Holes**

<b>Pipe material</b>	: Inconel 625
<b>Pipe Dia</b>	: 149.1mm
<b>length</b>	: 400mm
<b>Flaw type</b>	: Flat bottom hole
<b>Flaws diameter</b>	: 2.7mm
<b>Flaw depth</b>	: 1.2mm, 1.4mm, 2.0mm
<b>Thickness</b>	: 3.3mm

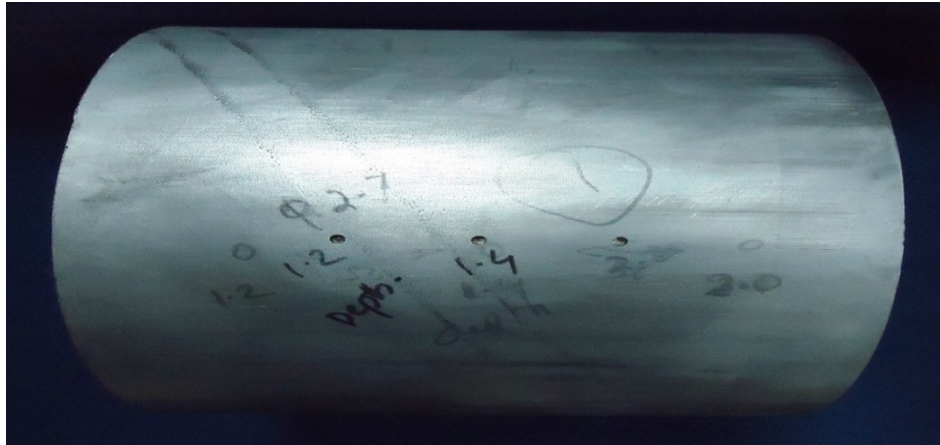


Fig: 4.a) Schematic Drawing of FBH Inconel 625 pipe

Eddy current C - scan image and surface plot of 2.7mm diameter of 1.2mm, 1.4mm, 2.0mm depth machined flat bottom holes with lissajous figures as shown in the below figure. Scanning have been carried inner surface of the pipe. C -Scan pallet have the options of two directional view such as Circumferential and axial. Defects which are in transverse to the scanning direction (transverse flaws) can be visualized in the circumferential channel view and the defects which are parallel to the scanning direction (longitudinal flaws) can be visualized in Axial channel view. Surface plot is used to view the indications in 3D direction.

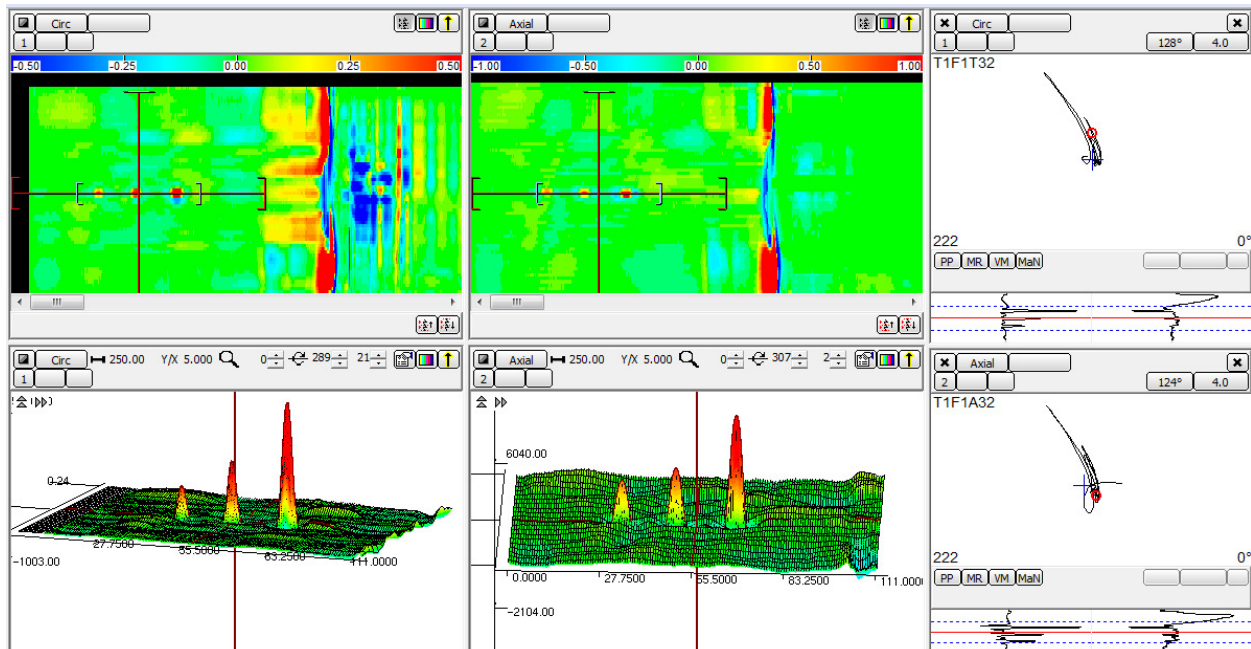


Fig: 4.b) C scan and surface plot image of the Flat bottom holes (FBH)

## 2. Experimental Results of Inconel 625 with longitudinal and transverse notches.

**Pipe material** : Inconel 625  
**Pipe Dia** : 149.1mm  
**length** : 400mm  
**Flaw type** : Flat bottom hole  
**Flaws diameter** : 2.7mm  
**Thickness** : 3.3mm

Block made by OD surface flaws of three longitudinal notches with various depth of the flaws are located side by the weld at different location as mentioned in the below sketch. As well three more transverse flaws are located perpendicular to the weld in different locations.

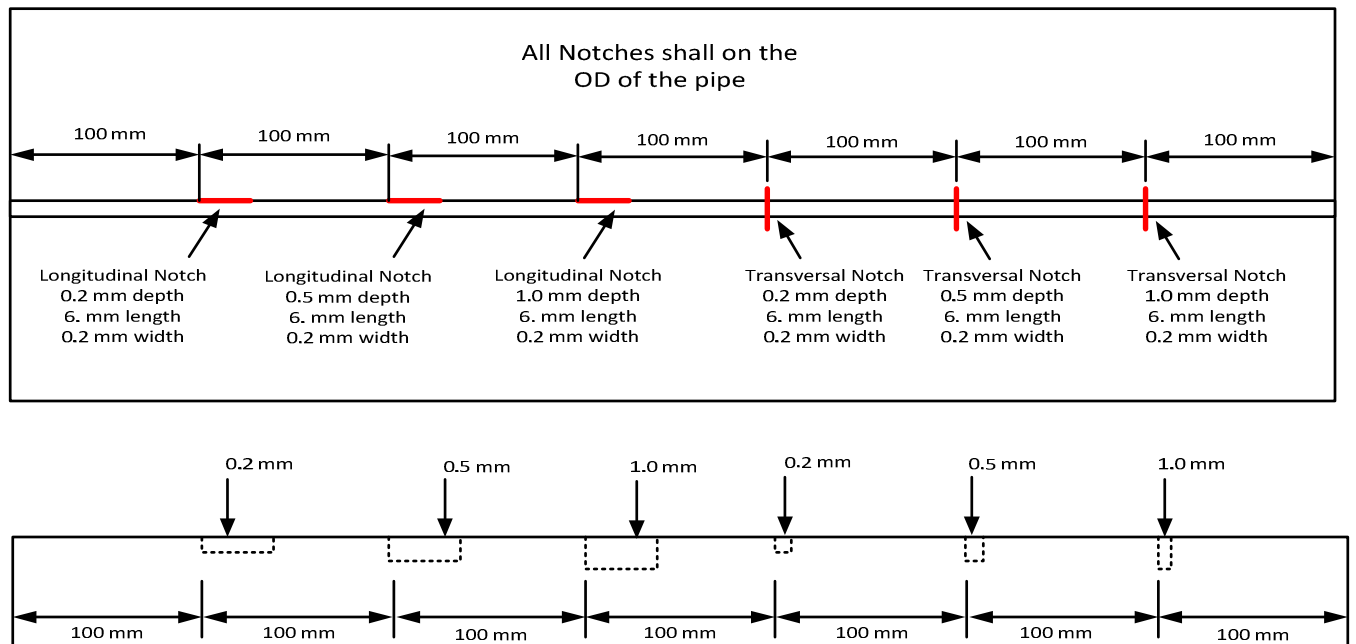


Fig: 5.a) Schematic diagram of Inconel 625 longitudinal and transverse notch drawing

Transverse notch flaws 0.2mm, 0.5mm, 1.0 mm depth are visible in the circumferential channel as well as in the surface plot and Lisajjious figure shown in fig 5(a) .Fig 5(b) represents the



Transverse notch flaw signals which are located parallel and side by the weld. Scanning have been carried on the same side of the flaws. Longitudinal Flaw signal 0.2mm (6% of the thickness) was not detected due to the size and lift off effect by the weld.

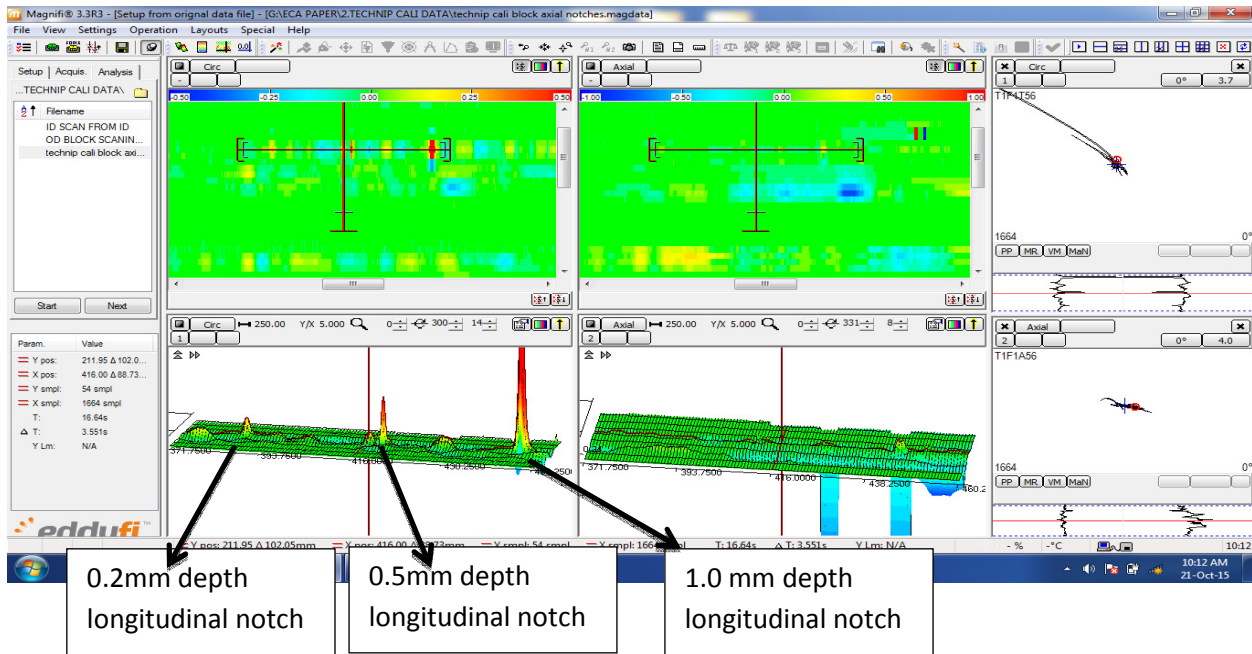


Fig: 5.b) C scan and surface plot image of the Transverse notches

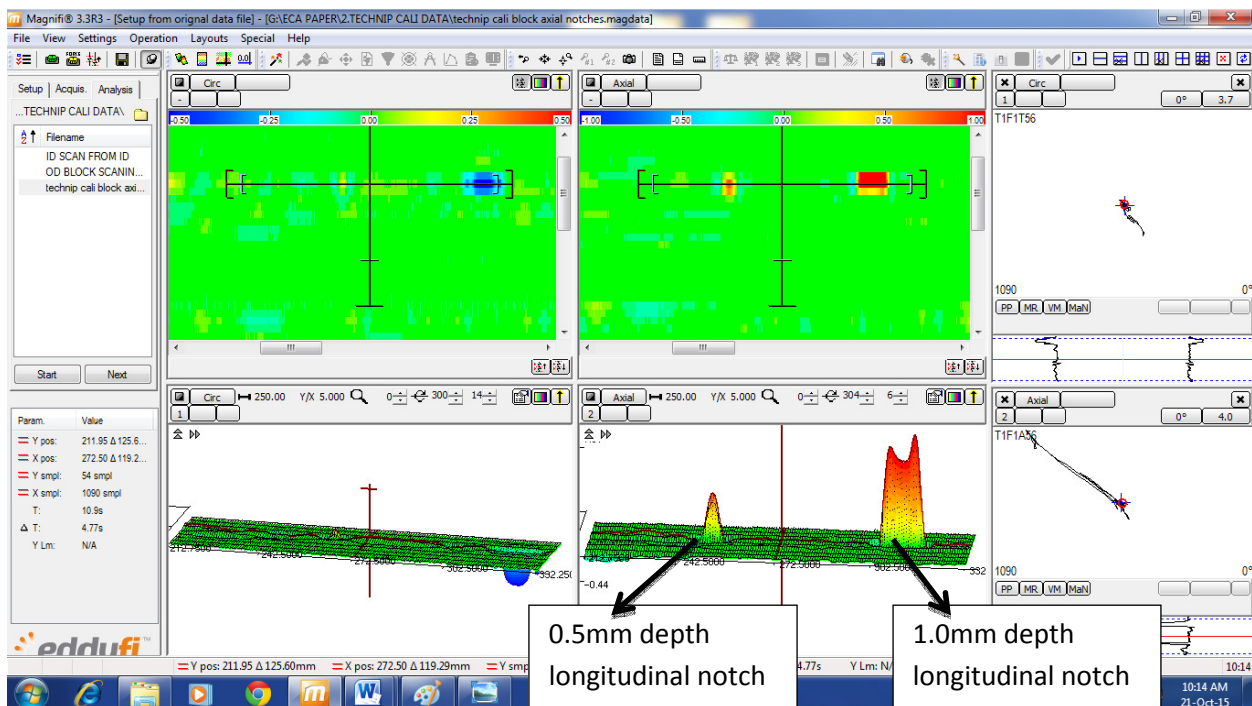
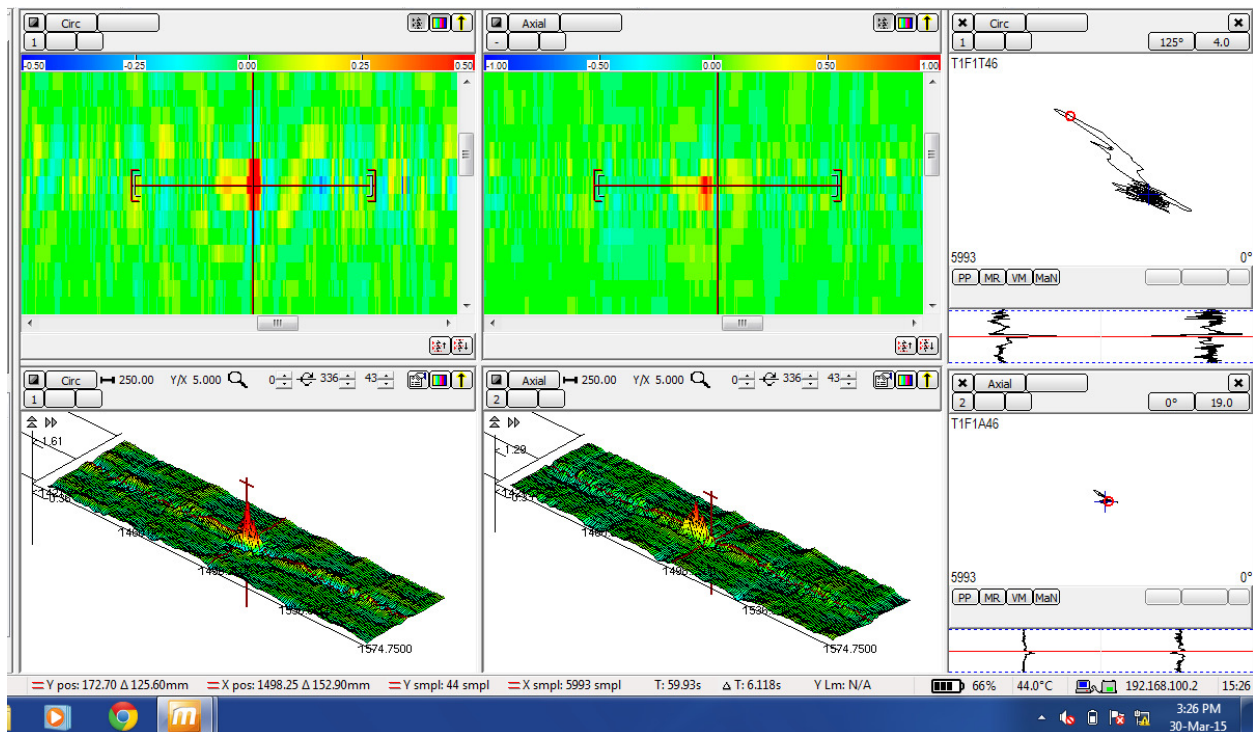


Fig: 5.c) C-scan and surface plot image of the Longitudinal notch flaws.

### One Of the Existent Field indication:



. Fig: 6.a) surface Flaw indication in the CRA Liner Pipe

### Conclusion:

1. ECA is extremely ideal for perceiving surface and sub surface flaws of CRA Inconel 625 liner bonded to the CS pipes in the process of Hydroforming.
2. Active shielded ECA flexible probe improve the detection near the edge of components (near the weld), creating a lot of possibilities.
3. The array elements which are constructed are capable to detect very small discontinuities and the flaws irrespective of their orientation
4. For practical reasons conventional techniques such as MT, PT are dismissed to inspect these CRA liner pipes and eddy current Array technique was considered to be excellent alternative.

5. In all orientations flaws, 10% of the thickness sensitivity level can be achieved by this ECA Technique.
6. Single pass scanning with good intuitive C scan imaging.
7. ECA Enables detecting previously undiscovered at the cladding OD surface.

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