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 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.

Key Words:

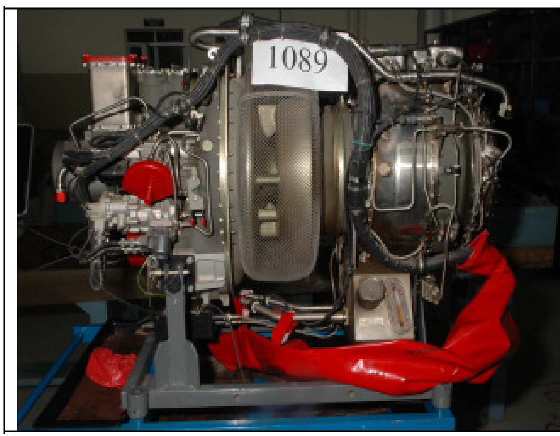
NDT: Non Destructive Testing
CNC : Computer Numerical Control

1. Introduction

1.1 Brief on TM3332B2 Engine

TM333 2B2 is a Tubo shaft Engine powers Advanced Light Helicopters (ALH Mark 1 and 2,Twin Engine) indigenously designed and developed by Hindustan Aeronautics Limited (HAL), Bangalore. Photograph of ALH is given in Fig 1 and photograph and schematic diagram of cross section of Engine is given in fig 2a and 2b below.

Fig 1. Photograph of Advanced Light Helicopter(ALH).



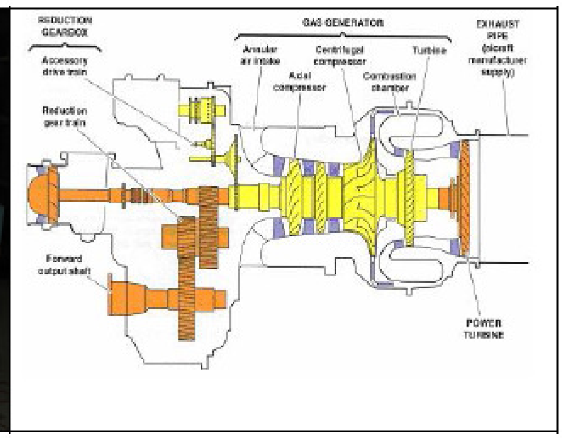


Fig 2 a. Photograph of the TM3332B2 Engine

Fig 2b. Cross sectional View of TM3332B2 Engine

This engine is repaired /overhauled under license from M/s.Turbomeca, France at Engine division, HAL, Bangalore. The Engine is of modular construction with annular air intake, two stage axial compressor together with a centrifugal compressor driven by a single stage turbine. The Engine has an annular reverse flow combustion chamber a single stage free turbine with a through shaft driving gear reduction gear unit located in the front.

During overhaul and repair of the Engines, there are many quality checks to be carried out as per Original Equipment Manufacturers (OEM) manual to certify the parts for next cycle of operation. One of such activity is Eddy Current testing of following critical components listed in the table 1 which are parts of Compressor and turbine assemblies.

1.2 A Brief on Parts

Eddy Current Inspection shall be carried out during overhaul and repair of the engine after 2000 hours of Engine run on bores of the parts as shown in the fig. 3 (Schematic diagram and Photos). The Eddy Current inspection is carried out for detection of any defects on the surface or which is located immediately under the surface of the bore.

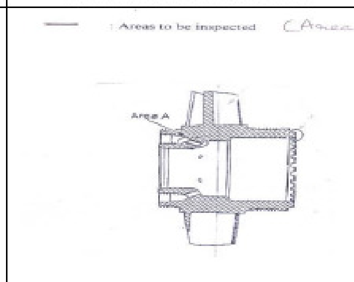
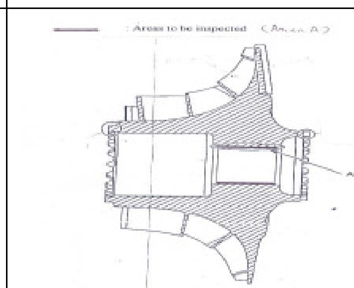
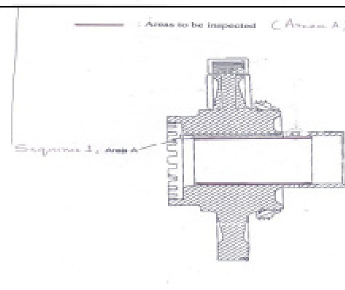
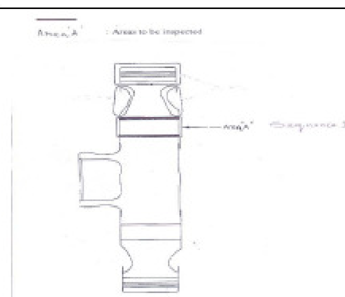
Part	Area on which Eddy Current Test to be carried out	Secondary Master blocks
 1st Stage Axial Wheel		
 Centrifugal Impeller		
 High Pressure Turbine Disc		
 Power Turbine Disc		

Fig 3. Photograph of the parts, Secondary master blocks and drawing shows critical areas of bore where Eddy Current Inspection is carried out.

Table 1. List of Parts undergo Eddy Current Inspection

Sl. No.	Part Name	Material	Function
1	1st Stage Axial Wheel	EZ3CND13-08(Alloy Steel)	Compress the inlet air to high pressure
2	Centrifugal Impeller	TA6VPq (Titanium Alloy)	
3	High Pressure Turbine Disc	NCK18K15TDA (Nickel Base Alloy)	To generate the power through expansion of gases.
4	Power Turbine Disc	NC 19 FeNb (Ni Base Alloy)	

2. Principle of Eddy Current Inspection

The principle of Eddy Current inspection is electromagnetic induction and consists in measuring the variations in the eddy Currents generated in the part by the alternating magnetic field of a coil fed with a sinusoidal electric current.

3. Eddy Current Technique Considerations

The Eddy Current Technique is generated for each part. The following points are to be considered while preparing and carrying out the Eddy Current Inspection of Parts.

3.1 Preparation of Parts

Parts for Eddy Current inspection are received after strip inspection. The part surface shall be free from superficial irregularities viz. scores, burrs, oxidation or peening etc. For Ferro magnetic materials the parts are demagnetized and residual field must be ≤250A/m in the areas to be inspected. For titanium parts non halogenated solvents shall be used for degreasing.

3.2 Areas to be inspected

Areas to be inspected is bores as shown in photo and drawing in fig 3. The surface finish of the bores are to be ensured (minimum 0.8 microns) before the inspection since it will affect the results of the inspection.

3.3 Eddy Current Test Equipment

Equipment is used for the inspection is Elotest B300 made by M/s. Rhomann GMBH UK with CNC based up and down system. A photograph of the Eddy current inspection set up is given in Fig 4. Technique parameters are fed as a program in the equipment (Elotest B 300) after finalization of the technique. During the inspection, particular program (CNC based up and down system CS 1500) related to the part and calibration block will be selected and inspection is carried out using the program parameters.

3.4 Master Calibration Blocks

Master Blocks are made of same material as that of the part to be inspected and have same electrical conductivity and magnetic permeability as that of the part to be inspected (±10 % max). Reference master blocks comprises either parts or pieces of parts with real damage or blocks with artificial damage. Secondary Master Blocks comprises of artificial damages which is calibrated with respect to the reference blocks. Secondary master blocks are used for inspection of parts at HAL, Engines division.

3.5 Special Tools

Initially, the scanning was done manually using rotary probes which are fixed to hand held rotors. In recently updated OEM overhaul manual automated inspection was introduced. Importing an automated testing facility would cost 1.3 crores. To get consistent and accurate results the CNC based up and down system is to be used for automated scanning. Hence Indian suppliers were contacted and a Bangalore based supplier has designed and developed a four axes CNC based up and down system (X, Y, Z and Rotary) as per HAL specification and proved out the equipment capabilities and which was demonstrated to the OEM and obtained the approval. CNC based up and down system will ensure following points.

a. Easy Rotation of probes at 1200 rpm.
b. Have a full control over scanning characteristics for the area to be inspected
c. Ensure a constant perpendicularity of the coil center line and the surface to be inspected at all points.
d. Ensure that there is a constant distance or a constant contact between the sensor and the surface of the part and no signal noise during inspection.
e. To get a regular displacement speed of the sensor along the bore at a velocity 1mm/sec for an operator controlled displacement.
f. To stop the sensor at any suspicious area of the bore.
   A photograph of the Entire set up is shown in the fig 4

Fig4. Automated Eddy Current Inspection Set up with CNC based Up and Down System

3.6 Eddy Current Probes and Rotors

The Eddy Current inspection of the bores is carried out with a differential rotating probes (Frequency range of 50KHz to 2.5MHz) using a sensor support with at least two magnetic core coils. The Rotating probes are selected in such a way that clearance between inner diameter of the part and outer diameter of the probe is ± 0.2mm. This is to get best sensitivity and avoid any liftoff effects and noise. The rotating probes are fixed to Rotors which will assist the probe rotation of upto 2850 rpm with medium frequency range from 10 KHz to 500 KHz.

3.7 Scanning Procedure

Scanning is done using rotary probes rotating at 1200rpm.The Probes are fixed to Rotors which are held in the up and down system and lowered to the bore at a velocity 1mm/sec by calling pre-determined program in up and down system. The required program saved in Elotest B300 equipment as per the technique data cards is recalled during scanning. The Continuous monitoring of the screen is required during scan for observing for signal from any defect present in the part.

3.8 Calibration setup

Both elliptical and time line(Y/t) display will be used on the screen. During the calibration, the artificial defects in the secondary standards (which are calibrated with respect to the reference blocks) are detected and signal from the defects is Kept 100% of the Full screen Height (FSH) using main amplifier and pre amplifier gain (dB), low pass and high pass filters, phase parameters. The signal obtained shall be symmetrical shape (schematic diagram as given in Fig 5). The following parameters are adjusted to get the right signal shape from the defect in secondary master block during calibration and the parameters are recorded in technique data sheet.

a. Frequency, Low Pass and High Pass Filter parameters are adjusted to get a curve of correct shape. The positive half cycle being equivalent to the negative half and giving the largest vectorial amplitude within the sensor operating frequency range.
b. Adjust the phase so that the signal is vertical with respect to the impedance plane.
c. Adjust the signal to a 100% amplitude by modifying the amplification so that the signal is symmetrical.

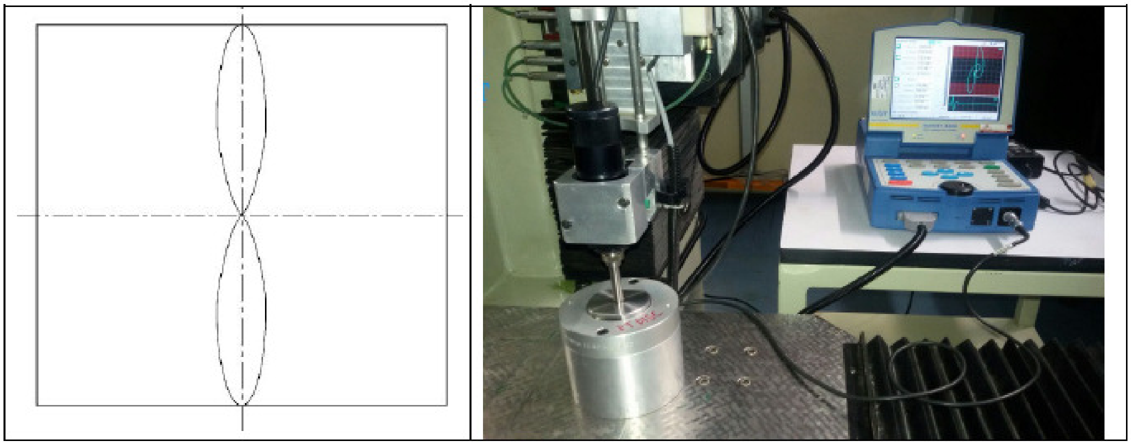


Fig 5. Schematic diagram of signal from secondary master block and photograph of Defect Signal – 100%FSH for calibration setup.

The parameters used for getting right signal is recorded, freezed and data cards are generated. The additional dB as given in the secondary master block will be added during the inspection of the part. It shall be ensured that the noise signal obtained is nil or maximum 10% of FSH.

3.9 Eddy Current Inspection and Evaluation

Eddy Current inspection of the part is carried out after successful calibration using corresponding secondary master calibration block. Additional gain (dB) as given in the secondary master block is added and part is scanned. Any defect signal obtained during inspection which is showing 50% FSH or more will lead to rejection of part. Figure 6 shows part scanning photographs with and without defects. After inspection of the part an end calibration will be carried out by using corresponding secondary master calibration block similar to the initial calibration to ensure that the Eddy Current system is working satisfactorily.

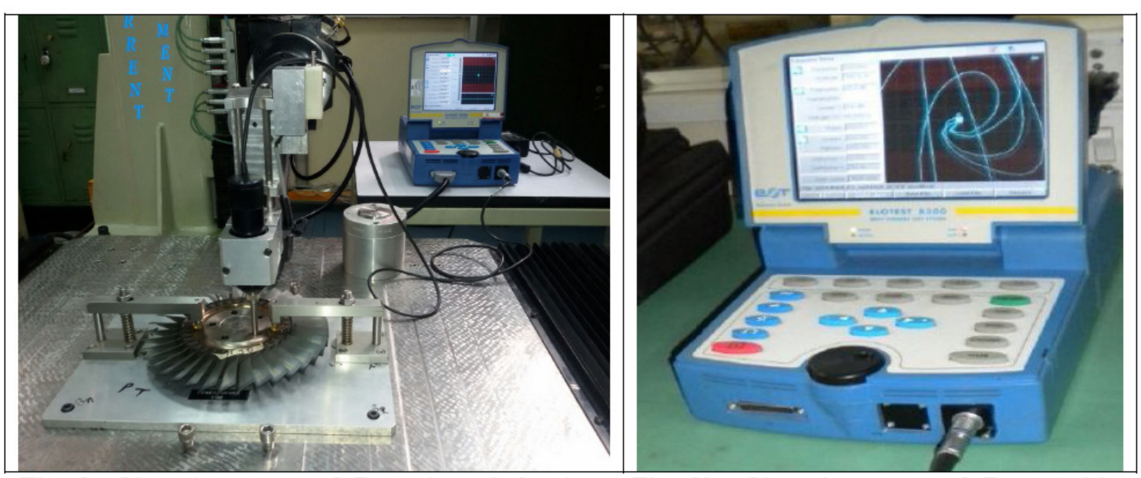


Fig 6. Signal output of Part (no defect) Fig 6b. Signal output of Part (with defect)

3.10 Process control Checks

Following Process Control Checks given in Table 2 are to be carried out at various frequencies to monitor the Process Performance.

Table 2.Proces Control Checks

Sl. No.	Process control Check	Frequency
1.	Eddy Current Equipment Calibration	Annually
2.	Secondary Master Blocks Calibration	Annually
3.	Verification of Rotating Probes and Sensors	Annually
4.	Amplifier Linearity Check	Prior to Every Inspection

4. Qualification of Personnel

The Personnel carrying out Eddy Current Testing are qualified to NDT Level 2 as per NAS 410 standard. The procedures and Technique Data Cards are approved by NAS410 NDT Level 3 Personnel.

5. Conclusion

Automated Eddy Current Inspection of aero engine components is indigenously designed, developed and manufactured to inspect Aero Engine parts during overhaul and repair. The indigenization of the testing facility has lead to 400% cost saving and conform to made in India concept. This technique uses secondary master blocks

With artificial defects to calibrate the Eddy current system. The Eddy Current inspection is proved effective in finding out service defects like fatigue cracks in the aero engine parts. The technique is approved by the original equipment manufacturer (OEM). This is the unique surface NDT method applied on Aluminium, Steel, Nickel Base and Titanium Alloy Parts. Automation technique has increased the reliability, repeatability, sensitivity and accuracy of the Eddy Current inspection on these parts. It can be also extended to bore inspection of other parts viz. compressor blades and discs of different Aero Engine Projects. This technique also reduced the time taken for the inspection of such jobs.

Further work on orientation of the defect, exact location and metallurgical evaluation of defect are to be carried out characterize the defect.

6. Acknowledgements

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7. References

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