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 etc.*

1. Introduction

Visual testing is the first and foremost preliminary NDE method of inspecting any component. The method is extensively used during raw-material stage, process stage and also during in-service stages. It can be used for the inspection of pipe-lines, heat-exchangers, pressure vessels, aerospace components and assemblies etc. Weld discoloration, incomplete penetration, incomplete fusion, cracks, voids and pores open to surfaces, root-concavity, undercut, mismatch, overlap and other surface anomalies can be detected.Corrosion and scale formation can be easily detected. Various standards have been generated for the inspection of castings, welds, procedure of inspection, inspection requirements, training of personnel etc. [1]. Visual testing can be classified as Direct visual testing and Remote visual testing [2, 3]. Direct visual testing can be again split as Unaided and Aided (mechanical or optical), depending on the usage of visual aids. Aided testing comprises the usage of equipments like mirrors, lens, optical flats etc [4]. Remote visual testing can be performed by using endoscope, fiberscope, videoscope etc. Choice of the equipment in either case depends on geometry and location of test object, manipulation capability of equipment, resolution, accuracy, requirement of permanent record of inspection etc. [2, 5]. Remote visual testing has been performed over years using endoscope and fiberscope which presents difficulty in terms of manipulation, operator fatigue, lack of permanent storage of data etc.This paper addresses the usage of industrial videoscope, its capabilities and some typical case studies pertaining to inspection of critical aero engine components.

2. Industrial Videoscope

Videoscope contains a CCD camera at the tip of the working cable. The equipment is shown in Fig. 1. A 50W metal-halide light source is fixed in the equipment and light is transmitted by optical fibers to the distal end for illuminating the area of interest. The image is focused on the camera by an objective lens and is electronically transferred to a LCD monitor for viewing. The spectral content of the light source almost matches that of sun-light. Hence the image is captured and displayed in true-colours. The resolution of the videoscope depends on the field-of-view and object-to-lens distance. Different types of adapters can be fitted to the distal tip of the scope for facilitating viewing in different directions. Direct-viewing, side-viewing, retrospective (backward) viewing is some of the adapters regularly used [6].

Fig.1: Industrial Videoscope

The diameter of the insertion tube is 4.4 mm and length is 3.5 m. 63.commercially, working lengths of 35 m is available for inspecting lengthy pipelines. The tip can be rotated in 4 directions upto 120^0 in each direction. Handheld remote controller is used for rotation, freezing and storing of image. The image can be later on transferred and stored in a PC by a serial cable. Apart from normal adapters, stereo adapter also can be fitted to the distal tip. This adapter consists of two parallax lenses which capture two separate images of the same region and then uses triangulation principle for measurement. Six different modes of measurement are available. They are:

1. Distance between two points
2. Point-to-line
3. Area
4. Depth
5. Profile
6. Lines for measuring on curved surfaces

These features are useful in the quantitative analysis and measurement of discontinuities.

3. Case studies

3a. Starting nozzle: Starting nozzle is a hot-end critical component and its primarily application is to inject compressed hot gases for inducing momentum in the High Pressure Turbine (HPT) for starting the engine. The photograph of the component is shown in Fig. 2a. The inner surface of the nozzle should have minimum surface roughness to ensure smooth laminar flow of the gases and has to be inspected qualitatively due to inaccessibility. During prototype development trials, the inner surfaces of the components were observed using Videoscope. It was observed that the surface roughness was high due to EDM process used for drilling the hole. This information was useful to the designers for deciding on the type of finish operations to be used.

Fig.2a: Starting nozzle

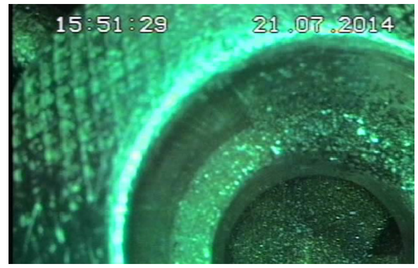

Fig.2b: Surface roughness on inner side

3b. Sub-Assembly Oil tank: The oil tank is a wrap around hardware around the engine and supplies oil to various sub-systems in the engine for lubrication and is shown in Fig. 3a. The sub-assembly is a welded Aluminium sheet metal structure with complicated internal cooling and circulation arrangement. The tank is sealed except for oil inlet, outlet and air vents. During typical engine run, it was observed that there was a rise of oil pressure and the oil filters were blocked. The tank was dis-assembled from the engine. Videoscopic inspection was carried out by inserting the adapter from inlet and outlet openings. The presence of extensive corrosion and debris were observed in various locations as in Fig. 3b, 3c and 3d.

Fig. 3a: Oil tank

Fig. 3b: Debris inside the tank

Fig. 3c: Corrosion and debris on baffle plate

Fig 3d: Extensive corrosion on inner pipe

These observations were attributed to process deficiency. Since then, videoscopic inspection has become mandatory for the oil tank during stage wise manufacturing, after every engine dis-assembly and has facilitated hassle-free engine operation.

3c. Low Pressure Turbine (LPT) Front Shaft:LPT Front Shaft is a critical rotating componentmade of Martensitic Stainless Steel (Fig. 4c). The shaft is machined from rolled bar stock and should have good surface finish for better fatigue properties.Initial development trials were proved to be insufficient as recast layer associated with flakes and copper impregnation were observed on the inner walls using Videoscope, detrimental to fatigue life of the component. This observation was immensely helpful to prove the manufacturing process and surface finish.

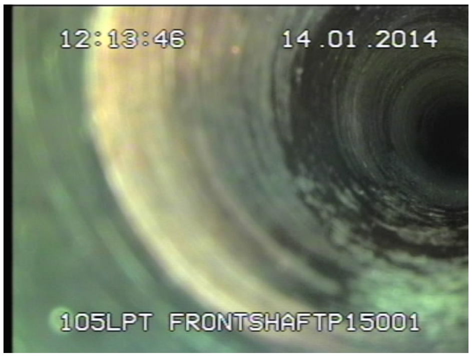

Fig. 4a: Recast Layer and Flakes

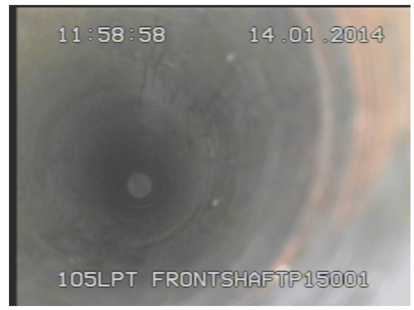

Fig. 4b: Copper impregnation on the inner wall

Fig 4c: LP Front Shaft

4. Conclusions

Visual Testing is the fundamental NDT method of inspection and gives valuable first-hand information on the quality and integrity of the components. Remote Visual Testing using advanced aids like Industrial Videoscope is finding increasing importance to ascertain the surface integrity which essentially dictates the fatigue life of the aero engine hardware. There is also continuous progress in extending the method from qualitative to quantitative techniques. This information can be useful for complementary NDT methods for comprehensive evaluation of the components.

5. References

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