Application of NDT & Metrological Methods for the Characterization of Starting Nozzle of an Aero Engine

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Abstract

During development of the aero engine, various methods are employed to characterize the components. Aero engine consists of varieties of components and it is necessary to evaluate the characteristics of these parts for the testing. Various metrological and NDT methods are adapted to study and evaluate these components. Non-destructive testing (NDT) techniques are used to probe the structures, materials etc. and different techniques are employed to give increased probability of detection. Current paper discusses about the characterization of the starting nozzle of an aero engine. Starting nozzle is a complex critical component in the engine and hence needs higher integrity. Different methods like casting, additive manufacturing etc. are employed to realize the component. Hence various metrological and NDT methods are employed to evaluate the quality characteristics of the part. Paper discusses about surface analysis and sub-surface detection in the part under study. Results of the various methods like surface roughness, visual inspection, radiography, penetrant testing, are explained and discussed.

Key Words

Non-destructive testing/examination, quality, radiography, sub-surface detection, videoscope, penetrant inspection, surface roughness etc.

Introduction

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 material used is Nickel based super alloy. The part is realized through various roots of manufacture like investment casting and additive manufacturing. Reliable performance of the part depends upon the pre-service quality and in-service degradation of the component under operating conditions [1]. The parts are under development process and a few hardwares are realized for evaluation purpose. The photograph of the component is shown in Fig. 1. Part is critical in nature as it involves intricate configuration, interfaces and flow passage important for the gas flow characteristics. Hence it is imperative to characterize the part with respect to quality characteristics important for the better functioning and integrity of the part. Characterization of the part is based on the metrological and NDT techniques. Co-ordinate Measurement Machine (CMM) is used to obtain coordinates of points (Cartesian system - X, Y, Z coordinates) on the external and internal surface [2]. Geometrical information of external surface of the nozzle containing freeform surfaces are measured using CNC CMM and surface texture of the internal passage is evaluated using surface roughness machine. Roughness is important it has a significant effect on the flow of the hot gases through the passages. Roughness is generally the marks made on a surface by the machining tool. Even when there is no machining involved, as in
casting/injection molding, the surface of the mold will have surface deviation, which in turn will be transferred onto the part [3]. The integrity of the part is evaluated by complementary non-destructive tests including Penetrant Testing for surface detection, Radiography and Ultrasonic Testing for the sub-surface detection. The part is under development process and a few prototypes are under study to characterize the component with respect to functionality and integrity.

Figure 1: Starting nozzle

Characterization using NDT methods

Penetrant Testing (PT) is necessarily carried out 100% on all non-magnetic components of an aero engine as the parts are vulnerable to surface defects. However, the choice of the PT method depends on the manufacturing method adopted for the realization of the component, the sensitivity and resolution of inspection required as per the acceptance standard. In this case study, Visible Dye Penetrant method was used for components realized through casting route and Fluorescent Dye Penetrant method for parts made through Rapid-Prototype (RP) technology. Fig. 2 shows the indications revealed on an RP part after Penetrant Testing. Additionally, the entire component is subjected to through-and-through Penetrant Testing to check for the presence of leakage.

Figure 2: Porosities during FPI

Radiography of the component is essential to obtain the geometry of the internal gas path and to ensure that it is free of blockages. Further, the casting integrity also has to be established with ASTM E192 as reference standard. The radiographic image of the nozzle is captured in Fig. 3. Retaining pins embedded in the walls of the nozzle can be clearly seen in the image.
The surface roughness of the internal passage is critical as it determines the nature of flow (Laminar/ Turbulent) of the gases. This parameter can be measured only in the accessible ends of the part. However, Remote Visual Inspection (Videoscopy) can be carried out to qualitatively ensure that the surface finish inside is within acceptable limits. A typical Videoscopic image of the internal passage is shown in Fig. 4.

Further, Ultrasonic Wall Thickness Testing is used to map the complete profile of the walls to ensure that minimum values are met as per specifications.

**Characterization using Metrology**

The critical dimensions of the nozzle like inside diameter, nozzle angles, interface dimensions and surface texture of the internal passage have to be ensured within specifications as they have significant effect on flow of the hot gases and start of the engine. The CMM measurements are carried out with respect to the CAD model used for the casting manufacture. Challenges involve offline programming based on the CAD model generated from the frozen design/stage specifications is used. The Metrological Inspection is based on CAD model for which datum is created by machining on the part to run the program for the measurement. Fig. 5 depicts the typical CAD model of the starting nozzle after measurements.
Surface texture of the internal passage of the nozzle is important as the hot gases flow through the area and hence the surface characteristics are important to have an optimum flow. Texture is measured in terms of average surface roughness (Ra) value. Because of the complex geometry of the part and internal passages, the roughness measurement is carried out with the set up as shown in the Fig. 6. Roughness measurement is quantitative based on measurement on accessible areas by contact probe whereas for the internal passage it is qualitative as revealed in videooscopic inspection.

Figure 5: 3D inspection model of starting nozzle

Figure 6: Setup for surface roughness measurement
Conclusions

Application of the NDT and Metrological methods is discussed for the characterization of the starting nozzle for usage in an aero engine during its development. Geometrical features are measured using CMM based on the CAD model capturing the intricate features in Calypso software. Complementary NDT methods are employed to characterize the staring nozzle.

Characterization based on NDT and Metrological methods can be effectively used to decide the feasible method of production during developmental trials. These results can be reviewed with respect to the flow test of the internal passage to arrive at the final acceptance of the component.

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References