Evaluation of Internal details in Rocket Motors using Computed Tomography

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Abstract

Rocket Motor is a highly complex aerospace component that consists of a metal casing, ablative liner and Propellant grain. The Rocket motor is to be inspected for various interfaces and defects such as debonds between metal casing & ablative liner and Propellant & ablative liner and delaminations in ablative liner and defects in Propellant. X-ray Radiography Testing (RT) and X-ray Computed Tomography (CT) methods are employed for identification of various interfaces and defects evaluation in rocket motor. RT could not show all the interfaces clearly whereas CT revealed all the interfaces with their boundaries clearly in a single cross-sectional image. The salient features of CT and its edge over RT in evaluation of internal details of rocket motor are highlighted.

Key words: Rocket motor, Computed Tomography, Radiography, propellant grain, internal details

1. Introduction

Rocket Motor is a complex and mission critical component having different materials with interfaces and defects in between them. It consists of a metal casing, ablative liner and Propellant grain. The Rocket motor is to be inspected for various interfaces and defects such as debonds between metal casing & ablative liner and Propellant & ablative liner and delaminations in ablative liner and defects in Propellant.

Non Destructive Evaluation (NDE) deals with the evaluation of structural integrity of hardware without affecting their functionality and useful lifetime. X-ray Radiography Testing (RT) and X-ray Computed Tomography (CT) methods are employed for identification of internal details such as to find out various interfaces and defects in rocket motor. X-ray radiography compresses 3D information into a 2D image due to which collinear defects and multiple defects are difficult to find. 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 [1]. Also these thin slices are stacked one over the other to generate a 3D image of the object. CT images are free from underlying and overlying areas of the object, collinear and multiple defects can be detected as compared to RT. Further, CT provides relative density and dimensional measurements there by allowing to identify the interfaces clearly, locating defects and measure their extent and sizes.

In this paper, the rocket motor has been inspected using RT & CT to find out the internal details. The merits of CT and its edge over RT in evaluation of internal details are highlighted.

2. Experimental details

Initially, RT was carried out on Rocket motor using film radiography. CT was done using DRDL’s indigenously developed 450 kV X-ray Industrial Computed Tomography (ICT) system. The ICT system consists of a 450 kV X-ray source, 256-channel detector array with 18 bit dynamic range and a 6-axes mechanical object manipulator [2]. The resolution of the system is 500 µm with 1 mm slice thickness.

3. Results and Discussion

Figure 1 shows the radiograph of the rocket motor showing the metal casing, ablative liner and propellant grain.

Fig. 1 : Radiograph of rocket motor showing metal casing, liner and propellant grain
However, these details are not very clear from Fig. 1, as the features get overlap since radiography compresses 3D information into a 2D image.

Figure 2 shows the close-up view of ICT system showing the X-ray source, detector along with a rocket motor on the manipulator. Figure 3 shows the Tomogram of the rocket motor (at the location marked in Fig. 2). Tomogram shows all the interfaces of the rocket motor with demarking their boundaries very clearly (Fig. 3) in a single cross-sectional image. Further, CT allows the measurement of relative densities, which helps in differentiating the interfaces from defects and dimensional measurements aid in sizing the internal features of interest. These features make CT a potential tool for this kind of application and provide an edge over other conventional NDE methods (RT) in identification, location and sizing of defects.

Figure 4 shows the Tomogram revealed that the position of grain got misaligned with respect to its web thickness. This misalignment might have occurred during Propellant casting inside the motor, which RT has not revealed due to overlap as explained earlier. A 10° deviation was confirmed from CT data. In the case of motors with star configuration propellant grains, the ablative liner thickness is modulated in such a way that liner thickness will be more at lesser web thickness of propellant so as to protect the motor casing from the heat of radial burning. Thus the propellant casting mandrel alignment w.r.t liner thickness variation is so critical that any deviation may lead to failure of rocket motor. CT can only bring out these details which helped in solving the misalignment issue for further processing of rocket motors. This study highlights the CT potential in solving the problems arise during processing, assembly in addition to defect detection.

4. Conclusion

CT with its extremely high contrast resolution (ability to measure small density differences) and high spatial resolution (ability to resolve fine structural details) make more attractive for critical inspection requirements of rocket motors, where failure would result in extremely high costs and total mission failure. Finally CT inspection is proved to be vital importance in revealing the internal details of all the interfaces clearly seen and the alignment of grain with respect to its web thickness, which are not possible to obtain through conventional NDE methods (RT).

References