Computed Tomography - A Diagnostic Tool

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Abstract

Pyrogen Igniter (PI) is a mission critical component used for igniting large rocket motors. PI is made up of propellant grain cast into a Synthetic Resin Bonded Paper (SRBP) tube, which in turn bonded inside Glass Epoxy (GE) casing. The variations in processing of PI may result in non-uniformity in thickness of its constituents and defects at interfaces that can affect performance of PI. X-ray Radiography is widely used to assess the quality of PI during different stages of manufacturing though Radiography compresses 3D volume information of PI into a 2D image. UT is less used because of couplant seepage and difficulty in interpreting the multiple reflection & refraction from different interfaces. This paper discusses the application of Computed Tomography (CT) in diagnosing the indications observed in RT of PI. Radiographs have shown a thickness variation between SRBP and Propellant grain but the boundaries could not be delineated due to the overlapping of the features. Then CT was employed to resolve the ambiguity in identifying the boundaries. CT could reveal all the interfaces, their boundaries including thickness variation noticeably without any overlap. Further investigation has concluded that the thickness variations were due to the mandrel shift during propellant casting.

Keywords: Computed Tomography, Pyrogen Igniter, Thickness variation, Quality Inspection.

1. Introduction

Pyrogen Igniter is made up of propellant grain cast into a Synthetic Resin Bonded Paper (SRBP) tube, which in turn bonded inside Glass Epoxy (GE) casing. PI is fabricated in different stages and deviations at any stage of the fabrication may result in thickness variation of its constituents or defects at various interfaces. Quality Assurance of PI involves evaluating PI for delaminations within GE casing, debonds between GE casing & SRBP tube, debonds between SRBP tube & Propellant and defects within the propellant grain such as cracks, voids, inclusions etc. Different NDE methods are employed to ensure quality of PI to meet the performance requirements.

X-ray Radiography is routinely used to assess the quality of PI. However, it is difficult to detect collinear and multiple defects using Radiography as it compresses 3D volume information into a 2D image. UT is difficult to apply at various processing stages of PI due to couplant seepage, and multiple reflection & refraction at different interfaces. Computed Tomography generates cross-sectional images of object without any overlapping of features from overlying or underlying areas. CT images are easy to interpret and finding the exact location and size of defect is possible. The CT image represents point-by-point distribution of linear attenuation coefficients in the cross-section of the object. The linear attenuation coefficient is approximately proportional to the physical density of the material, effective atomic number of the material and the energy of X-ray beam. CT images are highly sensitive to small density differences (<1%) between structures [1] and thus enable the operator to mark the interface boundaries and measure the constituent thickness. CT images can be stacked one over the other to generate 3D view that can be cut at any angle to view the extent of information in three dimensions.
In the present paper, CT has been employed to reveal the process variations in PI, compared results and discussed its merits over RT & UT.

2. Experimental details

Pyrogen Igniter was initially evaluated using X-ray film Radiography and a film digitizer is used to obtain digital radiograph. The cross-sectional images are obtained using DRDL’s indigenously developed 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

Fig. 1(a) is the photograph of Pyrogen Igniter and Fig.1 (b, c) shows X-ray Radiographs of PIs with and without thickness variation observed between SRBP and Propellant grain respectively. It was difficult to clearly identify the interface boundaries and measure the thickness variation from the radiographs due to overlapping of features. Fig. 2 (a) is the Tomogram of PI with thickness variation of propellant grain (shown by arrows) and Fig. 2(b) is Tomogram of PI with uniform propellant thickness.

Fig. 1 (a, b, c) Pyrogen Igniter, X-ray Radiographs with & without thickness variation

Fig. 2. Tomograms of Pyrogen Igniters (a) with thickness variation (b) Uniform thickness
Tomograms were taken at different positions to check extent of thickness variations along the length of PI. It is observed from Tomograms taken at different locations of PI that the thickness variation between SRBP and Propellant grain is present for the entire length of PI. Figs. 3(c, d) are tomograms of a good component showing uniform thickness at different locations. CT data was helpful in identifying the cause of the problem to a mandrel shift during the propellant cast. Tomograms also revealed debond between the casing and paper tube as shown in Fig. 3(a).

Tomograms could reveal all the interfaces of PI and their boundaries without any overlap compared to that of Radiographs of PI. This type of clarity about interfaces of PI with their boundaries including thickness variation in a single image is impossible to obtain in Radiograph. Evaluation of mission critical components such as PI using Tomography is must to avoid similar kind of defects which may go unnoticed during the routine inspection and can even lead to mission failure.

Image enhancement tools can be used to improve the appearance of CT images for better visualization and interpretation. Region of Interest (ROI) reconstruction is one such tool that allows selecting a particular portion of Tomogram and reconstructing it onto the entire image grid for enlarged view. ROI is different from Zooming, where pixelization effects could affect features of interest. Figs. 4(a, b) shows ROI Tomograms of PI with enlarged view of thickness variations between SRBP and Propellant grain and defects at interfaces. This type of information is not possible to obtain with RT and UT methods. Thus CT provided vital information over RT & UT and has emerged as diagnostic tool in evaluating the process variations in PI.
4. Conclusion

Tomograms of PI revealed the interfaces, their boundaries including thickness variation distinctly without any overlap whereas these details could not be obtained from Radiographs. The thickness variation is predominantly visible in Tomograms, which might be missed in Radiography. Thus CT has provided vital information over RT & UT and emerged as diagnostic tool in evaluating the intricacies of PI being a mission critical component.

5. References
