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Determination of the weld thickness of turbine for aircraft engine by high-energy X-ray tomography

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Abstract. It is necessary to test the weld thickness of turbine, as it is one of the most important parts for aircraft engine. The weld thickness of turbine for aircraft engine by high-energy X-ray tomography was determined. We used an X-ray tube and a betatron as X-ray sources. The wall thickness of two tubes and weld thickness of turbine were measured. It is shown that the high-energy X-ray tomography system is determined the wall thickness of the tube and the weld thickness of turbine with high accuracy. We also studied the method to reduce scattered radiation. All experiments were carried out in the non-destructive testing (NDT) Institute of Tomsk Polytechnic University (TPU).

1 Introduction

Recently the welds inspection is very popular subject of many researches [1-2]. To ensure the reliability of turbine for aircraft engine, it is necessary to test the weld thickness. In particular, the determination of the weld thickness is required to localize defects in the weld.

The comparative work [3] shows that the ultrasonic testing is not appropriate to identify typical micron-sized friction defects for linear welding. The only acceptable non-destructive method to control the internal defects is computed tomography (CT). The work [4] shows that by evaluating the state of defectiveness, we can define the period of the turbine operating. Many of similar studies [5-7] were conducted to determine the quality of welding in a turbine blade.

The purpose of non-destructive testing of the weld thickness of turbine is not only a determination of weld thickness and defects, but also recognition of their way to assess the potential danger of the defect.

2 Materials and methods

To determine the weld thickness of turbine for aircraft engine, we use high-energy X-ray tomography. The system of high-energy X-ray CT consists of a radiation source (X-ray tube or betatron), movement system, detector (line array), control system and image

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reconstruction system. The high-energy X-ray CT system was established in NDT Institute of TPU [8].

In our case, the object width exceeds the detector width, regarding of this, we use partial scanning method [9] for a complete image. In view of [10], the principle of scanning is that the symmetry axis of the object does not coincide with the rotation axes.

In order to verify the measurement accuracy, we measured the wall thickness of two tubes at first. Then we measured the weld thickness of the turbine. Tubes and turbine are shown in Figure 1.

a b c

Fig. 1. a – Tube 1: outer diameter 47 mm, wall thickness 4 mm. b - Tube 2: outer diameter 115 mm, wall thickness 11 mm. c - Turbine: outer diameter 600 mm, wall thickness 20-30mm.

3 Results and discussion

The parameters of scanning modes for tubes and turbine are given in Table 1.

Table 1. Parameters of scanning modes for tubes and turbine.

Object	Accelerating voltage / kV	Tube current / mA	Copper filter thickness / mm	Number of projections	Angular pitch /degree
Tube1	300	1600	2	4800	0.051
Tube2	450	1700	2	4800	0.051
Turbine	450	1700	4	4800	0.051

The clear external boundary of the tube we can see in Figure 2. The internal boundary is more noticeable in Figure 2d in compare with Figure 2a. It was resulted due to the increase of tube current and corresponds to the work [11]. After segmentation, we get the inner and outer radius of the tubes, the wall thickness and relative error, presented in Table 2.

Table 2. Measured sizes of tubes and their errors.

Object	Inner radius / mm	Outer radius / mm	Wall thickness / mm	Standard value / mm	Relative error / %
Tube1	19.32	23.49	4.17	4	4.25
Tube2	48.36	59.69	11.33	11	3.0

Figures 2 and 3 show images obtained by use VGStudio MAX 2.2.

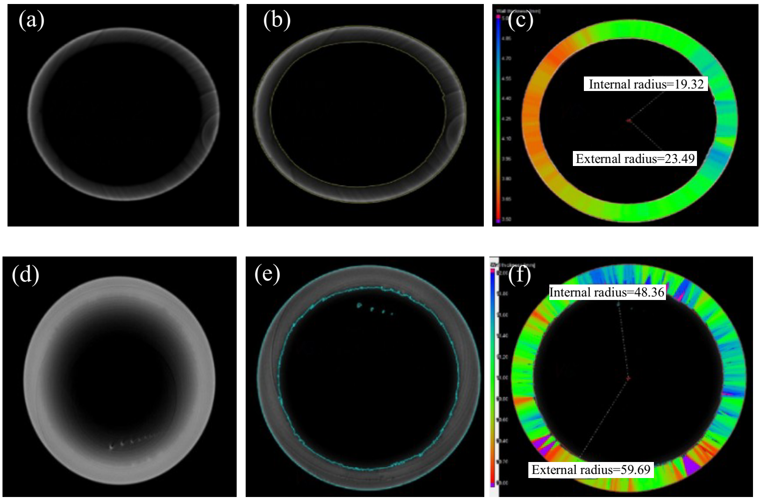

Fig. 2. a,d - 2D tomographic slice; b,e – Segmentation; c,f - Measurement of internal and external radius.

From the radiography Figure 3a, it was selected one sector of welding and shown in Figure 3b. The boundaries and defects shown in Figure 3c.

In order to reduce scattered radiation and obtain a clear inner boundary of the tube, we use gravel as absorber. Scanning mode was the same as in Table 1 for turbine. The result image is shown in Figure 4. In comparison with Figure 2d, the inner boundary became more pronounced.

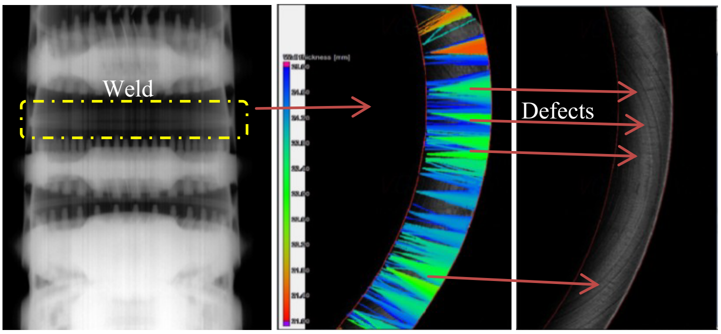

Fig. 3. a - Radiography, b - The definition of the weld thickness, c – Defects in weld joint.

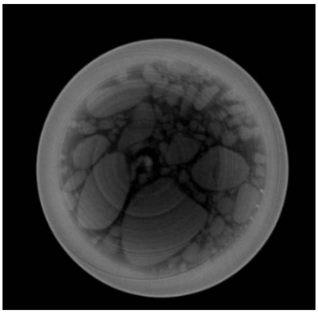

Fig. 4. Tomographic slice with gravel.

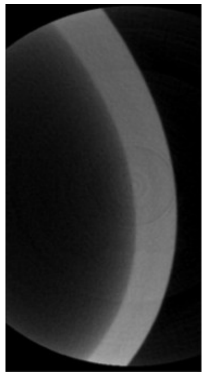

Fig. 5. A slice of turbine sector produced by the betatron tomography.

Figure 5 shows one sector of turbine, reconstructed for energy of betatron 3.5 MeV and for angle pitch 0.18 degrees. One can see that the inner boundary of the turbine is more clearly in comparison with Figure 3c.

4 Conclusions

Experimental results indicate that the high-energy X-ray CT system can determine the wall thickness of the tube and the weld thickness of turbine with high accuracy. The weld joint defects are identified by the tomographic measurement of the weld thickness. That can help to enhance the turbine welding technology and to prolong the turbine service.

We get a clear inner boundary of the tube by using gravel as absorber or betatron as radiation source. These results indicate that using absorber or increase the scanning energy are feasible methods to improve the image quality.

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