Recognition and Measurement of Small Defects in ICT Testing

Guo ZHIMIN, Ni PEIJUN, Zhang WEIGUO, Qi ZICHENG
Inner Mongolia Metallic Materials Research Institute, Ning bo, China
(Contact e-mail: nbbkyndt@163.com)

Abstract. This paper is based on the application of industrial CT testing in precise electron beam weld of precise part. Based on the existing industrial X-ray CT detection equipment, this project is aimed at resolving identification problem for small defects under the uncertainty of test result. This project is aimed at resolving identification problem for small defects under the noise, researching the measurement methods of small defect, and analyzing the uncertainty of test result. This paper combined with theoretical analysis and experimental research to reveal the influence rule of the noise on the small defects of the CT image, and established the statistical measurement models of recognition and the measurement of small defects. This paper research engineering applications closely, and integrated industrial CT practical application to solve the basic problems of the key research work to improve the accuracy of small welding defects of industrial CT quantitative non-destructive testing.

Introduction

In the process of the industrial CT detection, defect can be found is different with the defects can be distinguished or defect size can be measured. For example, BIR Company’s product ACTIS 300 industrial computed tomography (CT) system in the United States, this system can find single artificial defects with the diameter of 0.05 mm, but it’s hard to tell apart spacing of 0.05 mm of two adjacent holes with the diameter of 0.05 mm. During the experiment, the system take the full width half maximum method (FWHM), and the measurement results is 0.2 mm, the measurement error reach 400%. A large number of tests proved that when the defect size is very small, the size accuracy of measurement error is large, when the defect size is very big, traditional measuring method and error of the full width half maximum method (FWHM) is relatively small.

In view of the defect size, how can we apply the traditional measuring method and a half high width to achieve the better test result? In the practical test, many kinds of industrial computed tomography (CT) were used, for example, 160 -225 kV nano-tubes low-power CT, 225-600 kV conventional X-ray industrial computed tomography (CT), and high-energy industrial computed tomography (CT). The work piece size and equivalent steel penetration thickness is different, and the spatial resolution of the equipment also different.

Generally, the spatial resolution of nano-tubes CT or micro-focus CT can reach dozens of line pairs per millimetre, but the small focus also product small power, lower radiation dose, and longer sampling time, but defect detection can reach micron grade. Conventional X-ray industrial computed tomography (CT) has a small focus usually around 0.5 mm, tube current is controlled under 2 mA, cooperate with suitable detector, the spatial resolution can
reach 5 line pairs per millimetre. Defect detection can detect the defects of decades - a few hundred microns.

The focus size of the high-energy industrial computed tomography (CT) is about 2 mm, because of high radiation energy, the thicker the probe is needed to get effective energy deposition, so the probe channel size is larger, the spatial resolution is usually around 2.5 - 5 line pairs per millimetre. Defects can be checked out the defects of a few hundred microns.

Therefore, small defects are not an absolute dimensional constant, according to different industrial CT system, and different detection technology, the size of the small defects is also changing. This paper describes a measurement method based on statistical method, to resolve small size defect size measurement [1-3].

**Analysis**

Mathematical principles of Industrial CT detection are Radon transformation and Radon inverse transformation, and the reconstruction algorithm is also based on this mathematical formula. But in the process of the concrete implementation of the industrial CT, the mathematical principle of condition is different, mainly reflected in the gamma ray source is an ideal focal point in theory, but the focus is a certain size of the surface in fact, the data acquisition is an infinite number of angles in theory, but the data is limited in fact, And there is no noise in the CT system is the precondition of theoretical derivation.

Because the difference of actual implementation and principle of hypothesis above, causing the CT image of object is a limited fuzzy representation. According to standard ASTM E 1441, in the process of Point Spread Function (PSF) available (Point Spread Function, the PSF) and the effective beam width (BW) of systems described with details of the convolution. Relative to the different size details, relationship between details and the background of real contrast (line attenuation coefficient difference) shown in figure 1. And the background and display contrast (CT images of the background between CT value and the detail parts) also shown in figure 1.

![Fig.1 Influence in CT reconstruction of point spread function](image)

SW details can be seen from the diagram, when the size is smaller than the effective beam width, the point spread function (PSF) of system reduces the contrast details, and the contrast difference from the real contrast \( \Delta \mu \) drop to \( \Delta \mu (SW/BW)^2 \), the width of the details of the image increase at the same time; When the details size is equal to the effective beam width, the contrast the is same as the real contrast \( \Delta \mu \), details of the image at the same time into the bottom of 2 BW cone; When details of LW is greater than the effective beam width size, detail images into the bottom for (BW + LW), on the bottom (LW - BW), poor contrast.
for $\Delta \mu$ frustum of a cone. Point spread function (PSF) obviously, little influence on the characteristic of diameter greater than the details of the BW, and centre according to contrast the same as the real contrast \cite{4}.

In this paper, detailed features can be treated as defects. By the above analysis shows, small defects concept is not an absolute value, should be a relative value; According to different equipment, different detection technology, small defects of absolute value is different; the definition of small defects should be associated with BW value. So we can say when the defect size less than BW value can be considered a small defect.

**Small defect measurement algorithm**

The analysis shows that when the details size less than BW, CT image detail size increases, the display contrast is reduced, the conventional half high width method to measure the defect, size measurement, the deflection is no longer applicable. According to ASTM E 1441, when the details of the theory finally fuzzy feature sizes will be increased from (SW) to (BW+SW), the contrast decrease at the same time. But found in the actual process, because of the influence of noise, the actual situation is more complicated, but the change trend of the defects in CT image should have reference value. This paper using the change trend, design corresponding algorithm to measure small size defect.

Medical CT, the CT value has a strict definition, industrial computed tomography (CT), due to the regulation of CT value is not strict, can also be considered defective parts on CT image and the background pixel values of the difference between. Scanning process parameters of reconstruction matrix, the gamma ray source size a range, a single detector channel size , detector interval H, gamma ray source to the detector distance L, ray distance q, the source to the work piece the work piece material equivalent steel coefficient alpha, equivalent radiation energy data, and through the formula to calculate the value of the effective beam width BW in detail to observe the image characteristics, determine the detail characteristics of the required size measurement. In CT image characteristics near the place, and there is no obvious flaw work piece on the background of the selected area, an area of not less than 400 pixels and determine its CT average Aver, CT Max maximum, minimum, CT region standard deviation to Sd. A contains the detail feature selected area W, area for more than three times the size of the need to measure size. Statistical computing all pixels within the selection $f(x_i, y_j)$, including pixels on the boundary point, calculation of each pixel and the Angle of the centre pixel. The value is greater than 3 meter feature points for details (feature point number plus 1 for details), or discarded. Calculate the size of the individual pixels size $D/H$, features of $T_d$ = calculating details points by the number of pixels size square, $T_d$ - BW width after converted into equivalent diameter, the result is the detail characteristics of the final size.

**Experiment**

We choose the stainless steel design reference block, the corresponding to the reference block design and the material object as shown in figure 2, figure 3.
Fig. 2 Diagram of the reference block
(D: diameter of block, d: diameter of the hole, h: thickness of the block)

Testing equipment uses IPT6110 6MeV high-energy industrial CT system, the slice thickness is 0.3 mm, triggering frequency is 8192 Hz, micro motion is 10 times of 1.2 RPM, image size is 4096 × 4096, reconstruction of radius is 80 mm, figure 4 - figure 8 were the CT images of diameters of 0.2 mm to 0.6 mm artificial hole reference block.
Respectively using traditional full width half maximum method (FWHM) and the algorithm of this article describes software written (see figure 9) of the artificial hole size measurement, the measurement results are shown in table 1.

<table>
<thead>
<tr>
<th>Diameter</th>
<th>0.2mm</th>
<th>0.3mm</th>
<th>0.4mm</th>
<th>0.5mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half wave height method</td>
<td>0.28</td>
<td>0.33</td>
<td>0.46</td>
<td>0.55</td>
</tr>
<tr>
<td>Test method of this paper</td>
<td>0.17</td>
<td>0.32</td>
<td>0.43</td>
<td>0.51</td>
</tr>
</tbody>
</table>

In the process of measurement, the method of half wave height measurement repeatability is very poor, different personnel measurement result is different, the same measurement of personnel in different time measuring deviation is big, the main reason is the increasing of small defects, the artificial hole place in CT image, the influence of the noise and the point spread function (PSF), will have a great shape deformation. So the same defects of different direction measurement results have very big difference.

Methods in this paper because of less human disturbance factors in the whole measurement process, so the repeatability is good, in good defects after the selection box size, different people, different time measurement error in 2 decimal places without any deviation. Table 1 and by the measurement data can be found in this paper, the method of measuring results is better than half wave height method.
Inclusion

Algorithms is introduced in this paper considering the CT detection in the process of the process parameters, the focus of gamma ray source size, the size of the detector channels, the influence of such factors as size measurements for small defects is superior to the traditional method of half wave height, and have good practical value.

Reference:


