Industrial Detection Efficiency Based on Automatic Industrial CT Detection System

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Abstract. With the rapid development of industrial technology, nondestructive testing technology has been widely used in industry. Automatic industrial CT testing is an effective method for nondestructive testing of internal defects of large workpieces. In the 1980s, China began to study industrial CT technology. However, due to the limited conditions and demand, the automatic industrial CT has not been put into use. In this regard, the purpose of this paper is to explore the efficiency of industrial detection under the automatic industrial CT detection system. In the actual X-ray CT inspection, for the small workpiece with complex internal structure, the best detection method is to detect along the section of the internal structure of the workpiece, so that the collected data can make CT imaging clearer. At the same time, with the acceleration of nondestructive testing automation process, the traditional rotary table X-ray CT detection system has been unable to meet the needs of actual production testing. According to the existing problems, a new automatic CT detection system is proposed in this paper. The system is a CT system based on 6-DOF Industrial robot. It has 6 spatial degrees of freedom, which can flexibly realize the clamping and spatial positioning of parts. It is an effective solution to replace the rotary table for radiographic inspection. And only according to the reasonable design of the clamping device according to the testing parts, it can be directly applied to industrial production, which speeds up the development process of nondestructive testing automation technology. Finally, this paper compares the CT detection system with the traditional industrial detection system, and studies the industrial detection efficiency of the two systems. The experimental results show that the efficiency of CT detection system proposed in this paper is 33% higher than that of traditional industrial detection system. At the same time, the proposed CT detection system provides a feasible solution for the automation of industrial X-ray CT detection.

Keywords: Automatic Industrial CT Detection; Traditional Rotary Table X-Ray CT Detection; Comparative Experiment; Industrial CT Technology

1. Introduction
With the rapid development of social economy, the labor cost of enterprise production is not only rising, but also human resources are becoming increasingly tense. The mode of low cost, high efficiency and high income is the production mode that any enterprise pursues and yearns for, which is
more needed in manufacturing industry and OEM industry. In recent years, with the rapid development of computer technology and the rapid innovation of automation technology, automatic industrial CT detection system has been gradually applied to industrial production. Relying on its advantages of high work efficiency, requiring only a few or no people to participate, it is gradually widely used in industrial production by enterprises. This is also a new direction for the future development of manufacturing industry.

Industrial CT detection is of great significance to military products. Great importance has been attached to its development and research at home and abroad. Foreign Jaber proposed an intelligent automatic CT detection algorithm. Firstly, the adaptive threshold segmentation algorithm is used to segment the image, and then the features are extracted from the segmented image. Finally, the defect is classified by the recognition algorithm. This method can automatically detect defects, but the difficulty lies in the establishment of all defect databases [1]. In China, Tong Zheng Rong studied an adaptive defect recognition method for industrial CT images based on innovation orthogonality. Firstly, the two-dimensional state space model of projection image was established, and then the dynamic evaluation function of defect image area size and gray level was defined. Finally, the image data adaptive compensation algorithm was proposed[2].

In this paper, the efficiency of the proposed automatic industrial CT detection is compared with that of the traditional CT detection under the environment of vigorous development of industrial CT detection technology at home and abroad. In this paper, first of all, through consulting the relevant information, it is important to realize the automation, high efficiency and intelligence of industrial CT image defect detection, and to study a more intelligent defect detection algorithm is very important. Therefore, this paper proposes a new automatic industrial CT detection system to replace the traditional industrial CT detection. The automatic industrial CT detection system proposed in this paper improves and improves the algorithm, and has higher efficiency than the traditional industrial CT detection. It is of great significance to the development of industrial CT detection.

2. Technical Research on Industrial Detection Efficiency Based on Automatic Industrial CT Detection System

2.1. Basic Process of Industrial X-ray CT Testing
The basic process of industrial X-ray CT inspection is as follows: firstly, the corresponding voltage and current parameters of the ray source are set to make the ray source emit the corresponding energy rays, and the ray passes through the workpiece to be measured and attenuated. The detector detects the attenuated ray and converts it into corresponding electrical signal according to its intensity; then, the A/D of the data acquisition system is converted into digital projection value and send it to the computer, which is stored by the computer [3]. After that, it controls the translation and rotation of the scanning mechanism to obtain enough projection values; then the computer system uses the phase according to the different acquisition modes the image reconstruction algorithm should be used to reconstruct the sectional image, and then the specific situation of the obtained image is processed accordingly. Finally, the sectional image is analyzed and quantified, and the internal defects of the detected workpiece are obtained, and the reconstructed sectional image is stored and filed [4].

2.2. CT Scanning Mode
CT technology began to enter a period of rapid development, and the CT scanning mode was also quietly changing [5]. At the beginning, parallel beam scanning was developed to small fan angle fan beam scanning, large fan angle fan beam scanning, circular cone beam scanning, single/multi-layer spiral scanning, and finally spiral cone beam scanning. With the evolution of scanning methods, the scanning efficiency is getting higher and higher. The following is a brief introduction to the scanning mode of CT.

2.2.1. First generation CT system
The first generation of CT system is a parallel beam scanning CT system. The system consists of a ray source which can only emit one X-ray beam and a single detector unit. During scanning, the radiation source only emits one beam of X-ray at a time, and it is accepted by a single detector unit through the workpiece to be tested. Only one projection data can be obtained each time. Therefore, in each angle, it is necessary to synchronize the translation of the source and the detector to obtain the complete projection data at that angle. Then, the workpiece is rotated to the next projection angle or the X-ray source and detector are rotated to the next projection angle to obtain the complete projection data at the second angle. In the same way, enough projection data is obtained until one rotation to complete the reconstruction of the image of the workpiece to be measured. The first generation CT system has the advantages of simple design and wide range of application, but its scanning efficiency is low, which can’t meet the needs of daily detection.

2.2.2. Second generation CT system
The second generation CT system uses small fan angle fan CT scanning system, and also adopts translation and rotation scanning mode. However, it is different from the first generation CT in that small angle fan-shaped ray beam is used instead of single beam, and one-dimensional short linear array detector is used instead of single detector unit. This scanning method can detect a wide range of objects, and the scanning time has been improved compared with the first generation CT system, but it still can not meet the requirements of people for detection efficiency, and the scanning method is easy to generate a large number of redundant data.

2.2.3. Third generation CT system
The third generation of CT system will be the second generation of CT system after increasing the fan angle of ray beam and lengthening the length of one-dimensional linear array detector, which is called fan beam scanning CT system with large fan angle [6]. The large fan angle fan beam can completely cover the fault of the object to be measured, so the ray source and detector do not need to make translation movement at each projection angle, only need to rotate to complete scanning, so the scanning time is greatly reduced, so it is widely used in medical diagnosis and industrial detection.

2.2.4. Fourth generation CT system
The fourth generation CT scanning system is almost the same as that of the third generation CT system. The difference is that the fourth generation CT system replaces the linear detector array in the third generation system with a fixed closed ring detector. During scanning, the object to be measured is placed at the center of the ring detector, and the ring detector is fixed. The whole scanning can be completed only by rotating the radiation source [7]. The advantage of the system is that it has a good ability to resist ring artifacts, and the stability and scanning speed of the detector are greatly improved compared with the third generation CT system. The disadvantages are complex structure, high cost and easy to be affected by X-ray scattering.

2.2.5. Fifth generation CT system
The fifth generation of CT system is spiral CT. The scanning mode of spiral CT increases the scope of CT imaging and enhances the detection ability of traditional CT. In the spiral CT system, the ray source and the detector rotate synchronously, and the object to be measured moves along the axis of rotation at a certain speed, so that the projection data can be obtained continuously. Since the motion track of the ray source relative to the detected object is a spiral line, it is called spiral scanning. In this way, the projection data of the whole part of interest can be obtained by multi circle spiral scanning. Spiral CT can be divided into single-layer spiral and multi-layer spiral. Multi-slice spiral is developed in single-layer spiral. The detector of single-layer spiral CT is a single row linear array detector [8]. Later, in order to obtain the higher efficiency of spiral slice, such as 256 slice, 16 slice spiral slice and so on, were proposed.
2.2.6. Sixth generation CT system

The sixth generation CT system is cone beam CT system. Cone beam CT can solve the problems of multi-slice spiral CT reconstruction image longitudinal artifacts, poor axial resolution and high scattering. Cone beam CT system uses high-density flat-panel detector, which has the advantages of fast scanning speed, high X-ray utilization rate, consistent axial resolution and horizontal resolution of reconstructed image, etc. According to the scanning mode, it can be divided into circular trajectory cone beam scanning and spiral trajectory cone beam scanning. The circular trajectory mode is displayed. It is necessary to adjust the position of the object to be tested so that the detected part can completely enter the cone-shaped ray beam area. The ray source and panel detector can complete the scanning by rotating around the rotation axis of the object to be measured. For the workpiece with long length to be measured, there is no way to fully include it into the ray area, which needs to be realized by spiral cone beam scanning or image splicing in the later stage [9].

2.3. Physical Basis of CT Examination

The automatic CT detection in this paper is based on the X-ray attenuation law. When the ray passes through a certain material, the ray will decay, and the attenuation obeys Lambert Beer's law.

$$I = I_0 e^{-\mu \Delta x} \quad (1)$$

The formula is the X-ray attenuation formula, where $I$ is the ray intensity of the original single energy, $I_0$ is the ray intensity after the ray passes through the material, $\mu$ is the linear attenuation coefficient of the object material, and $\Delta x$ is the thickness of the material. The formula shows that the narrow single energy X-ray photons in homogeneous materials decay according to simple exponential law. In fact, $\mu$ is a physical quantity which changes with the incident ray energy and the selected material. If the equivalent atomic number of the material is expressed by $Z$ and its density is expressed by $\rho$, then the linear attenuation coefficient $\mu$ should be written as $(\mu, \rho, Z)$. In this case, when the radiation intensity of each element is not uniform, it can be described as the attenuation coefficient of each element. When a single energy X-ray passes through a series of small elements, the output beam current of one element is the incident beam of the next, which can be expressed by the following formula:

$$I = I_0 e^{-\mu_1 \Delta x} e^{-\mu_2 \Delta x} e^{-\mu_3 \Delta x} \cdots e^{-\mu_n \Delta x} = I_0 e^{-\sum_{n=1}^{N} \mu_n \Delta x} \quad (2)$$

Where $n$ is the number of cascaded units.

In the application of CT, $I_0 \Delta x$ represents the intensity of incident X-ray, which should be constant in principle. Therefore, this formula can be standardized when the unit thickness is taken as infinite hours

$$p = -\ln \left( \frac{I}{I_0} \right) = n \frac{l_0}{T} = \int L \mu_n dx \quad (3)$$

Where $L$ is a straight line in the x-axis direction. The above calculation shows that there is a cascade linear relationship between the incident intensity $I_0 \Delta x$ of a single energy X-ray beam with sufficiently small cross-section and the negative logarithm of the ratio of X-ray intensity $I_0$ after attenuation along a straight line along the x-axis direction [10]. $P$ is the projection data we need to get, which is numerically equal to the line integral of the attenuation coefficient on the X-ray path.

3. Experimental Study on the Efficiency of Automatic Industrial CT Detection and Traditional Industrial CT Detection

3.1. Experimental Data

The experimental results are as follows. The number of defects detected by automatic industrial CT system is 8, the image integrity is 10, and the number of bright spots presented by defects is 8. The number of defects detected by the traditional industrial CT system is 6, the image integrity is 7, and the number of bright spots presented by defects is 5. The number of defects detected by automatic
industrial CT system every five minutes are 16,34,46,58,63 respectively. The number of defects detected by traditional industrial CT system every five minutes are 9,17,23,36,44 respectively.

3.2. Experimental Process
This paper compares the detection efficiency of automatic industrial CT with the traditional second generation CT system. First prepare a batch of defective industrial parts, the size of the selected parts should not be too large. After that, the second generation CT detection system and the automatic industrial CT detection system proposed in this paper are used to test the parts respectively. Under the condition that the detection time is the same, two kinds of CT images are generated respectively. Finally, the number of detected defects, image integrity and the number of bright spots presented by defects were recorded by comparing the CT images presented by the two images, and the detection efficiency of the two images was compared. The detection time selected in this experiment should not be too long, otherwise the generated CT images may be similar, which is not convenient to compare the detection efficiency. In order to make the comparison results of detection efficiency more intuitive, we display and save the images generated by the two CT detectors every five minutes until the end of 25 minutes. Record the number of defects detected every five minutes.

4. Experimental Analysis on the Efficiency of Automatic Industrial CT Detection and Traditional Industrial CT Detection

4.1. Drawing Parameters of Automatic Industrial CT Detection System
In this paper, the new automatic CT detection system and the traditional industrial detection system are used for direct drawing, and the overall effect map, slicing and local magnification of the two systems are compared. The results are shown in Table 1 and Figure 1.

| Density | Brightness | Transfer Offset | Transfer Scale | Fps  |
|---------|------------|-----------------|----------------|------|
| New system | 0.05f | 5.40f | 0.00f | 2.16f | 61.5 |
| Traditional system | 0.05f | 3.80f | 0.80f | 1.0f | 62.1 |

Figure 1. Drawing parameters of automatic industrial CT detection system

From the experimental data, we can see that the automatic CT detection system proposed in this paper has better rendering parameters than the traditional industrial detection system, so the rendering effect is much better. This is because the automatic CT detection system proposed in this paper can
achieve high-quality real-time rendering, and the rendering results have clear structure, no obvious aliasing and quality loss, and fast interaction. Compared with the effect of realistic direct volume rendering technology, it can display the defect characteristics complementary, obtain the three-dimensional industrial component intuitive image, and obtain the three-dimensional shape of the defect scientifically and accurately. The information of shape, spatial position, spatial size and density distribution can effectively solve the problem of detecting the internal non-obvious boundary defect structure of castings, and provide theoretical and experimental models for further scientific and accurate research on the types and grades of internal defects of components, accurately determine the serviceability of components and evaluate the service life, and study the defect repair.

4.2. Industrial Detection Efficiency of Automatic CT Detection System
In this paper, the new automatic CT detection system and the traditional industrial detection system are used to detect the defects of a batch of parts, and the effective detection number is counted every five minutes, and then the detection efficiency of the two systems is analyzed. The experimental results are shown in Figure 2.

![Figure 2. Comparison of detection efficiency](image)

From the experimental data, we can see that the defect detection efficiency of the automatic CT detection system proposed in this paper is much higher than that of the traditional detection system, and the quality is high. There is a big gap between the two. This is mainly because the system is based on the 6-DOF Industrial Robot CT system, which has 6 spatial degrees of freedom, can flexibly realize the clamping and spatial positioning of parts, and is an effective solution to replace the rotary table for radiographic inspection. And only according to the reasonable design of the clamping device according to the detection parts, it can be directly used in industrial production, so its degree of automation is very high. And the research work of industrial CT non-destructive testing volume rendering technology is mainly focused on the display and analysis of data, which can better show the body details of industrial CT detection objects, create a real three-dimensional working environment in line with human operation habits, so that users can easily and directly operate and observe the information represented by the data, and then carry out realistic dynamic simulation.

5. Conclusions
This paper studies the efficiency of industrial detection based on automatic industrial CT detection system. By comparing the traditional industrial detection efficiency, this paper highlights the advantages of the automatic industrial detection efficiency proposed in this paper. The experimental results show that the traditional detection method can detect the object size range is general, the scanning time can not meet the requirements of people for detection efficiency, and the scanning
method is easy to generate a large number of redundant data. The automatic industrial CT system proposed in this paper adopts high-density flat panel detector, which has the advantages of fast scanning speed, high X-ray utilization rate, consistent axial resolution and horizontal resolution of reconstructed image, and can meet the needs of people for detection efficiency and accuracy. Therefore, the automatic industrial CT detection system will be widely used in industrial production, which is of great significance to industrial CT detection.

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