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Application of full data acquisition technology in automatic ultrasonic inspection

Yongping TENG, Di WU, Zhongling ZHAO
Beijing Jiaotong University
Shangyuancun 3, Hai Dian District, Beijing 100044, China
Tel: +86-10-51687052, Fax: +86-10-51688213
E-mail: ypteng@bjtu.edu.cn, diwu@bjtu.edu.cn, zhlzhao@bjtu.edu.cn

Abstract

The ultrasonic full data acquisition method was that all the waveforms from every channel at each TR time were recorded in the real-time testing. Using the full data, many kinds of post processing methods could be used to identify the flaws, such as the image processing, the flaws identification, the image display and the detection process playback. This article represented the realization method of full data acquisition technology and introduced its applications in the automatic multi-channel detection for the work pieces such as the center bore of turbine rotor, the locomotive gear, the locomotive axle and the petroleum drilling rod joint. Finally, the full data acquisition technology was compared with the traditional automatic multi-channel inspection method and its characteristic was summarized.

Keywords: Ultrasonic testing, Multi-channel, Automation, Full data acquisition

1. Introduction

The ultrasonic multi-channel automation inspection system was applied to inspect the standard work piece with fast speed. The general system had the large probe quantity and few probe types and the flaw signal was easy to be identified. For example, five probe types (altogether 450 probes) were used for the on-line ultrasonic inspection of locomotive wheels [1]. In the pressure vessel or seamless steel pipe ultrasonic inspection systems (UT & Thickness gauge), three probe types (used to wall thickness gauge, transverse flaws, longitudinal flaws, altogether 32 probes) could satisfy the inspection request [2].

However, for the non-standard work piece, the inspection was hard to be implemented because of the changes of inspection parameters (such as sensitivity, refraction angle, and so on) and the testing region while the probes moved to the different position of the work piece.

Different inspection methods were adopted regarding to the particularity of the non-standard work piece inspection. One method was appending mathematical model of the work piece shape into the inspection software, simultaneously establishing the database about the inspection parameters and the work piece shape. The inspection system adjusted the real-time inspection parameters and distinguished the flaws automatically. Another method was gathering all waveform data of each probe and simultaneously saving the waveform data and shape parameters of the work piece and got the flaw information by data post-processing. The latter was called the full data acquisition method.

2. Full data acquisition method

The plate inspection was taken as an example to demonstrate the full data acquisition method. The plate inspection usually used the straight beam probe with the contact coupling or water immerging method. The typical waveform was shown in Figure 1. Gate G-I was the tracking gate of the interface echo, only applied in the water immerging inspection method. Bottom echo gate G-B was available to monitor the ultrasonic penetrability or the coupling condition. Flaw gate G-F was used to detect internal defect in the plate. In general application, one G-I gate, one G-B gate and one or more G-F gates were used.

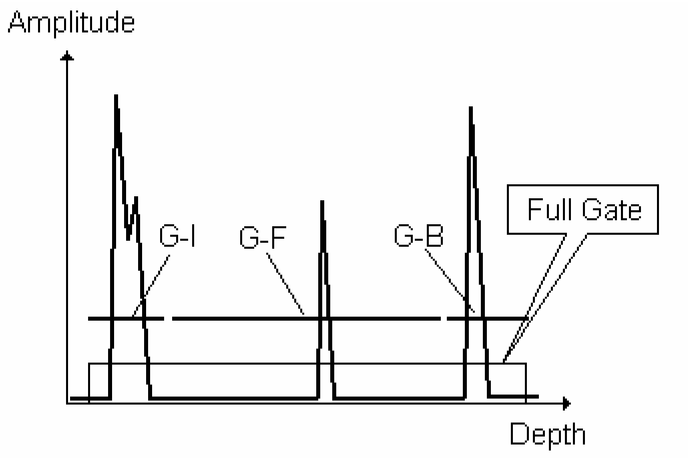

Figure 1. Full data acquisition gate

Considering the changes of water thickness and the plate thickness, the width of three gates (G-B, G-F, G-I) must have certain redundancy, which had certain gaps between the gates in the plate inspection. Otherwise, the system was possible to fail to detect the flaws or get the misinformation. Therefore, dead zone of upper surface and undersurface of the plate inspection were increased.

When using the full data acquisition method, only one gate was used and its width was wide enough to cover all echoes. The flaw information was withdrawn after necessary process to the data. This method could reduce dead zone of the inspection at maximum limit.

The full data acquisition method required the inspection equipment have the large data storage space, the high data transmission and processing speed. The data transmission speed of A/D conversion data of ultrasonic signal was the key to affect the inspection speed in the method. Generally DMA of PCI bus or AD data acquisition card on EPCI bus could be used to enhance data transmission speed. Besides, the technology of the DSP or FPGA could be used to process the data and transmit effective data alternatively. Moreover, the multi-channel parallel work mode could be used to increase the speed of the full data acquisition.

3. Typical application of full data acquisition

3.1 Ultrasonic automatic inspection for center bores of turbine rotors[3]

This inspection system used the straight beam probe to detect internal flaws of the rotor, as shown in Figure 2(a). Double channels were used, probe A was to detect the deep region and probe B to detect the near surface region. The scan mode of the probes was “revolving - step - reverse revolving - step ”.

Because the wall thickness of different position was possibly different, the inspection system needed to track the position of bottom echo to determine the effective scope of the inspection depth. The full data acquisition display and image processing result was shown in Figure 2(b).

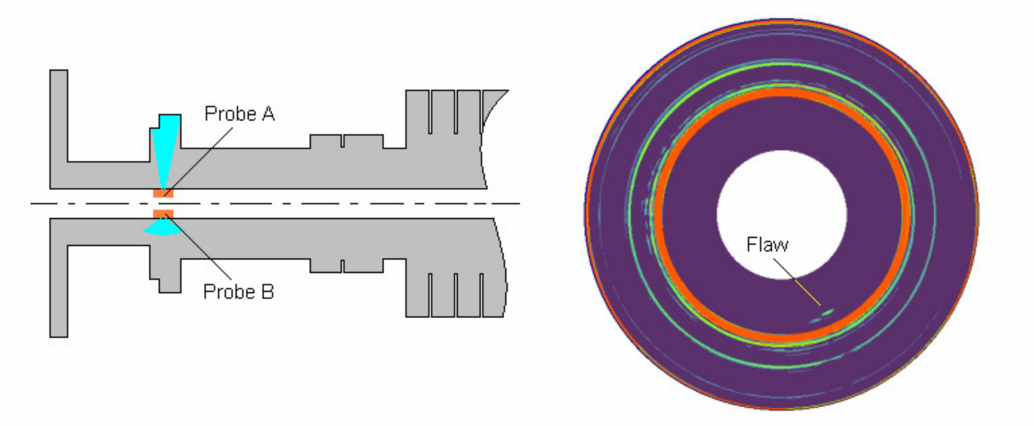

Figure 2. Ultrasonic automatic inspection for rotors center of turbine bores:
(a) Schematic drawing (b) Full data B image

3.2 Ultrasonic automatic inspection for locomotive drive gear [4]

This system used 8 channels to detect flaws at the root region of gear from different angles shown in Figure 3(a). The probes were fixed while gear was revolving in the inspection process. The shape echoes of gear root were strong and the moving scope was large. But because the flaw echoes of gear root were in the moving scope of the shape echoes, the system was unable to use the fixed gate to identify flaws.

Because the shape echoes had the obvious characteristic shown in Figure 3(b) after full data acquisition, the oblique line integral method could be used to identify the flaw signal from the shape echoes.

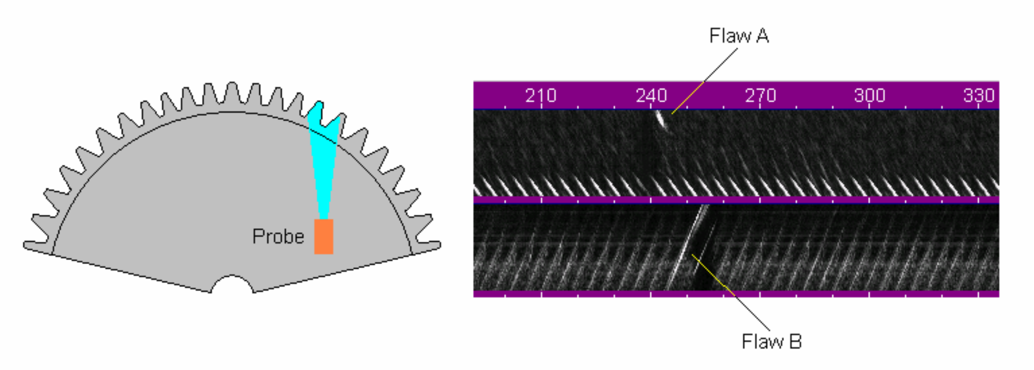

Figure 3. Ultrasonic automatic inspection of locomotive drive gear:

(a) Schematic drawing (b) Full data B image

3.3 Ultrasonic automatic inspection for drill head [5]

This system used 24 independent probes of two types, dividing into 4 groups and 6 probes in each group. Probe A was used to detect the transverse flaws, installed according to the sound beam direction (front or back of the axis). Probe B was used to detect the longitudinal flaws, installed according to the sound beam direction (left or right of the axis). The head revolved and probes moved according to different areas of the head during detection.

Because the shape of head had the characteristic of variable outer diameter and wall thickness, any inspection channel was unable to use the fixed gate. In this circumstance, the full data acquisition method could be used and shown in Figure 4(b). The full data contained the flaw echoes and the shape echoes and the flaw signal could be identified through image processing.

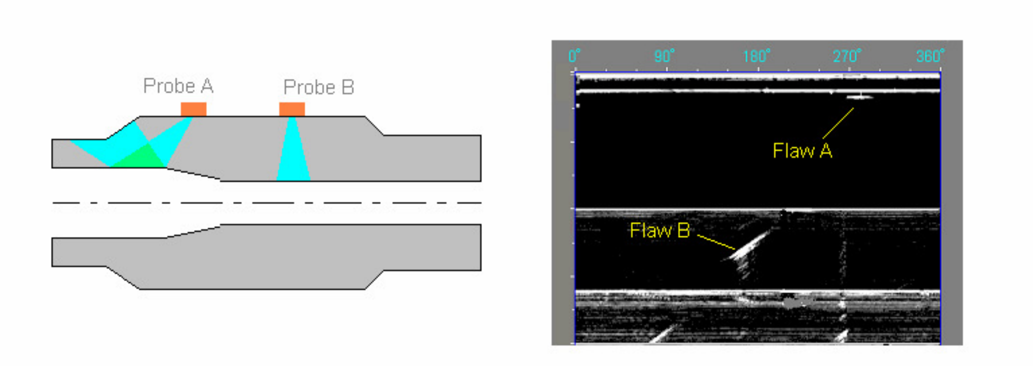

Figure 4. Ultrasonic automatic inspection for drill head:

(a) Schematic drawing (b) Full data B image

4. Image display and post-processing

Taking the CZT24 ultrasonic automatic inspection system for the radial inspection of the locomotive axle as an example here, the commonly used display and the data processing method was explained in the full data acquisition.

4.1 Mathematical model

The CZT24 system used 24 independent probes to inspect internal flaws of axle and ultrasonic penetration. All probes were the same type and divided into 4 groups. Each probe group had 6 probes and installed on one scanner. The four scanners were driven by four servo motors. When the inspection started, one servo motor drove axle revolving. At the same time, four scanners inspected the axle moving along the axial direction.

Regarding to the axle of any specification, the inspection surface was divided into the different inspection parts. When the operator inputted the coordinates of each part, the mathematical model of the scanned axle was established and the 4 scanners were assigned to scan the different parts. Each scanner moved and inspected independently according to respective track during inspection. The tracks were shown in Figure 4.

The mathematical model could be used both in contact coupling inspection and in water immerging inspection.

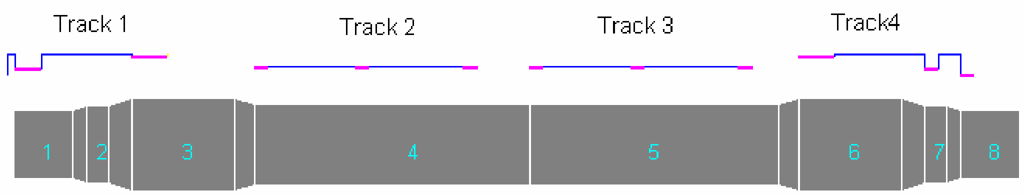

Figure 4. The mathematical model of the axle inspection

4.2 Image display

The CZT24 inspection system used the full data acquisition method. The gate contained the interface echo of minimum axle diameter and the bottom echo of maximal axle diameter. Figure 5 was the data display software interface. C-SCAN and B-SCAN were the real-time inspection display images. A-SCAN was the post processing waveform playback window, demonstrating both the frozen waveform of one position and dynamic waveform playback of entire inspection process. In addition, the system could also choose the real-time B scanning image of axle profile, as shown in Figure 6.

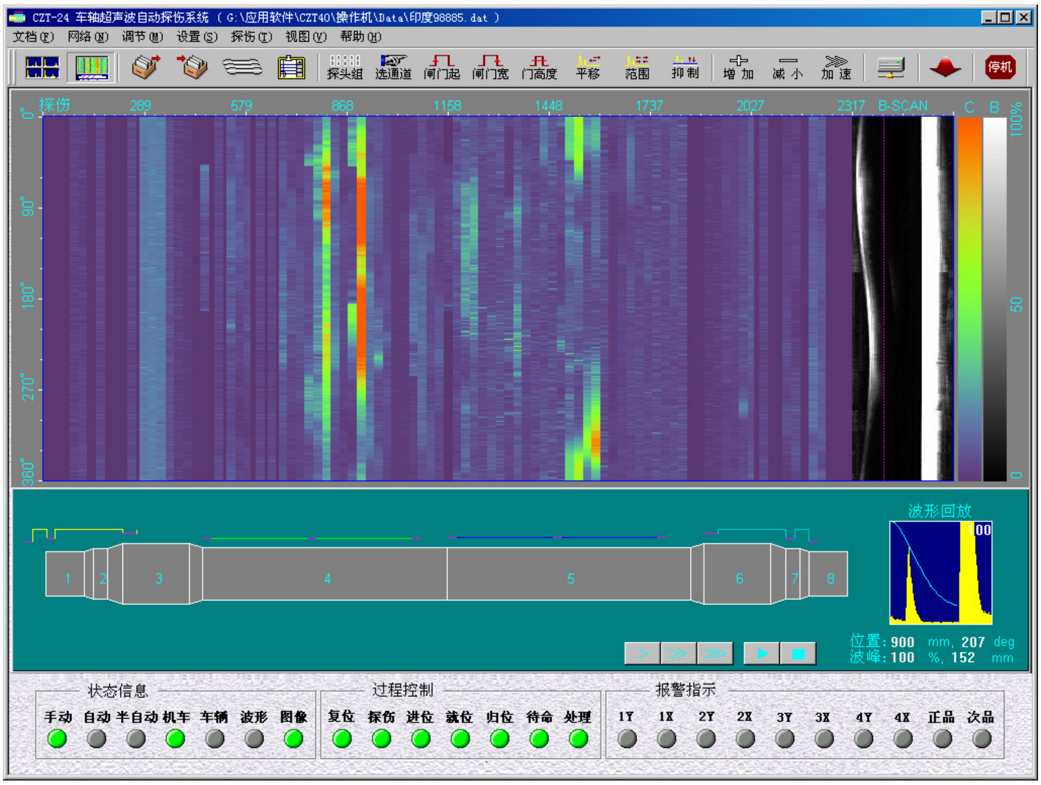

Figure 5. Automatic ultrasonic inspection image display for axle

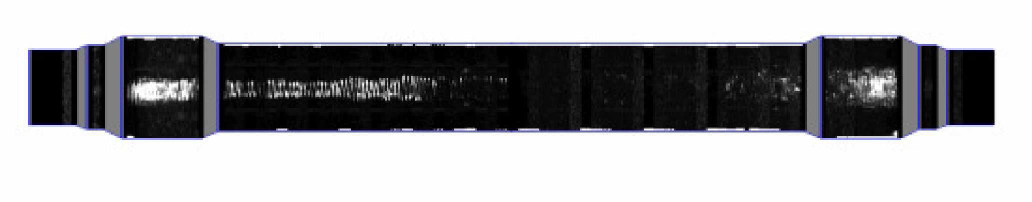

Figure 6. Full data B image for axle automatic ultrasonic inspection

4.3 Image processing and flaw identification

According to the UT standard, the different inspection sensitivity must be used when detecting the axle of different outer diameter. The different sensitivity in the identical position was also used to inspect the internal flaws and ultrasonic penetration separately (inspecting bottom echoes). Based on mathematical model in the CZT24 system, the inspection sensitivity for each probe was first set to detect the internal flaws of the axle, and then it was transferred to the penetration sensitivity to detect bottom echoes.

According to detecting range of each probe, software could directly process the full data to do the C image display or the outline B image display. The image contained the flaw image and possibly contained the shape image, the interface echo image and the bottom echo image. The flaws were not easy to be found in the image shown in Figure 7(a).

When the inspection of the current axle completed, the software could process the full data and image once more according to the mathematical model and the sensitivity curve. The shape image, the interface echoes and the bottom echoes could be deleted, and the remains were the flaw images shown in Figure 7(b).

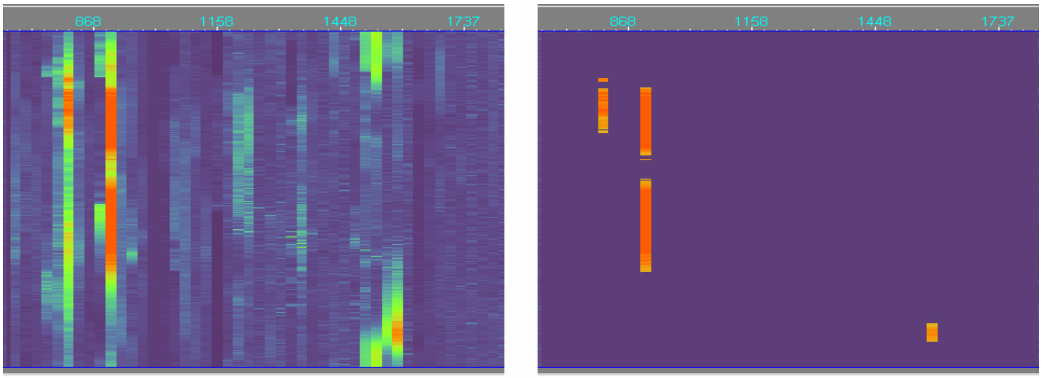

Figure 7 Axle automatic ultrasonic inspection image processing

(a) Real-time image (b) Processed image

Regarding to the major specification of the axle, the real-time processing and image display of the full data acquisition could be realized when combined the mathematical model and the detection parameters.

5. Conclusion

According to the principle of full data acquisition and application above, the full data acquisition had the following characteristic:

(1) Save all effective data in the inspection process;

(2) Easy to implement post-processing image methods;

(3) Have many kinds of image display, including waveform playback in the entire inspection process;

(4) Suitable for ultrasonic inspection for the non-standard work pieces;

(5) Realize real-time inspection and data processing with mathematical model;

(6) Widespread application of the full data acquisition with enhancing the data acquisition and the transmission speed.

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