Research on the Ultrasonic Test System for the Complex Curved Surface Based on Robot

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Abstract: Only keep the tracing points of the robot a one-to-one match to the inspected points on the tested part can the detected ultrasonic signals collect the defect information of the tested part correctly during the ultrasonic testing for the complex curved surface. To solve this problem, in this paper, the 6R robot and the ultrasonic sensor are applied to the automatic detection system for the complex curved surface. First, the frame of system is presented, and then the synchronous acquisition between ultrasonic echo signal and the position of robot is described in detail. Taking for example Staubli TX90XL robot with six freedom degrees, this paper uses mixed synchronous trigger based on time-position to detect the aeronautic engine blade. The ultrasonic signal is acquired and then analysed briefly to test the synchronism of the system.

Keywords: ulrasonic testing; robot;data acquisition; synchronization

1 Introduction

At present, the ultrasonic inspection is a nondestructive detection technology, which is the most widely used. However, the traditional manual testing methods can not meet the requirements of the complex curved surface in the modern production. How to make nondestructive testing quickly is becoming a research focus [1]. With the rapid development of industrial robot, Automatic detection system consisted of industrial robot, ultrasonic testing instrument and computer has becoming the main development direction of ultrasonic testing technique [2-3]. The ultrasonic imaging testing is based on a one-to-one correspondence between ultrasonic testing data and the inspected points on the tested part [4]. In order to address this problem, in this paper, the 6R robot and the ultrasonic sensor are applied to the automatic detection system for the complex curved surface. First, the frame of system is present, and then the synchronous acquisition between ultrasonic echo signal and the position of robot is described in detail. Finally, the automatic detection of the complex curved surface can be realized by the ultrasonic testing robot .

2 Structure of ultrasonic testing system

The ultrasonic testing system for the complex curved surface is mainly composed of three parts:(1)subsystem of scanning motion, including six degree of freedom robot and its controller, which is responsible for receiving the control trajectory from a computer file, holding the measured surface, realizing scanning movement, and providing an external trigger for data acquisition system.(2)subsystem of data acquisition, including ultrasonic probe, ultrasonic transceiver and a high-speed data acquisition card, which is responsible for transmitting ultrasonic wave , receiving the echo signal, and displaying the result in the form of images after dealing with the ultrasonic signal. (3)subsystem of detection and control, including industrial control computer and related software, which is responsible for realizing the communication between subsystem of data acquisition and subsystem of scanning motion, setting parameters, sending control commands, reading the data of detection, and achieving synchronous acquisition between ultrasonic echo signal and the position of robot. The system composition block diagram is shown in Figure 1.

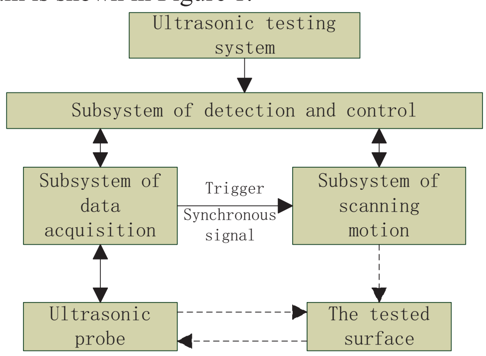

Fig.1 System composition block diagram

In this paper, an ultrasonic immersion testing method is adopted. The ultrasonic probe will be fixed in the tank , water will be used as the couplant, and then the six degrees of freedom robot will finish the complex spatial motion related with the ultrasonic probe with clamping

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surface to be tested. The ultrasonic scanning method of measured surface is used for testing internal defects.

3 Synchronous acquisition between ultrasonic echo signal and the position of robot

Synchronization refers to two or more amount of change over time in the process of change to keep certain phase relationship. In this system, we need to keep synchronization between ultrasonic echo signal and the position of robot to ensure the correctness of the test results.

Synchronous acquisition based on the time triggered or the position trigger is often used in realizing synchronous acquisition of automatic ultrasonic testing system.

3.1 Synchronous acquisition based on the time triggered

Synchronization technology of ultrasonic signal acquisition based on time trigger is namely ultrasonic signal acquisition controlled by the internal fixed triggering frequency signal of ultrasonic pulse transceiver. General steps as follows: The ultrasonic testing robot achieve continuous scanning trajectory by calling the motion command of its controller. Ultrasonic pulse transceiver provide the excitation voltage for ultrasonic probe in the way of fixed sampling frequency f, ultrasonic probe receives the echo signal of the tested blade and transmits it to the signal acquisition card. Then the signal acquisition card collects the ultrasonic echo signal. The scanning image is displayed with ultrasonic echo signal produced each triggering time 1/f and trajectory planning of the tested blade through the gray processing.

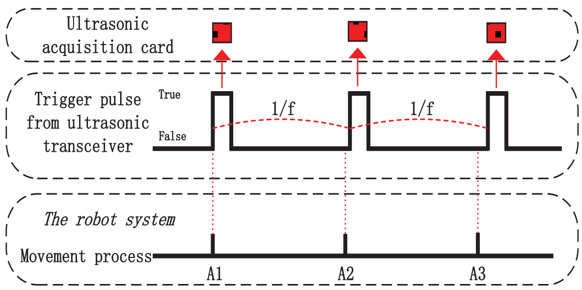


Figure2.1.The Synchronous acquisition based on the time trigger

Disadvantages: This trigger mode is only adapted to the testing of the regular surfaces, and not suitable for complex irregular surface. For the triggering time of ultrasonic transceiver is not a one-to-one correspondence according to the position of planning point in the process of detection, the position is likely to deviate from the tracing points, which can lead to failure of synchronization acquisition between ultrasonic echo signal and the position information of the robot.

3. 2 Synchronous acquisition based on the position trigger

Synchronization technology of ultrasonic signal acquisition based on position trigger is namely ultrasonic signal acquisition controlled by the trigger signal of position. General steps as follows: ultrasonic testing robot moves by clamping the tested blade according to the trajectory planning in advance, and then the signal of its controller is sent out to the ultrasonic transceiver and signal acquisition card when arrives at the first point of trajectory planning. Next, the received pulse echo peak will be stored in an array and converted to grayscale values which combined with coordinates of the tested blade when getting signal of trigger out from robot's controller to form information of scanning image. Once again, the ultrasonic echo signal is triggered when reaching the second track points. In the same way, robot completes the movement according to the track of all points. At the end, synchronous acquisition of position information is corresponding with the ultrasonic echo signal of each trajectory point. The test results is in the form of all coordinates and grey value, which often referred to as C scan images.

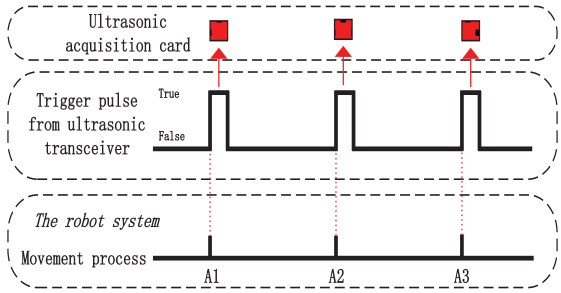


Figure2.2.The Synchronous acquisition based on the position trigger

Disadvantages: This approach will lead to a phenomenon of pause in the process of ultrasonic testing robot work for the reason that it can not move to the next point of a trajectory planning until receive the ultrasonic information of the former.

3.3 Mixed synchronous trigger based on time-position

For high detection resolution requirements and the small spacing points, the controller of robot must give the output trigger at higher frequencies and the actual location coordinates of robot for the moment if high scanning speed is also required. At present, frequency of the ultrasonic testing system in the industrial application is 1kHz-10kHz. But it is hard to meet the demand for the brand robot's controller for the acquisition frequency of real-time position information is only 250Hz. Therefore, This paper puts forward a new method that combines with time trigger and position trigger for high efficiency according to the analysis of the synchronization of the ultrasonic testing system. The specific implementation technology scheme is shown in Figure 3.1.

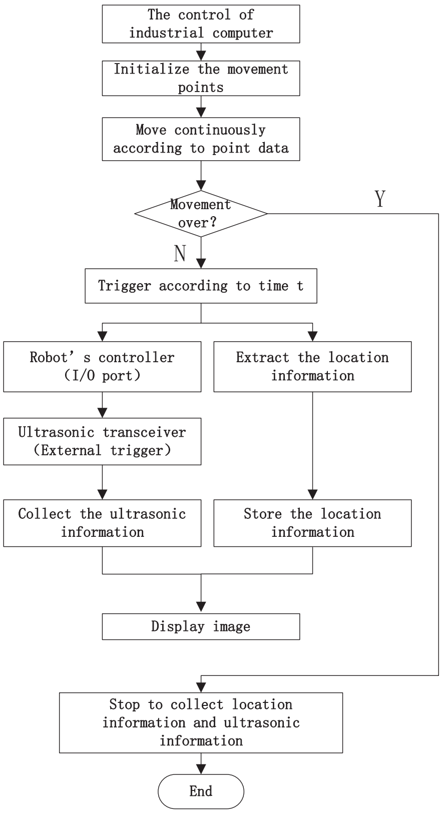


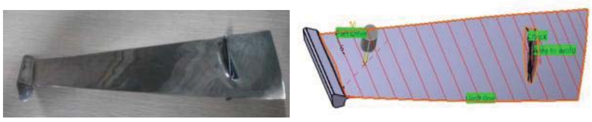
Figure3.1.The synchronization scheme of mixed trigger

System's synchronization acquisition is divided into three modules: module of movement, module of Signal trigger and Module of extracting the location information.

3.3.1 Module of movement

Usually the application is the important mean to realize the robot's motion control. In this paper, the Staubli TX90XL robot is adopted in our automatic ultrasonic testing system. We can control the robot movement with programming the robot's controller through Variable Assembly Language which (VAL for short) in the desired way. VAL3 is used by this version after two generations of improvement.

First of all, we will get the moving data points after trajectory planning for the tested blade and coordinate transformation for the robot[5], so that the ultrasonic testing robot can continuously move, shown as fig. 3.3.



(a) (b)

Figure3.3.(a)The tested blade.(b)schematic diagram of blade's trajectory planning

3.3.2 Module of Signal trigger

The signal of digital synchronized trigger is sent from the I/O port of robot's controller to the trigger signal port of data acquisition card. The robot's controller provides I/O interface of 16/16 that can send trigger out to the ultrasonic transceiver. Each interface is associated with Input and output variables of fin and fout that provided by its controller. It is convenient for the interaction and coordination control between robot's controller and industrial computer.

Output variables fout is a Boolean variable of type, which has two states, namely, true and false. The output interface corresponds to fout is high level when fout=true. The output interface corresponds to fout is low level when fout=false. Fout defaults to false when the application starts running. In order to get external trigger pulse, the voltage is increased through the output variable fout sets to true and then discreased through the output variable fout sets to false, so that a square wave pulse is produced. The width of the square wave is related to speed of operation in the system of VAL3, which can be used to trigger for ultrasonic acquisition system.

The controller of robot send out the trigger according to the fixed period t, and then ultrasonic transceiver generates trigger, further, the high-speed data acquisition card collect echo signal through the ultrasonic probe.

3.3.3 Module of extracting the location information

The system of VAL3 provides a function here() which is used to record the current position of robot in real time. It may call the function here () to obtain the position information at the moment while a pulse is produced to ultrasonic transceiver by the controller and finally stores it in the array.

Next, keep a one-to-one corresponding between ultrasonic information and location information every moment to display image.

Terminating the acquisition of ultrasonic signal and the location information at the end of movement, then the ultrasonic testing of the complex curved surface is completed. To improve the flexibility of the system, it may be necessary to change the trigger time of synchronous way according to the different of scanning precision and speed of the tested blade automatically.

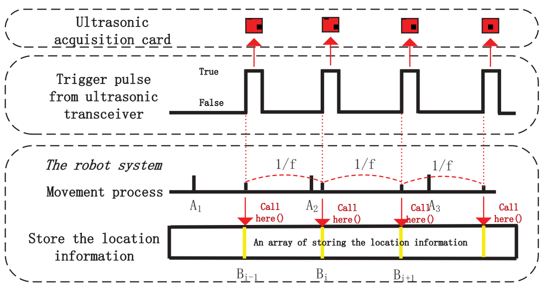


Figure3.3.The Synchronous acquisition based on the time-position

4 Test and simulation

Here, we use mixed synchronous trigger based on time-position to detect the aeronautic engine blade. In comparision with the previous two methods, the following conclusions shown in Table 1 are reached: the focus probe with 10 MHz main frequency and one external trigger is produced by robot controller every 5ms can detect the inclusion and crackle flaws in the blade accurately.

Table 1. The test data of different trigger modes

Trigger mode	Scanning speed (mm/s)	Scanning precision (mm)	Number of planning track points	Number of sampling points	
				Location data	*Ultrasonic acquisition data*
Time trigger	150	0.6	3000	3000	3000
Position trigger	150	1.5	3000	3000	3000
Time-position trigger	150	0.075	3000	129087	129087
Time-position trigger	300	0.15	3000	68195	68195

The result of tested blade is shown in Fig.4.

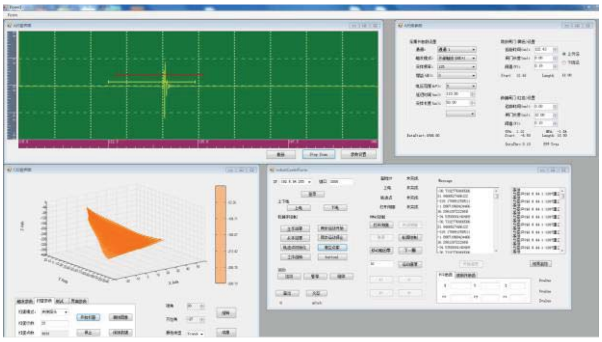


Figure4. C-scan image of ultrasonic testing robot

The conclusions from test results are as follows:

1) The mixed trigger mode can keep ultrasonic testing data a the one-to-one match to the inspected points on the tested part correctly.

2) For avoiding the influence of motion commands to trigger time, the mixed trigger mode can improve the detection speed compared with the traditional data collection methods,and finally solve the key technology of high speed and high accuracy for the blade.

5 Conclusions

An automatic ultrasonic scanning system for the complex curved surface is proposed. In this paper, its basic structure is introduced briefly. The synchronization acquisition technique of achieving real-time accurate synchronization which combining time trigger with position trigger is described in detail. In this way, we effectively solve the technical problem of real-time control, synchronous acquisition based on robot. The method can be used to realize automated ultrasonic nondestructive testing for complex surface with high efficiency. Further, we provide the basis for analysis of defect location, accurate measurement of the size and the qualitative and quantitative analysis.

Acknowledgment

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