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The application and research of high-frequency ultrasonic reflection technique used in the measurement of small diameter's tube cavity size

Mingquan Wang, Deshui Han, Shilin Li *

Dynamic Testing Technology Key Laboratories, North University of China, Tai Yuan 030051, China
Information and Communication Engineering, North University of China, Tai Yuan 030051, China

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ABSTRACT

Based on the problems that the photoelectric detection method and the X-ray testing method cannot provide the ideal accuracy when they are applicated to detect the cavity of small workpiece with diameter $\Phi 6$ mm and the general probes cannot stretch to the internal of the workpiece, we propose a high-frequency ultrasonic reflection technique which is used to measure the cavity size of diameter tube. The method uses ultrasound to measure the thickness. It can extract information about the wall size of workpiece through signal processing, feature extraction and other methods. By using this information, we can measure the size of cavity. Compared with the test results showed by a venire caliper and screw micrometer, we can get the conclusion that the immersion focusing probe with center frequency of 10 MHz can accurately detect the cavity of the workpiece. The experiment shows that the method gives consideration to the accuracy and computational efficiency of the workpiece's cavity parameters. It can get data supplely and effectively. There are other advantages of this method such as stable performance, easy installation, and lower power consumption and penetration ability. It is suitable for the precision measurement of the workpiece.

1. Introduction

With the continuous development of manufacturing technology and the rapidly growing demand for cavity components of precision parts, its application continues to grow in the areas of aerospace, Weapon Industry, nuclear industry, medical science, oil exploration and other areas. The inner scales measuring technique for precision workpiece provide a strong test guarantee for the manufacturing and processing of cavity components of precision parts and thus it plays an important role in the development of new technologies. As the workpiece's diameter is tiny, so surfaces under test in the internal are greatly restricted, measuring instruments are subjected to space and the general probe cannot stretch into the interior of tested parts. As a result, the measurement cannot successfully carry out, and the development of scale technology is greatly limited. Then the measuring theory and method of the inner dimensions become the internationally important technical problems in the field. A large number of domestic and foreign scholars have made a number of nondestructive testing methods, such as optical detection, radiation detection, laser holographic, through lots of researches [1]. To some extent, the methods meet the requirements of certain applications, but they also have disadvantages. Ray detection exists ray pollution which is harmful to human body, so the protective measures are necessary. And its accuracy is not ideal. Photoelectric test requires stable power, reliable performance of photosensitive components. At the same time its installation requirements also is higher. It is easily affected by external factors and its accuracy is not ideal. Therefore, this is the reason why we propose the ultrasound-based precision measurement method of cavity size [1,2].

* Corresponding author at: Information and Communication Engineering, North University of China, Tai Yuan 030051, China.
E-mail address: 464789656@qq.com (S. Li).

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2. An overview of ultrasonic inspection methods

Ultrasound-based precision measurement method of cavity size has been developed for almost 50 years. It integrates the mechanical, electrical and computer technology. The method is currently one of the most important measurement tools and is widely used in machinery manufacturing, electronics, automotive and aerospace industry, etc.

Most of the current domestic steel companies use the standard measurement tools to measure workpiece, such as manually measurement with caliper, which can only measure a limited number of dimensions with low precision and a lack of description about the cases of the workpiece. Therefore, ultrasound-based precision measurement method of cavity size is necessary to make automatic detection of the workpiece's cavity available. The development of mathematics, computer science, and digital image processed technology provides a new measurement technique for the cavity scale of the workpiece [4]. This paper presents the ultrasound-based precision measurement method of cavity size. It not only has a general measure of the function, but also can make automatic measurement of complex workpieces. After the automatic measurement, we can get the main parameters of the workpiece through data processing. At the same time, we can get the conclusion about the workpiece's cavity size according to the relevant judgment on the known indicators.

As shown in Fig. 1, the ultrasound-based precision measurement method of cavity size include the data exquisite module, data processed and displayed module, system mechanical devices and other parts. The data exquisite module include probe and the card which can launch and receive ultrasonic; data processed and displayed modules include industrial PC, data processed software and displayed equipment; mechanical devices include the probe case and device clamping specimen and so on. According to certain requirements, the probe mounted on the box, while the probe is connected to the data line and ultrasonic transmitted and received card. The ultrasonic transmitted and received card is built-in interior of industrial PC through the PCI interface [3]. The motor control card controls motor operation through the motor driver and it is also built-in interior of industrial PC. The functions of controlling motor are integrated in the data processed software of system. Through the software, we can control motor movement patterns. After the data are collected, they will be integrated and processed through data processed software in the industry PC and the results will be shown by the display device.

3. The theory and algorithm of ultrasonic test

Ultrasonic is radioactive. When it spreads in a certain media, its speed remains constant. But in the interface of different media, reflection, refraction and wave conversion will happen. Based on this nature, ultrasound can determine the thickness of the material's wall. As shown in Fig. 2, a pulse reflecting technique is generally used when ultrasonic tests a workpiece. This technology is based on a basis of wave. Ultrasound spreads to the workpiece at a certain speed. A part of ultrasound is reflected back at the surface of workpiece, the other part continues to inject the workpiece. Ultrasound will be reflected at the innermost side of the workpiece, thus the wave reflected in the outer wall (first wave) and the inner wall (bottom wave) is formed. Then we will calculate the wall thickness (R) of the workpiece through the formula.

$$R = \frac{c}{2} \cdot t \tag{1}$$

c is the speed of sound in the material. t is the round-trip propagation time when sound waves encounter in wall.

3.1. Algorithm processing

In this paper, the ultrasound-based precision measurement method of cavity size is adopted to measure the wall thickness of the workpiece. Then we can calculate the cavity size and determine the main parameters of the workpiece's cavity size. In order to ensure the safety of measurement, we can make a non-contact measurement of the workpiece's thickness by using a set of ultrasonic probes. And at the same time, measurement data will be integrated. Through processing the multiple probes' data of different angles, different times, different levels, we can determine cavity size, shape and distribution of the measured object. Then we will make the cavity size's comprehensive evaluation of the workpiece [5,6].

$$l_1 = \frac{vt_1}{2} \tag{2}$$

$$l_2 = \frac{vt_2}{2} \tag{3}$$

Fig. 3 shows geometric size of the workpiece's cutaway view. R is the diameter of the products, v is the sonic velocity in this medium, l_1: the thickness of above wall, l_2: the thickness of below wall. After both sides of the wall's thickness is measured, the diameter of cavity (d) can be get by

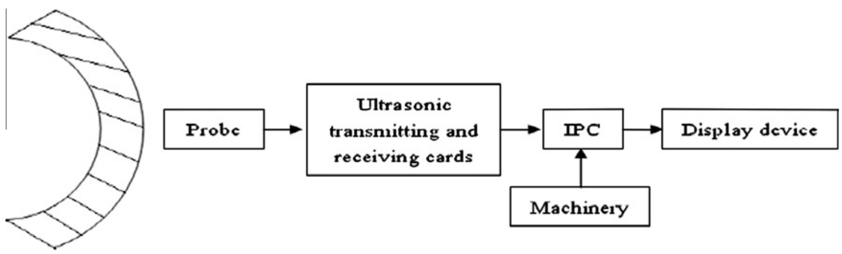

Fig. 1. System diagram.