Design and research of UT inspection tool in flaw inspection of large-size forging shaft parts

Chang’an Hu*, Linghui Kong, Min He
National Institute of Measurement and Testing Technology, Chengdu, 610021, China
*Corresponding author’s e-mail: 569964114@qq.com

Abstract. With the development of mechanical equipment towards large-scale and complexity, the size and operational reliability of its key core components is gradually improved. Aiming at the problem of large radial structure size and high mechanical performance of MP1000 miner forging spindle, but low efficiency and reliability of ultrasonic nondestructive testing, which makes it difficult to detect uneven material in forging process, the finite element numerical simulation of ultrasonic flaw detection process of forging spindle is carried out by using software. By analyzing the locations of ultrasonic probes on different buses on the surface of the spindle, the edge areas of the steps and the processing of the ultrasonic probe, the problem is analyzed. The instantaneous distribution of the sound field in the hole position is summarized. The design method of UT testing special tool for large forging spindle is summarized, and the corresponding testing unique tool is designed. This tool can cooperate with UT equipment to effectively detect the uneven defects in the material of shaft parts and effectively improve the detection efficiency of ultrasonic nondestructive testing in the application of heavy forging spindle parts.

1. Introduction
The development of high efficiency system of heavy mining machinery requires very strict forging shaft parts. Because of the increase of bearing capacity, high quality forgings are required. The quality of forgings is closely linked to the cost, which involves the control of forging materials and forging process control box. In order to avoid subsequent costly waste and production delays, it is necessary to detect the defects of forgings in early manufacturing or machining.

MP1000 series forging spindle is one of the key parts of the mining machine. Because of its convenient and accurate installation, reliability and scalability of parts combination, matching has the advantages of neutrality, it has been extensively used in the mechanical industry. Cone crusher is a part of the main types of large-scale mining crusher. Its key component, the taper spindle, has a profound influence on the shape accuracy of the crusher owing to its large working load and bad working environment. Therefore, its spindle design has a high processing accuracy. The current checking fixture can only be detected in the final inspection, but not in the process of processing, which results in low pass rate of one test and high cost of processing. At present, the principal shaft workpieces of typical large mining machines are widely processed on CNC lathes[1]. To improve the accuracy of machine spindle processing, in the process of its testing, according to the measured results in the process to select suitable for error compensation [2], in terms of taper detection, domestic existing taper detection is based on the literature [3], the NC machine tools abroad is increasingly motors, five-axis linkage machining and compound machine tool has been rapid development. This machine currently has the highest level in the United States, not only produce small precision machine
tool, and research and development of large precision machine tool [4], such as the UK, Cran field, Japan's Toshiba, machinery, machine tool error compensation can improve the precision of 3 ~ 4 times [5]. At the same time, it can greatly improve the efficiency of processing, and the cutting tool technology is developing rapidly [6], numerous design covers the whole process of cutting tools, and new tools to meet the requirements of smooth processing and vibration resistance, the implementation of DDS method to compensate for the workpiece and the taper of the circular runout error successful experiment [7]. The existing technology, Literature [8] released a taper fixture, through the increase in the fixture positioning of who set of greatly improving the measurement accuracy, and reduce the measurement error, and submit the taper [9] due to its structure size limit can only be applied to small final inspection of the product can not be applied to process measurement, but now three coordinates detector as off-line measuring instrument is based on the above situation. At present, domestic and foreign ultrasonic inspection methods for inspection of adhesion quality are used, but the methods for determining the sensitivity are different and lack of theoretical calculation, so they cannot meet the requirements of standardization, resulting in poor consistency of test results.

In view of the existing testing identified and potential risks mentioned above, not only are forgings plants interested in the application of mechanized NDT, but most energy equipment manufacturers also accept only parts tested by automated or mechanized testing systems. In addition to overcoming human factors, the main reason for this requirement is that continuous testing is required during service. This study in a typical forging shaft parts as the research object, through the analysis of ultrasonic probe located on different bus and main shaft surface testing experiments, summarized by less number of tests to find the best parameter combination of uneven material defects, improve the ultrasonic nondestructive testing in large size forging shaft parts inspection detection efficiency of the application.

2. Background of forging spindle UT detection
The mining machine occupies the very important position in the mine daily production. Therefore its performance and the mine efficiency and safety has the very direct connection. The spindle plays a bearing role in the everyday production of the miner. The main parts of the miner, such as bearings, clutches and couplings, are fitted to the spindle. Because the working environment of the mining machine is very harsh in everyday production, it needs to bear very large torsion load. And because of the accuracy of its design drawings and processing accuracy directly determine the mining machine spindle bearing capacity and the length of its service life, so the stability of the mining machine spindle is very important. And the spindle processing accuracy is higher, the spindle bearing capacity is stronger, to ensure the high productive capacity of equipment, and the fineness of broken products. Therefore, the bearing capacity of the principal shaft of the cone crusher plays a crucial role. And mining machine spindle in the design, has a large eccentric, high speed, taper small characteristics and strong bearing capacity, not only to achieve the high efficiency of equipment, but also further improve the fineness of broken products.

Spindle occupies the important position in the cone crusher, the normal use of the spindle, to a certain extent relations with the efficiency of the whole equipment, if the main shaft appear problem, not only cannot operation and bad said the entire system has to stop check, have a big impact to production, and ensure the normal use of cone crusher spindle, advance foresee there may be potential risks in the process of production can effectively avoid the occurrence of the problem..

3. Determination of test benchmark
In the determination of the mining machine spindle process specification, to determine the positioning datum, because the future process are based on the determination of positioning datum to calculate, determine the positioning datum for the subsequent measurement has a very important significance. And determine a good positioning datum for spindle processing is essential, because a suitable positioning datum can improve the machining accuracy of the spindle, but also for the future spindle
processing process line order has an important role. When selecting the positioning datum, the three basic principles of selecting the positioning datum shall be observed.

- Fiducial coincidence principle. To design the spindle part drawing, to the datum coincidence as far as possible, so easy to calculate, but also in the future spindle machining datum misalignment error reduction, improve its machining accuracy.

- The principle of easy clamping. In the choice of positioning datum, to simplify the processing process, it is necessary to achieve multiple worksteps in a process, and multiple worksteps to ensure its efficiency, it is necessary to be simple, convenient and fast clamping spindle.

- To facilitate the principle of zero, reduce the spindle detection error, improve the detection efficiency.

Therefore, the spindle center hole is selected as the positioning datum, which conforms to the principle of datum coincidence and unifies the positioning datum as much as possible, unifying the coarse datum and the fine datum. The coordinate system is shown in figure 1.

![Figure 1. Determination of the reference coordinate system.](image)

4. Special test fixture design

According to the shape of the spindle, it only detects the outer surface of the spindle in the detection equipment, which is the outer surface and the center hole for positioning. So choose four jaw chuck and center as a fixture, and the center and positioning plate with support spindle. To realize positioning and clamping, the positioning element of the fixture is the top, the tool guide element is the cutter block, and the clamping element is the four-jaw chuck, as figures 2 and 3.

![Figure 2. Left side chuck is installed and positioned.](image)  ![Figure 3. Right positioning plate with center.](image)

According to the appearance analysis of parts, it can be observed that in the detection process, features such as end face, straight section and cross hole, cylinder intersecting hole and sinkhole need more than one positioning datum. According to the shape and position of the hole, three positioning datums are determined, which are respectively the circular outer surface of the spindle. The main shaft’s shape for the rotary surface, so the design of the fixture positioning elements for u-block, clamping elements for the pin. And clamping force of the point selection is also important, the principle of choosing it needs to meet: positioning components must be within the scope of the cover of the clamping force point, and to ensure that the clamping force of the point on the rigid good place,
so that you can make to reduce error of the spindle by clamping deformation design of fixture locating and clamping as shown in figure 4.

Figure 4. U-clamp fixture.

5. Test process simulation
The simulation model of the established detection process is shown in figure 5. We can select EDIT mode in the virtual software and press PRGRM to enter the prepared detection program name for virtual calculation.

Figure 5. Virtual simulation of detection process.

In the actual detection process, the forging spindle should be guaranteed freedom of sundries, clean, and, under the condition of ensuring the coverage of magnetic powder, the measuring head should be as close as possible to the workpiece. When measuring in the vertical direction, in order to reduce the precision loss, the equipment should be placed in the middle of the measured size of the workpiece as far as possible. For the workpiece with high measurement accuracy requirements, the forging spindle shall be placed in a constant temperature in a constant greenhouse before the measurement is started.

6. Conclusion
In this paper, starting from the process system of domestic and foreign MP mining machine spindle, the detection technology of this series of spindle is studied, appropriate processing equipment is selected, corresponding supporting tooling is designed, and a complete set of large taper spindle detection tooling design is given. At the same time, error compensation is also essential in the detection process, and the design of the fixture is also crucial, which can effectively improve the detection accuracy and detection efficiency, thus reducing its cost. According to its shape, it designed a special fixture that uses four-jaw chuck and top to locate and clamp, to ensure positioning and clamping, so that the spindle detection becomes stable.

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