Design and Testing Method of Geometric Tolerances for Deep Stepped Hole

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Abstract. Effective process checking tool is an important means to control the first pass rate and machining quality of large-size and high-precision parts in precision manufacturing. Its testing method and testing precision directly affect the reliability of precision manufacturing process system. Aiming at the problems of high machining and assembling precision, many machining parts and difficult detection of large-scale parts, the precision detection method for complex parts with high precision and deep step hole design characteristics was studied. Based on the drilling-expanding-rough boring-fine boring process, the control factors of coaxiality error and the machining errors caused by the weight of larger cutting tools in high-speed machining process are analyzed. The position relationship of the measured coaxial stepped holes is studied. A special measuring tool is designed to measure the coaxial machining error quickly and accurately. The corresponding process measuring method is given. The method is applied to the precise manufacturing process of this feature. The testing results are verified by a three-coordinate measuring instrument. The comparative study shows that the tool can effectively measure the coaxiality error of two holes in long distance, and visually display the size and position of the coaxiality error of two holes, effectively improving the efficiency of coaxiality error detection with two holes in long distance.

Introduction

Coaxality is a common location tolerance in geometric tolerances for machine parts inspection. According to the national standards, coaxiality refers to the different degrees of the axis of the tested parts to the reference axis. Various spindles and testing instruments can be used to test coaxiality.

Coaxiality is a position parameter which is difficult to measure. Large-scale boring and milling machines are generally used to process the structural features of large size and large hole spacing[1]. However, the diameter compensation is also needed when machining the inner and outer circles of the shafts with high precision[2]. Especially in the structure of large parts with small space where the coaxial holes are located and mass-produced. The accuracy and efficiency of two-hole coaxiality measurement is an important factor affecting the quality and efficiency of product production. Therefore, the necessary prerequisite for accurate machining of inner and outer circles of parts with deep and long stepped holes is to inspect them in the process of machining, and choose the corresponding compensation according to the measurement results, so as to adjust the follow-up processing. Because of the displacement gap of the large machine tool itself which compensates the weight of the parts, the measurement and compensation of the machining process is especially important for the precision machining process system of the large-size and high-precision conical shaft parts[3]. Therefore, the design of the measuring tool for form and position tolerance in the machining process around the validity and efficiency is widely used by engineers and technicians.

General concern.

The accuracy of dimension detection affects the quality of parts, so the dimension detection of parts is an important field of vision application. XingRen [4] used machine vision to detect the coaxiality of the cone surface, the accuracy can reach micron level. Zenkouar [5] use the edge model of Logistic function to extract the sub-pixels of the part image, and carry on the size
detection, the detection accuracy is very high, can reach 0.001 mm. It can be seen from this that the machine vision technology can meet the requirements of high precision inspection for mechanical parts. The traditional way to detect the line width is to detect two edges separately and calculate the linewidth. The traditional methods of subpixel line width detection include interpolation, fitting, etc. But these methods have some problems, such as low accuracy, or large amount of calculation, so it is difficult to meet the requirements of real-time online detection. Legendre orthogonal moments have been widely used because of the least redundancy of information and simple inverse transformation. Ghosal et al. [6] proposed a sub-pixel ideal step edge detection model based on orthogonal moments, and has been widely used. Muhammad et al. [7, 8] proposed a subpixel linewidth measurement method of Legendre orthogonal moments to measure the linewidth of 100 m standard granules in ampoules. Literature [9] discloses a kind of taper measuring device, which greatly improves the accuracy of measuring taper and reduces the measuring error by adding a positioning sleeve in the measuring device. However, because the technical scheme has a fixed measuring base plate, the measuring device can only be used in the final inspection of products and cannot be used as a process measuring tool. However, this method does not Accurate values of taper deviation can be obtained, which cannot be further measured through the feedback processing, and cannot play a role in compensating and guiding the processing. Develop a testing device which can be used in taper machining process, and get accurate testing results, can effectively guide the processing process, and improve processing efficiency.

Based on the above situation, according to the calculating formula of taper and roundness tolerance, this paper designs a taper measuring tool which can be conveniently applied to the machining process of large conical shaft parts. By modifying the measuring tool, the deviation value of actual taper and theoretical taper and the position of machining error can be accurately obtained, which can further guide the follow-up machining and improve the large-scale and high-precision machining. The forming rate and machining accuracy of the taper shaft parts can improve the production efficiency of high-precision products.

Sources of Problems

The above situation is not uncommon in the manufacturing industry, just as the cylinder bore on the block of a large diesel engine, because of the installation of the cylinder liner, so the cylinder bore on the block is designed to be the upper and lower two ladder holes, and the axial distance between the two is larger, the coaxiality design index is 0.02, as shown in Figure 1.

![Figure 1. Design requirements for coaxiality of stepped holes with large spacing on a part.](image)

This index for the larger size of the long-distance ladder holes added. Manufacturing process causes great difficulties, if the tolerance does not meet the design requirements will lead to the decline of the performance of the engine block, seriously affecting the life of the engine block. When productivity is high, the measurement workload will be large, not only the spacing between
holes is small, but also not in a plane. In this case to achieve rapid measurement between processes is indeed a difficult problem. Therefore, the accuracy and efficiency of the gauge must be taken into consideration in its manufacturing process.

**Design Principles of Fixture**

In the appendix (1) to the national standard for shape and position tolerance, several coaxiality error detection schemes are recommended, one of which is a mechanical measuring tool scheme as shown in Figure 2. As can be seen from the diagram, the solid spindle at the left end of the measuring tool is inserted into a hole in the workpiece when it is in use, and a measuring lever is set at the right end of the measuring tool. The two ends of the lever are the probe contacting the hole under test and the anvil contacting a thousand (hundred) meters respectively. When the mandrel rotates a circle, a cross section of the hole is measured, which can be measured on one or more sections. The maximum difference between the maximum and the minimum readings of a micrometer (assuming several sections are measured) is the coaxiality error of two holes.

![Figure 2. Design requirements for coaxiality of stepped holes with large spacing on a part.](image)

In the national standard, the coaxiality tolerance of the axis is defined as "the tolerance zone is the area within a cylindrical surface with a diameter of and the axis of the cylindrical surface is coaxial with the reference axis". It has the following three control elements: (1) the establishment of the reference axis; (2) the establishment of the axis of the object under test; (3) considering the actual work or assembly requirements for flexibility.

However, the existing universal testing tools can only be limited to the measurement of the shape and angle of the block, but cannot achieve a rapid and accurate measurement of coaxiality size of the upper and lower cylinder holes of the internal combustion engine block. If the upper and lower cylinder holes do not meet the predetermined standards, the engine block cannot operate reliably after assembly, and the subsequent correction of the hole position often occurs. A great deal of time is needed, which is an important factor affecting the overall processing efficiency and quality.

**Design of Coaxality Gauge**

When machining large internal combustion engine block or hollow shaft parts, it is often necessary to detect the coaxiality error of upper and lower cylinder holes in the block. If the reference elements and the measured elements of the error are not at the same end of the axis, and the detected space is small, the inspection process is more complex, it is difficult for the inspectors to observe the inspection process intuitively, and the inspection results are not very stable. As shown in Figure 1, the coaxiality of the upper and lower cylinder holes is 0.03mm. In order to improve the measuring accuracy, the workpiece is installed vertically when it is heavier, and the measuring error caused by the axis offset caused by the workpiece weight is reduced. Therefore, the coaxiality measuring tool can be designed by using taper positioning. As shown in Figure 3, the testing principle of the coaxiality measuring tool designed in this paper is based on the concept of coaxiality, and the taper positioning method is used to reduce the unnecessary error caused by the installation process of the measuring tool.
Figure 3. Coaxial measuring tool based on taper positioning principle.

The checking device comprises a checking concrete (a), one end of the checking concrete (a) is fixedly connected with a contact ring (b) through a bolt, and the other end is fixedly supported by a locking nut (c). The lower positioning plate is installed in one hole of the stepped hole, and the other is replaced by a dial. When the lower end plate rotates in one of the cylinder holes, the coaxiality error of the two cylinder holes can be quickly and accurately obtained by changing the dial pointer.

The tool can realize the fast and accurate measurement of coaxial cylinder hole machining on the internal combustion engine block and improve the production efficiency. It mainly aims at the problem of whether the main quality factors are qualified in the process of processing the cylinder hole of the internal combustion engine block, and provides a kind of rapid measurement and can also detect the specific deviation value. According to the definition of coaxiality, the fixture must ensure that the inspection is completely coaxial and vertical with the contact ring. The contact part of the contact ring is a circular arc surface, and the support frame can be adjusted by locking nuts to ensure the inner surface runout of the hole in the range of 360 degrees during the measurement. The above-mentioned technical problems of the coaxiality measuring tool are mainly solved by the following technical schemes, including a cylinder hole coaxiality measuring tool body, a matching ring and a bracket for fixing a dial meter. One end of the measuring tool body is provided with a matching ring contacting the cylinder hole, and the measuring tool body and the ring are fixed on the bracket through threads. The locking nut is used to fix the dial indicator. A measuring part of the measuring tool is mainly used to detect the coaxiality of two coaxial holes on the assembly. The measuring device can not only install a scratch needle for scratching measurement, but also install a dial meter to display specific coaxiality values. The measuring device is suitable for the special testing tool of the internal combustion engine block. The matching ring on the testing tool is aligned with the corresponding cylinder hole position of the internal combustion engine block. The measuring tool is installed on the bracket to measure. When the deviation between the hole position and the hole position is needed, the dial is installed on the bracket, and the dial's base pin and the cylinder hole are aligned. Surface contact, the fitting ring will be contacted with another hole inside the circle, rotating the fitting ring and observing the dial pointer changes, then the specific deviation value can be obtained for subsequent correction. As a preferred method, the contact ring and the cylinder bore should be smooth enough and wear-resistant, and the lower end of the contact ring and the lower circular surface contact with the cylinder bore, so the force is concentrated. As a preferred choice, the body of the measuring tool should be completely coaxial and perpendicular to the contact ring, and the length of the body of the measuring tool should be longer than that of the two cylinder holes, so as to install different measuring heads. At the same time, for the convenience of replacement, the connecting part of the body of the measuring tool and the contact ring is threaded, the main advantage of which is that it can be quickly and accurately connected. The coaxality deviation is measured, and different measuring heads can be installed for marking and leveling, which is convenient and practical.
Measuring Method for Concentricity of Stepped Holes

As shown in Figure 1, the coaxiality special checking tool includes a checking tool body, a contact ring and a bracket. In the structure diagram of the measuring tool, the lower structure is a contact ring, which is used to contact with one of the cylinder holes in the testing process. The middle structure is the measuring tool body. The two are connected and fixed together by threads, and the support frame is fixed at the upper end of the measuring tool body, which is used to fix dial gauge or scratch needle in the measuring process. When the coaxiality of the two cylinder holes of the engine block needs to be detected, the contact ring of the detection device is connected with one of the cylinder holes of the engine, the percentage is installed on the support frame, the dial contact needle is pressed with the other cylinder hole, the dial head reading is adjusted to a certain value, and then the dial contact ring is rotated so that the dial contact head is in the cylinder. The value is the coaxiality deviation of two cylinder holes. On the other hand, when the needle is mounted on the support frame, the same operation can be done by turning the needle one circle to draw the contour line on the inner surface of the hole. The specific measurement steps are as follows:

**Preparation before Measurement:**

The surface of the measuring tool and the part under test is cleaned to prevent foreign bodies from entering the contact surface, which results in the failure of the measuring tool to contact the surface of the part under test precisely and the accuracy of the measuring data.

**Loading Card:**

Install the contact disc of the measuring tool in the small hole of the two step holes and ensure that it is fully in contact with the hole under test. Then adjust the dial gauge to the same height as the other hole. Install the dial gauge on the support. The dial gauge and the inner surface of the hole are in contact to ensure that the dial gauge pointer rotates one time and readjust the dial gauge. The zero point, as the zero reference point of the coaxial degree, is installed. The fixed profile and the stepped hole state are shown in Figure 4.

Coaxiality Measurement:

Turn the contact disc gently and observe the dial reading. Record the dial reading once every 30 degrees. Complete the coaxiality detection within 360 degrees. Draw the coaxiality curve in and out of Figure 5 to analyze and guide the next finishing process compensation method.
Conclusion

Equations Aiming at the problems of complex process, narrow space and inaccurate detection of coaxiality of long-distance stepped holes, a special testing tool for coaxiality was designed. The utility model relates to a quick measuring mechanism for processing the internal combustion engine block. The detection mechanism mainly includes the detection of specific, specific one end of the fixed contact ring, the other end is equipped with adjustable height of the support frame, can achieve the internal combustion engine block up and down cylinder bore coaxiality size of rapid and accurate measurement. The detection device can not only install a scratch needle for scratching measurement, but also install a dial meter to display specific coaxiality values, which is convenient and practical.

References


