# Research on High-Precision Measurement Method for the Extension Position of Engine Threaded Holes Based on Threaded Core Shaft

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**Abstract: Aiming at the problems of insufficient accuracy and imprecise data acquisition when measuring the extension position of threaded holes with a three-coordinate measuring machine, this paper proposes a new method based on the auxiliary measurement of threaded mandrel. This method converts the internal features of the threaded hole that are difficult to measure directly and precisely into external cylindrical features that are easy to measure with high precision by designing and installing a threaded mandrel that fits precisely with the threaded hole. The article elaborates in detail on the structural design principle, measurement process and key precautions of the threaded mandrel. The experimental results show that the thread mandrel measurement method can effectively avoid measurement errors caused by factors such as thread profile and pitch. The fluctuation amplitudes of measurement deviations in the X, Y, and Z axes are significantly smaller than those of the traditional extended measurement method, demonstrating excellent measurement stability and repeatability. This method provides a reliable and efficient solution for high-precision detection of the positional accuracy of threaded holes.**

**Keywords**: **Three-Coordinate Measurement Threaded Hole Position Degree; Threaded Mandrel Measurement Accuracy; Extension Position Degree**

## 1. Introduction

With the rapid advancement of technology and the continuous development of society, all links in the production process have put forward increasingly higher requirements for the measurement accuracy of machines [1]. Especially in the field of mechanical manufacturing, the accuracy of three-coordinate measurement technology in the extension position accuracy of threaded holes has always been an urgent problem to be solved [2]. Traditional measurement methods have many limitations in application, and their measurement results are often widely questioned by operators, maintenance personnel, quality control personnel, process and product designers.

In actual operation, many mechanical manufacturing enterprises only measure the positional degree of the bottom hole of the threaded hole (smooth hole), and take the measurement result as the final evaluation criterion [3,4]. This measurement method is only effective in controlling the positional accuracy of threaded holes where the processing tool is a tap. However, when the bottom hole has undergone complex drilling processes such as turning, milling or extrusion forming, the quality of the threaded hole's positional accuracy is difficult to control and the risk is relatively high. For threaded holes that are directly tapped on the blank holes, the measurement of their positional accuracy is an even more challenging issue. Due to the surface condition of the blank hole, the uniformity of the material, and many uncontrollable factors during the processing, it may have a significant impact on the final positional accuracy of the threaded hole. Therefore, in order to ensure the stability and reliability of product quality, enterprises adopt three-coordinate measurement to improve the accuracy of the extension position of threaded holes [5-7].

The accuracy error of the three-coordinate measurement for the extension position of threaded holes is relatively large, which is a problem plaguing the mechanical manufacturing industry. Necessary measures and norms can be adopted to improve accuracy [8]. When constructing the thread hole axis, sampling errors should be minimized as much as possible to ensure that the sampling axis is completely coincident with the thread hole processing axis. In addition, when evaluating the positional accuracy of threaded holes, the evaluation points must be fixed on the same cross-section [9]. Although certain norms and improvements have been made to the measurement methods, each improvement can only solve a single type of problem or can only reduce the measurement error to a certain extent [9]. For measurements with high requirements for the position of threaded holes, even if there are reasons such as deformation during the processing of threaded holes, it is impossible to guarantee the repeatability and consistency of the measurement. The measurement method of the three-coordinate threaded hole position accuracy still needs further improvement, especially the error caused by sampling measurement needs to be further optimized [10-12].

In response to the above problems, this paper proposes a novel three-coordinate measurement method with relatively small errors and a wide range of applications. A threaded mandrel is introduced for measurement, and the accuracy of this method is explored through actual measurement.

## 2. Design of Threaded Mandrel Assisted Measurement Method

To ensure the precision and positional accuracy of the threaded holes, it is proposed to add a threaded mandrel to the threaded holes. The threaded mandrel can serve as a measurement reference and can also more accurately locate the position of the threaded holes. The three-coordinate sampling point diagram is shown in Figure3, which clearly demonstrates how to select the measurement points on the threaded mandrel. After installing a threaded mandrel in the threaded hole, four points should be taken on the same cross-section of the threaded mandrel to measure a circle. These four points should be evenly distributed on the cross-section of the threaded mandrel to ensure the accuracy of the measurement results. To calculate the positional degree of the center of this circle relative to the evaluation reference, it is generally necessary to measure at least two cross-sections. Construct a cylindrical element at 8 points, and the axis of this cylinder is the axis of the required threaded hole.

By comparing the positions of the axis line with the evaluation reference, the positional degree of the threaded hole axis line relative to the evaluation reference can be accurately calculated. This positional degree is an important indicator for evaluating the machining accuracy and positional accuracy of threaded holes. Similarly, this cylindrical element can also be used to determine whether the axis of the threaded hole is inclined. When the axis of the cylindrical element is not parallel to the evaluation reference, it indicates that the axis of the threaded hole is inclined. This tilt may affect the performance and assembly accuracy of the threaded holes, so it is necessary to make timely adjustments and corrections.

**Figure 1. Schematic Diagram of Sampling Points for Installing Threaded Core Shafts on Threaded Holes**

## 3. Actual Measurement

To verify the reliability of the measurement method for the position of threaded holes introducing a threaded mandrel, this measurement method was first applied to the detection of the position of M10 threaded holes on the right cylinder bore surface of a certain product body of the company. As shown in Figure 4, the position dimensions of multiple threaded holes on the cylinder bore surface of the body with an extension length of 86.1 mm were measured. Based on the principles of the two measurement methods, a three-coordinate measurement program was edited, and a comparative measurement experiment of the measurement methods was carried out. The same part and multiple identical holes were measured three times respectively. Each time the measurement was conducted, the sandwich shaft was reinstalled, and the measurement results were output. The three measurement results of the two measurement methods were analyzed to observe the trend of the distribution graph.

 

**Figure 2. Actual Measurement Diagram**

### 3.1 Threaded Mandrel Measurement Method

The thread mandrel measurement method is an effective way to precisely measure the position of the thread hole's axis. During the measurement, a thread mandrel that matches the thread is installed on the thread hole. On the smooth cylindrical surface of the outer circle of the mandrel, set the step width of the probe for the measuring needle to 0.5mm. This step width is based on a comprehensive consideration of measurement accuracy and efficiency, ensuring measurement accuracy while also improving measurement efficiency. According to the pre-programmed measurement program, as shown in Figure3, the outer circle of the mandrel is scanned and measured. Two sections were selected for scanning, and 57 points were collected from each section. The data measured by the three-coordinate measuring machine can be processed by the least square method, which can correct the probe measurement points, filter and eliminate gross errors, so as to eliminate the influence of large errors.



**Figure 3. Three Coordinate Measurement Program Setting Diagram**

The sampling point diagram is shown in Figure 4. From this figure, it can be clearly seen the stepping mode of the probe tip on the outer circle of the threaded core shaft and the sampling points.

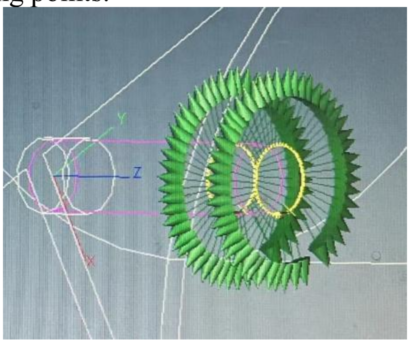

**Figure 4. Schematic Diagram of Measurement Sampling Points**

### 3.2 Measurement Precautions

The precautions during measurement are as follows: 1. Before measurement, ensure that all the threaded core shafts on the measurement surface are properly installed to avoid measurement errors caused by installation during the measurement process. 2. The measuring circles of the two smooth cylindrical ends of the measurement core shafts should be at an appropriate distance. 3. The threaded holes should be clean and free of burrs, and there should be no gap between the core shaft and the threaded hole for a proper fit.

## 4. Analysis of Measurement Results

The same threaded hole of the same workpiece was measured by the thread core-axis method three times respectively, and the measurement results in the three axial directions were compared and analyzed.

The maximum absolute value of the measurement deviation of the three threaded mandrel shafts is 0.2637mm, and the minimum value is 0.0468mm. The overall numerical deviation is about 0.1mm with a small fluctuation range and strong stability. It can be seen from this that the thread mandrel method has obvious advantages in measurement stability and repeatability, and is suitable for the detection of the positional accuracy of threaded holes in high-precision assembly requirements.

The maximum absolute value of the Y-axis deviation in the three mandrel measurements was 0.1366 mm, and the minimum was 0.0153 mm. The overall numerical deviation was approximately 0.05 mm with a relatively small fluctuation range, and its stability was largely superior to that of the extended measurement method. The reason for the error in the measurement of the threaded mandrels is that the tolerance zone of the threaded hole and the tolerance zone of the threaded plug gauge fit together, resulting in an error gap between the threaded hole and the threaded plug gauge. There is a coaxiality error between the axis of the thread plug gauge and the axis of the outer cylinder. There is an error affecting the perpendicularity between the thread hole axis and the end face.

The maximum absolute value of the Z-axis deviation measured three times for the thread mandrel is 0.1235mm, and the minimum value is 0.0035mm. The overall numerical deviation is within 0.05mm with a small fluctuation range and strong stability

Data analysis and conclusion of the measurement results of the threaded mandrel measurement method: The deviation of the extension accuracy of multiple threaded holes of the same type measured three times on the cylinder bore surface of the same machine body is relatively gentle up and down, and the stability is strong. The dimensional divergence of the threaded hole extension positions measured three times on the cylinder bore surface of the same machine body is very small and all are within the tolerance range, with a deviation ratio of 0.

In the measurement method of threaded mandrel, after the threaded mandrel is screwed into the threaded hole, measuring the smooth cylinder above the surface of the cylinder hole can eliminate the error influence caused by the thread profile, pitch, rotation direction and depth of the threaded hole, making the measured extension position size of the threaded hole more accurate and stable. Therefore, it can be judged that the measurement result of the threaded mandrel and the measurement method have relatively high accuracy.

## 5. Conclusion

The three-coordinate measurement method based on the threaded mandrel proposed in this paper provides a practical and feasible new approach for the detection of the high-precision extension position of threaded holes. This method simplifies the complex internal feature measurement into high-precision external feature measurement through ingenious reference transformation, fundamentally solving the problems of poor repeatability and large error in traditional methods. The experiment verified the significant advantages of this method in terms of measurement stability, repeatability and accuracy, and it can control the total measurement error within an extremely small range. This method is of great significance for improving the product quality in precision assembly fields such as engine manufacturing.

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