Machining Error Compensation of Single Shaft Part Based on Touch Trigger Probe

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Abstract. The precision machining of shaft parts is of great significance in the fields of aerospace, automobile manufacturing and so on. For important high precision shaft parts processing, especially in the beginning of mass production, it is easy to produce single piece of waste. Aiming at the error compensation problem of single shaft part, this paper proposes that after the semi-finishing, the dimensional accuracy of the workpiece is tested by the trigger probe, based on the measurement result, the least squares mathematical model of machining error is established, through the CNC macro program, in accordance with the cutting position,the error is compensated in the finishing stage.Therefore, single shaft part on-line detection, error compensation, precision evaluation are integrated into one,which is good to improve its processing efficiency,processing conditions, and the quality of processing. Experiments show that this method can reduce the limit error by about 52.5%.

INTRODUCTION

During the process of shaft parts on CNC lathe, the factors such as the original machine tool error, the error caused by the cutting force, thermal error and tool wear error can be reflected to the workpiece, which result to the taper error or waist drum error and greatly affect the business efficiency[1].

It is a general method to perform the off-line detection by the coordinate measuring machine to compensate error to improve the machining precision when machining the precise shaft parts.However,this approach is not only prone to secondary positioning error and high cost, the implementation is also very complex[2].Therefore,some researchers at home and abroad began to study the monitor of the processing process to improve the accuracy of parts by the online detection method.BANDY[3] gets its corresponding error vector according to the measured information, and corrects the tool path according to the error vector information ;CHO[4] has developed an on-line detection system for contour milling, and proposes a machining error compensation method based on detection database.A mathematical model of machining error of batch shaft workpiece is established by FAN Kai-guo[1], base on Newton interpolation theory,and according to the workpiece number and cutting position,the error is compensated through the macro program;Chen Yueping[5] achieves the error compensation by modifying the NC program code.But the existing error compensation technique usually can only amend cutting parameters of other workpieces based on a certain number of which has been processed.For important and high-precise shaft parts, especially at the beginning of the mass production, is still prone to single-piece waste, which leads to enterprises suffer losses.

ORGANIZATION OF THE TEXT

On - line detection system based on touch trigger probe

As shown in Figure 1, the on-line detection system based on the trigger probe consists of a software part, a hardware part and a position control part. In the turning center, the touch trigger probe is installed in the tool magazine, the axis of the workpiece and the spindle center coincide,

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with the instruction used to call the tool to call the probe, the probe can stop and measure the workpiece size when the workpiece is touched, then the measurement results can be locked in the macro variables of numerical control system[6].

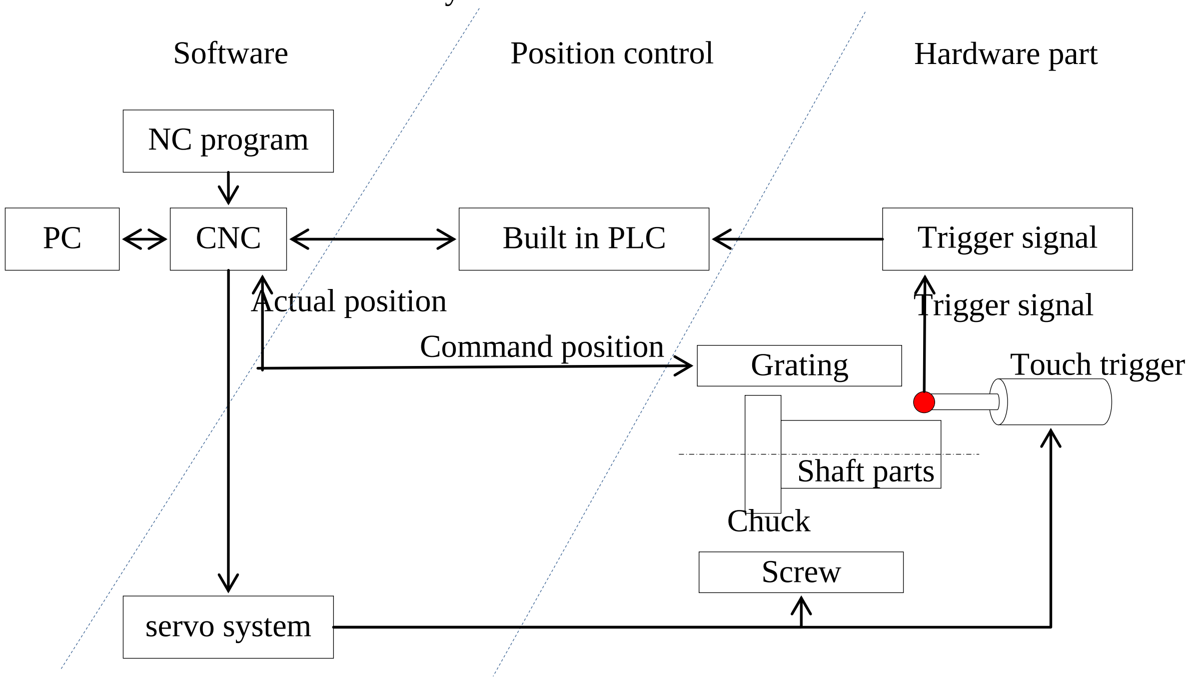

FIGURE 1. On - line detection system based on touch trigger probe.

Compensation of Machining Error of Single Shaft Part

Processing error data acquisition

The shaft part does not need to be disassembled after semi-finishing. When the positioning reference is constant, the actual size is measured by the probe, and then the machining error value can be obtained according to the formula (1) compared with the ideal size.

$$\varepsilon=\sqrt{(x_m-x_s)^2+(y_m-y_s)^2+(z_m-z_s)^2} \tag{1}$$

In the formula, (x_m, y_m, z_m) indicates the coordinates of the measuring point on the actual machining surface,and (x_s, y_s, z_s) indicates the coordinates on the ideal surface.

For shaft part processed by the turning center, the Y coordinate is zero, which is $y_s = y_m = 0$.In the study of its radial dimension, it will not be affected by the Z-direction error, and the Z-direction error can be neglected. Therefore, the machining error value of the shaft part can be calculated according to the formula (2).

$$\varepsilon=\sqrt{(x_m-x_s)^2+(y_m-y_s)^2+(z_m-z_s)^2}=\sqrt{(x_m-x_s)^2}=|x_m-x_s| \tag{2}$$

The machining error is the difference between the actual measured value and the theoretical value, so the machining error is (3).When the actual measured value is larger, the machining error is positive, while the actual measurement value is smaller, the processing error is negative.

$$\varepsilon = x_m - x_s \tag{3}$$

In order to facilitate the calculation of the dimension, the length of the workpiece is set to 1, the measurement position is the distance between the measuring point and the end face of the workpiece, the values are 1 / 6,1 / 3,1 / 2,2 / 3,5 / 6 and 1. Under the touch trigger probe detection, the processing error as shown in Table 1.

TABLE 1. Processing error table.

Measuring position x	**1/6**	**1/3**	**1/2**	**2/3**	**5/6**	**1**
Processing error ε (10μm)	4.5	4.6	4.7	4.9	5.1	5.5

Machining error modeling

The measurement results in Table 1 show that for a single shaft part, the machining error is proportional to the measured position,and the distribution is non-linear.If the quadratic Newton polynomial is used to fit the machining error, it is found that the high order coefficient is very small.Therefore,the relation between measuring position and processing error can be approximately linear.The reasons for the need to approximate are that on the one hand, the computational power of the NC macro program is weak for error compensation,and many times of the high order calculation will lead to the decrease of the precision,on the other hand, the compensation of the linear error is the most convenient and fast.Linearly fitted by least squares method, the result is (4).

$$\varepsilon = bx + a \tag{4}$$

In the formula,the b and a can be calculated according to the formula (5) and (6).

$$b = \frac{\sum_{i=1}^{6} x_i \varepsilon_i - (\sum_{i=1}^{6} x_i \sum_{i=1}^{6} \varepsilon_i)/6}{\sum_{i=1}^{6} x_i^2 - (\sum_{i=1}^{6} x_i)^2/6} \tag{5}$$

$$a = \bar{\varepsilon} - b\bar{x} \tag{6}$$

Take the value in Table 1 to calculate and retain the six significant digits, b = 1.14857, a = 4.21333.

Error compensation

The cause of the machining error may be the original error of the machine tool, the error caused by the cutting force, the thermal error or the tool wear error and so on, for any reason, the error value can be inverted and regard as the compensation value, and compensate to the cutting parameters according to the position at the finishing stage.As the change of the compensation amount with the cutting position is linear, it is equivalent to the process of cutting the tool path is actually a cone.When writing the compensation procedure, compensate the cutting start position and the stop position, tool path will naturally form a cone in accordance with the principle of interpolation of CNC machine tools.

The cutting start point position in finishing stage is stored in # 800,The cutting end point is stored in # 801. The coefficient b of the machining error linear fitting equation is stored in # 802, the coefficient a is stored in # 803. The compensation value of cutting start point is stored in # 804, and the compensation value of cutting end point is stored in # 805.The relationship of these parameters is as follows.

#800=#800-#804 (7)

#801=#801-#805 (8)

#804=#802*1/6+#803 (9)

#805=#802+#803 (10)

To be finished the finishing stage,he workpiece diameter to be re-tested by the probe, it will alarm if there is a out of tolerance.

application

To test the error compensation results, two groups of experiments ,the experimental group and contrast group were set up.The experimental group compensates errors in the finishing stage in accordance with the method described above,while the comparison group experiment does not compensate.After the trigger probe detection, the final results shown in Figure 2 and the experimental site shown in Figure 3.

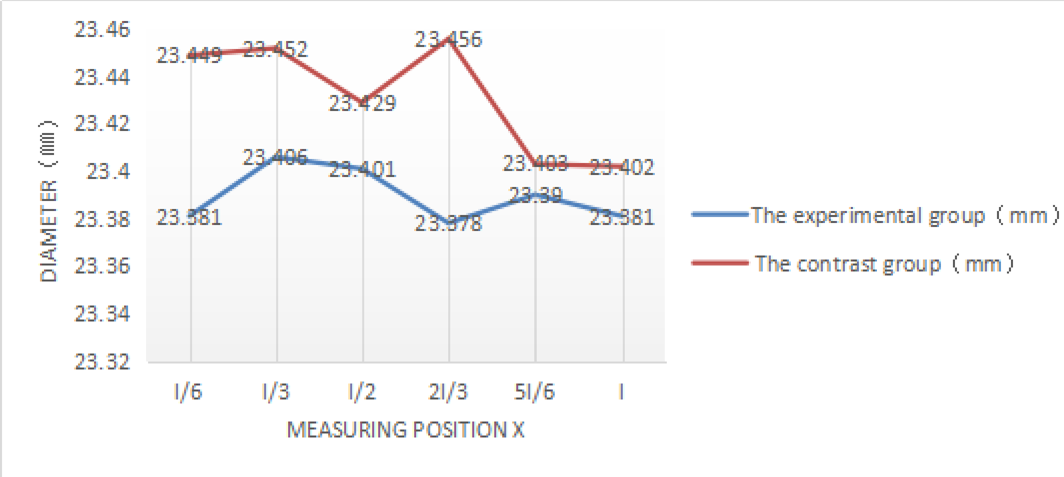

FIGURE 2. Comparison of experimental results.

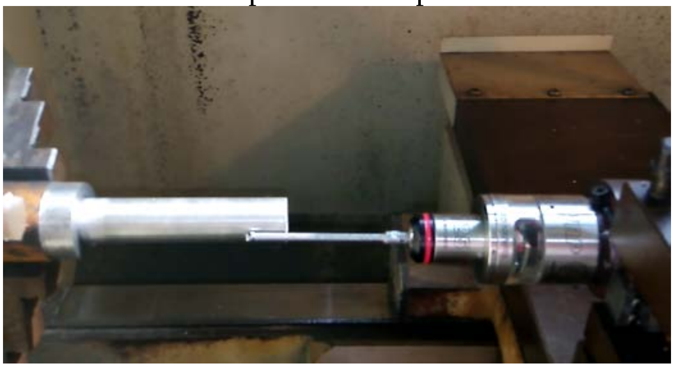

FIGURE 3. Experimental site.

Obviously,the average diameter of the experimental group was 23.389mm, the average diameter of the contrast group was 23.432mm, and the dimensional accuracy was significantly improved compared with the final processing target of 23.2mm.

CONCLUSION

The results show that the machining error model established by the least squares method according to the semi - finishing test results can be used to calculate the actual machining error accurately.The error value can be inverted and regard as the compensation value, and compensate to the cutting parameters according to the position at the finishing stage,after which the limit error is reduced by about 52.5%, and the precision improvement effect is remarkable.

In contrast, the results of the comparison group show that the workpiece has been out of tolerance in the absence of compensation, and the measurement results of the experimental group are within the allowable range, which avoids the production of waste or secondary processing,and improves the efficiency.

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REFERENCES

[1]. Fan Kaiguo,Yang Jianguo,Yao Xiaodong,et al.Error Compensation for Shaft Parts in Batch Manufacture Based on Newton Interpolation[J].Journal of Mechanical Engineering,2011,09:112-116.

[2]. Zhong Xingguo.Application of 3D Measuring Probe in NC Machining[J].MACHINE TOOL & HYDRAULICS,2015,04:165-167.

[3]. BANDY H T， DONMEZ M A， GILSINN D E.Methodology for compensating errors detected by process-intermittent inspection[M]. Gaithersburg:National Institute of Standards and Technology，2001.

[4]. CHO M W，KIM G H，SEO T I，et al. Integrated machining error compensation method using OMM data and modified PNN algorithm[J]. International Journal of Machine Tools and Manufacture，2006，46(12-13)：1417－27.

[5]. Chen Yueping,Gao Jian,Deng Haixiang,et al.On-line detection and error compensation method for complex curved surface parts[J].Journal of Mechanical Engineering,2012,23:143-151.

[6]. Valino, G., Suarez, C. M., Rico, J. C..Comparison Between a Laser Micrometer and a Touch Trigger Probe for Work piece Measurement on a CNC Lathe[J].ADVANCES IN MATERIALS PROCESSING TECHNOLOGIES,2012,498:49-54.