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Design of Cylindrical Error Assessment Software Based on Genetic Algorithm

Zhiyong ZHANG[a,b,c1] and Shiqiang WANG[a,b,c]
[a]*College of Mechanical Engineering, Zhengzhou University of Science and Technology, Zhengzhou Henan 450064, China;*
[b]*Henan Digital Intelligent Equipment Engineering Research Center;*
[c]*Zhengzhou Advanced Manufacturing Engineering Research Center of Key Parts for Dental Implant*

Abstract: Cylinder error detection of rotary parts is of great significance in the application of high precision end parts, and is an important component of the construction of national standard tolerance system. In view of the complexity and low efficiency of the cylindrical parts detection system, this paper designs a special evaluation software with the interface of GA genetic algorithm. Finally, the validity of the existing data of this design has very important practical value.

Keywords: Cylindrical degree error; Genetic algorithm; MATLAB; Error measurement

1. Introduction

With the rapid development of modern science and the continuous improvement of the production level, the requirements of the manufacturing accuracy of the machinery industry and related testing and measuring instruments are more and more strict, so the cylindrical degree error evaluation is a hot topic in the field of measurement technology[1]. The cylindrical degree error is defined as the variation of the actual cylindrical surface compared to the ideal cylindrical surface, whose value is equal to the difference between the maximum and minimum dimensions of any vertical section of the axis part. Cylindricity error mainly includes the error of axis section and transverse section, that is, it can reflect the circle error and straightness error of the part. The common measurement methods include three-point method, two-point method or three-coordinate measurement method.

A new generation of GPS standard cylindrical degree error common fitting way mainly include: the least squares method [LSC], minimum area method [MZC], maximum internal method [MIC] and minimum external method [MCC], the minimum area method calculation result is the most accurate, but because it is a nonlinear

[1] Corresponding Author: Zhiyong ZHANG, (1990-), male, born in Nanyang, Henan Province, is a lecturer at the College of Mechanical Engineering at Zhengzhou University of Science and Technology. He holds a master's degree and focuses on precision engineering, digital instruments and technology. Email: zky_zzy1990@163.com

measurement calculation, many scholars at home and abroad to study the minimum area method optimization algorithm and provides a variety of optimization calculation scheme. At present, the calculation methods of cylindrical degree error can be divided into two categories: computational geometry optimization algorithm and intelligent optimization algorithm.

Shi Xu yi[2]Establish and solve the measurement model of cylindrical degree error, on the basis of standard whale optimization algorithm, improve, design a secondary interpolation whale optimization algorithm, finally, through the cylindrical degree measurement data, simulate and test the algorithm, prove that the algorithm on the cylindrical degree error evaluation accuracy and convergence speed has been further improved. Liu Yue lei[3]By collecting the surface data of the parts through the measurement system, establishing the mathematical model and designing the algorithm, analyzing and processing the collected data, obtaining the cylindrical degree evaluation error, and comparing with the evaluation results of the data measured by the three-coordinate measuring machine. The results show that the system ensures the efficiency and accuracy of the detection, and can provide data support for the field processing and repair work.Ankit Agarwal[4]A computational framework is proposed for estimating the cylindrical degree error caused by cutting forces during the end milling of thin-walled round parts. This framework combines computational elements such as mechanical force model, finite element analysis (FEA) -based workpiece deflection model, tool deflection model based on cantilever formula, and cylindrical degree estimation algorithm based on particle swarm optimization (PSO). It is observed that the static deformation of cutting tools and thin-wall parts can significantly affect the cylindrical degree error. Subsequently the inevitable aspects associated with end milling of thin-walled circular parts, such as convex side machining and workpiece stiffness. It is observed that the cylindrical error in the concave process is much less due to the geometry of the thin-walled parts. This study also shows that a proper combination of effective cutting conditions and component thickness can significantly reduce the cylindrical degree error. The results of this study were confirmed by performing a set of computational simulations and vertical milling experiments under a wide range of cutting conditions.Amira A.Khattab[5]The effect of the number of scanned circles and spiral rings on the estimated cylindrical degree error is studied. We show that the effect of the sampling rate on the estimated cylindrical degree error value is more significant than the number of measured circles or spiral rings, even for the same number of data points. This paper examines the effect of the change in sampling rate on the estimated cylindrical degree error value when using two different strategies.

At present, scholars have conducted theoretical research on the calculation method of cylindrical degree error, but there is no relevant literature to discuss the practical application of cylindrical degree error. Considering the accuracy and robustness of genetic algorithm, this paper designs a software system of cylinder error measurement of MATLAB with genetic algorithm as the optimization algorithm. Finally, the system can be calculated accurately and stably by calculating the measured data.

2. A Mathematical Model for the Evaluation of the Cylindrical Degree Error

The position of the intersection of the ideal cylinder axis and the coordinate plane XOY is set as, and the direction vector of the L axis is set as:, then this axis equation can be expressed as:$\overline{\mathrm{A}} = \{\mathrm{a}, \mathrm{b}, 0\}\overline{\mathrm{S}} = \{\mathrm{p}, \mathrm{q}, 1\}$

$$\frac{x-a}{p}=\frac{y-b}{q}=\frac{z}{1} \tag{1}$$

$P_i(x_i,y_i,z_i), i=1,2,3\ldots n$ The sampling point on the measured cylinder is marked as, and the vector built to each sampling point based on the rounding point is as follows:. The distance from the sampling point to the ideal axis can be expressed as:$\overrightarrow{P_i}(x_i,y_i,z_i)Ld_i$

$$d_i=\frac{|\vec{P}-\vec{A}\times\vec{S}|}{|\vec{S}|}=\frac{|(x_i-a,y_i-b,z_i)\times(p,q,1)|}{\sqrt[2]{p^2+q^2+1}} \tag{2}$$

When evaluating the cylinder error using the LSC, the ideal cylinder is determined according to the principle of the principle of least squares. The radius of the least squares cylinder is marked as Rf, The distance of each discrete sampling point to the least squares column is:

$$d_i=\frac{|\vec{P}-\vec{A}\times\vec{S}|}{|\vec{S}|}-R_f=\frac{|(x_i-a,y_i-b,z_i)\times(p,q,1)|}{\sqrt[2]{p^2+q^2+1}}-R_f \tag{3}$$

According to the evaluation of the cylindrical degree geometry model shown in Figure 1.a, the cylindrical degree error is the difference between the maximum and the minimum distance between the measured element and the least squares ideal cylinder. The least square cylindrical objective function used to evaluate the cylinder degree deviation can be expressed as:

Least square method (LSC):

$$F(a,b,p,q,R_f)=\min\left\{\sum_{i=1}^{n}(d_i)^2\right\} \tag{4}$$

According to the fitting criteria of Figure 1, the mathematical models of the other three fitting methods are:

Minimum external connection method (MCC):

$$F(a,b,p,q,R_f)=\min\{\max[d_i]\} \tag{5}$$

Maximum Inner Cut Method (MIC):

$$F(a,b,p,q,R_f)=\max\{\min[d_i]\} \tag{6}$$

Minimum area method (MZC):

$$F(a,b,p,q,R_f)=\min\{\max[d_i]-\min[d_i]\} \tag{7}$$

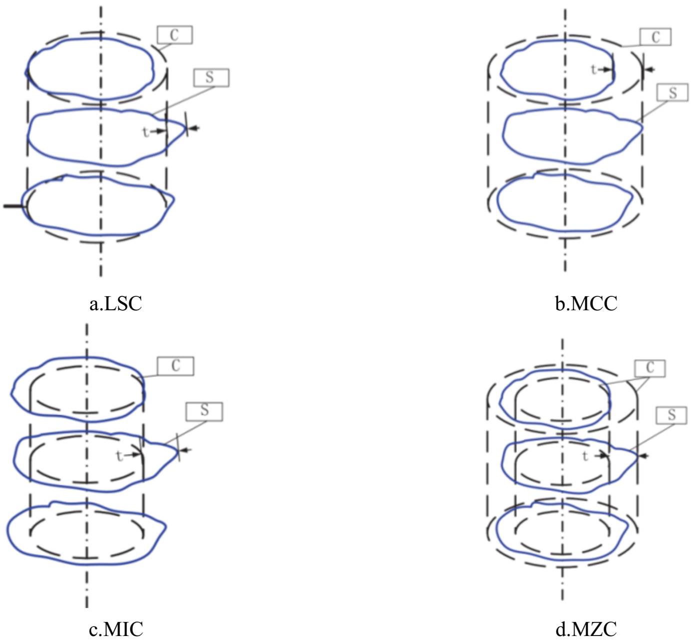


Figure 1. Display of the mathematical model of cylindrical degree error evaluation

3. The genetic Algorithm Evaluates the Cylindrical Degree Error

3.1. Overview of the GA

The GA describes the solution to the problem as the survival of the fittest on the "chromosome". Through the continuous development of the 'chromosomes' group, including selection, crossover, and mutation, we eventually converge to the "optimal environment" individuals to obtain the best or satisfactory solution to the problem. Selection, crossover, and mutation are the three main players of genetic algorithms.

3.2. Evaluation of Cylindrical Degree Error Process by Genetic Algorithm

According to the mathematical model of cylindrical error, the cylindrical degree error is calculated based on the idea of genetic algorithm. The specific calculation steps are as follows:

(1) Initialized population: there are four optimal variables (a, b, p, q) to form m chromosome Um=(am,bm,pm,qm).

(2) Construct the fitness function, and evaluate the value of each chromosome. The fitness function refers to formulas (5), (6) and (7).

(3) Selection operation: according to the fitness value of the individual, the value with the optimal calculation result is the parent of the next generation.

(4) Cross operation: Cross operation of the selected parent individuals to generate new offspring individuals.

(5) Variant operation: the mutation operation of the offspring to introduce certain randomness and diversity.

(6) Update population: combine the parent and offspring individuals into a new generation population.

Repeat steps 2 to 6 until termination conditions are reached (if the maximum number of iterations is reached or a satisfactory fit is found).

(7) Output results: the individual with the best output fitness, that is, the individual with the optimal combination of cylindrical surface parameters.

4. Based on the MATLAB Cylindrical Degree Error Measurement System Design

The software is programmed in MATLAB to realize human-computer interaction, and the software system can complete the cylindrical degree error assessment. Figure 2 shows the process flow chart of least squares method, minimum area method, minimum external method and maximum internal cutting method:

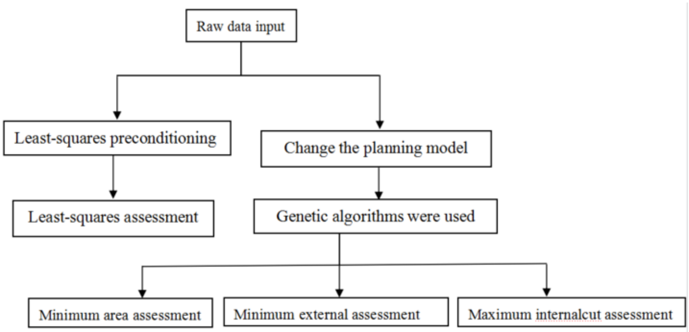


Figure 2. Flow chart of the evaluation procedure

Figure 3 shows the main page of the cylindrical error evaluation system. It can be seen that it is mainly composed of command panel and display panel. The command panel mainly issues evaluation commands, mainly including Open, LSC, MCC, MIC, MZC, amplify, Translate, Ratate, Ratate, R educe, Exit commands. Users can choose by themselves and easy to operate.

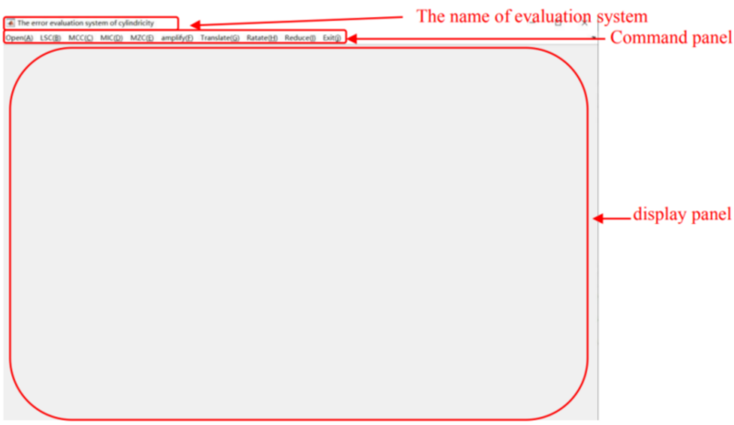
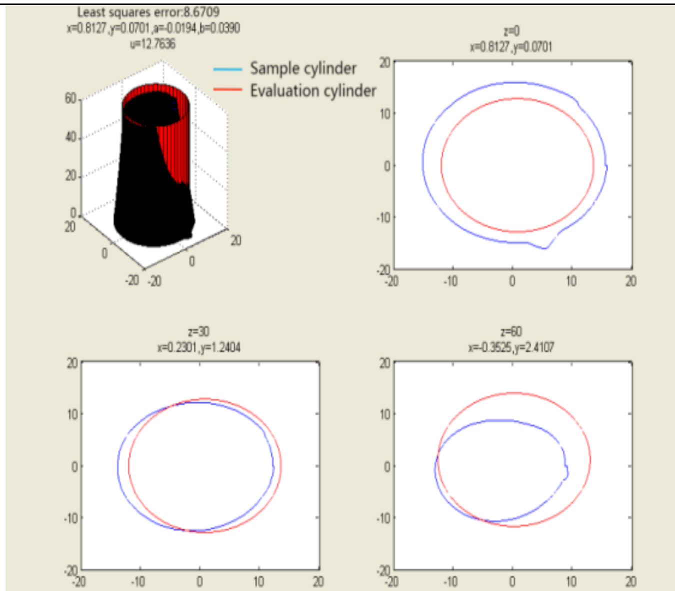
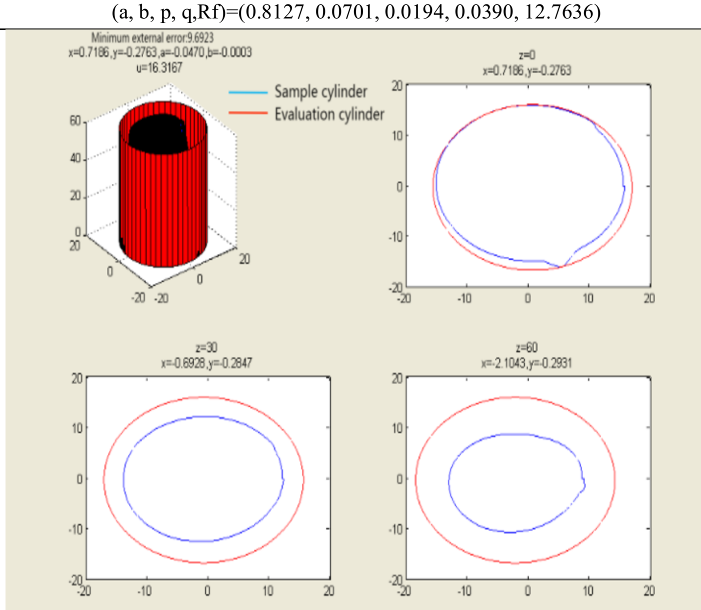


Figure 3. Main page of cylindrical degree error evaluation

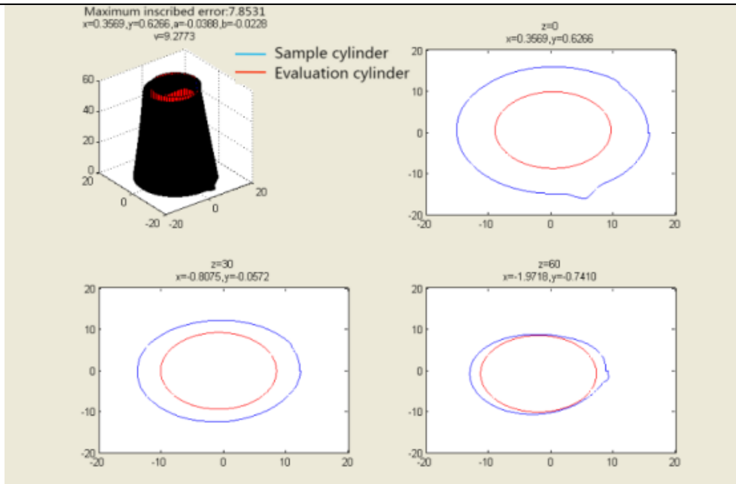
Click 'Open' to pop up the data input dialog box. If the data file has been established, you can directly call the data file. After selecting the required data, select the evaluation method according to the needs: least squares method, minimum external method, maximum internal connection method, and minimum area method. The running results are shown in Figure 4:



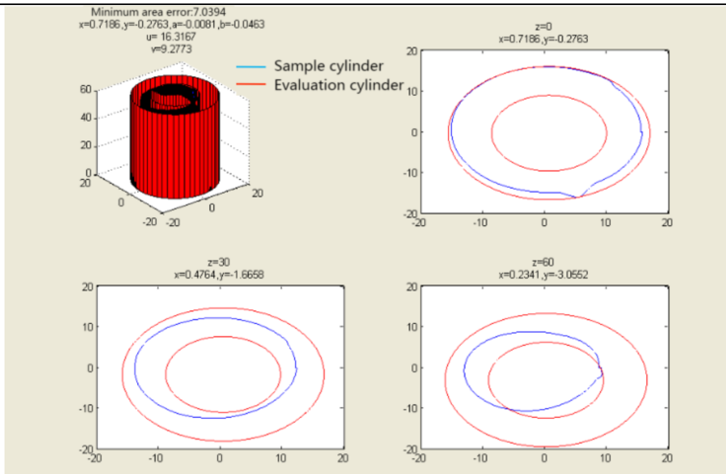
a. LSC: Cylindricity error =8.6709
(a, b, p, q,Rf)=(0.8127, 0.0701, 0.0194, 0.0390, 12.7636)



b. MCC: Cylindricity error =9.6923
(a, b, p,q,Rf)=(0.7186,0.2763,0.0470,0.0003,16.3167)



c. MIC: Cylindricity error =7.8531
(a, b, p, q,Rf)=(0.3569,0.6266,0.0388,0.0288,9.2773)



d. MZC: Cylindricity error =7.0394
(a, b, p, q, Rf)=(0.7186,0.2763,0.0081,0.0463,16.3167,9.2773)

Figure 4. Results of cylindricity error calculation

5. Conclusion

Based on the genetic algorithm, this paper realizes the design of cylindrical error evaluation system through matlab, which makes up one of the gaps in the practical application scenarios of geometric error. The specific work of this paper is mainly: 1. Establish the mathematical model of four fitting methods of cylindrical degree error; 2. Select the genetic algorithm to realize the evaluation of four fitting criteria of cylindrical degree error; 3. By calling the GA structure of matlab. In this scheme, the cylindrical degree error can be calculated according to the data collected by the cylindrical rod axis. The calculation results are fast, accurate and stable. However, considering that the genetic algorithm has a certain probability of falling into the local optimal solution, the future research will focus on the program implementation of the algorithm with better robustness.

Acknowledgments

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