Study on Coaxiality Measurement System of Compound Gear Shaft Based on Non-contact Optic

YE Zhibin[1], *LU Yonghua*[1*], *TAN Jie*[2], *LI Yanlong*[2], *CHAI Zhong*[1]

1. College of Mechanical and Electrical Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, P. R. China; 2. State-Owned Jinjiang Machine Factory, Chengdu 610043, P. R. China

(Received 29 March 2021; revised 14 May 2021; accepted 3 June 2021)

Abstract: Aiming at the shortcomings of traditional contact measurement methods such as low measurement efficiency, high cost and low accuracy, a non-contact optical measurement method based on the laser displacement sensor is proposed. According to the relevant regulations of the coaxiality error evaluation standard and the structural characteristics of the compound gear shaft, we have designed and built a set of supporting software system as well as a hardware test platform. In this paper, the distance difference threshold and scale threshold methods are used to eliminate outlier data. The least squares circle is selected to calculate the center of the circle and the minimum containment cylinder axis method is used as the reference axis of the composite gear shaft. Compensated by the standard step shaft calibration, the coaxiality error of the composite gear shaft can be measured to be within 0.01 mm in less than two minutes. The range value of the multi-section measurement test is 0.065 mm. The average coaxiality error is ∅0.476 mm.

Key words: compound gear shaft; non-contact measurement; laser displacement sensor; coaxiality; measuring system

CLC number: TP212 **Document code:** A **Article ID:** 1005-1120(2021)03-0393-11

0 Introduction

Due to various uncertain factors, there is always a certain error between the actual size of the final product and the ideal size, which results in the difference between the geometric features and the ideal situation in the machining process. Concentricity is a type of position error. In some occasions of rotary motion, part of the reference is eccentric. The mechanical transmission device will generate vibration and noise which will directly damage the device more seriously.

Traditional coaxiality detection methods for the outer contour of shaft parts mainly include the rotation axis method, coordinate method, tip method, simulation method, etc. The common feature of most traditional measurement methods is that the data points are collected by contacting the probe with the surface of the part to be measured. Whether the parts meet the requirements depends on the measurement data obtained according to the change in the reading of the indicator. These are all contact measurement methods, which can achieve high accuracy but are too slow for complex parts. The new non-contact measurement methods mainly include laser ranging method[1] and processing photos through machine learning to get coaxiality. The development of coaxial measurement technology in foreign countries is relatively early with more mature measurement methods and high precision measurement equipments. Kühnel et al.[2] designed a non-contact roundness and cylindricity automatic measuring device. They reduced the effects of factors such as eccentricity, tilt, and swing of the turntable on the measure-

*Corresponding author, E-mail address: nuaa_lyh@nuaa.edu.cn.

How to cite this article: YE Zhibin, LU Yonghua, TAN Jie, et al. Study on coaxiality measurement system of compound gear shaft based on non-contact optic[J]. Transactions of Nanjing University of Aeronautics and Astronautics, 2021, 38(3): 393-403.

http://dx.doi.org/10.16356/j.1005-1120.2021.03.004

ment results to be within 10 nm while the measurement speed has been greatly improved by the automated measurement process. Jun et al.[3] conducted research on the measurement of coaxiality and levelness between bolt holes during the assembly of the main wing of the T-50 supersonic advanced trainer aircraft. The quantitative measurement of the coaxiality and levelness error between two bolt holes was achieved through the analysis of reflected polarized light. Li et al.[4] presented a new contactless measurement prototype based on a laser displacement sensor that automatically evaluated the rolling performance of the sharp shaft. They applied laser displacement sensors to determine that changes in the size of the roots were related to surface residual stress and microhardness. Domestic coaxial measurement technology is still in the research stage, but there have been major breakthroughs in recent years. Wang et al.[5] proposed a method for measuring the coaxiality of piston rods based on machine vision technology to solve the problems of low accuracy and low efficiency of coaxiality error measurement during the manufacturing process of piston rods in 2015. And high-precision coaxiality measurement has been realized based on genetic algorithm. In 2017, Yan Minwei, a researcher of Xi'an Jiaotong University and others designed a coaxial detection device based on a two-dimensional laser displacement sensor to detect coaxiality errors in bearing holes of the bridge shell of the axle reducer[6].

The bevel gear-spline compound gear shaft is a relatively common type of composite shaft parts which consists of spline, cylindrical shaft and bevel gear. The real object is shown in Fig.1.

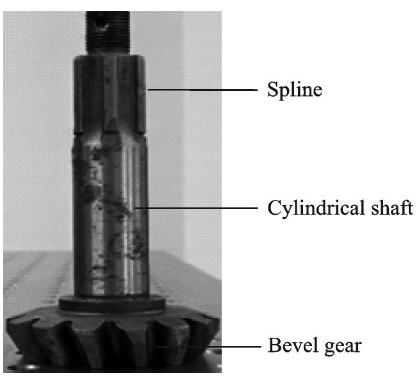


Fig.1 Bevel gear-spline compound gear shaft

At present, the coaxiality measurement method of the bevel gear-spline compound gear shaft part is also contact. The measurement tool is used to clamp the part rotated manually by the inspector. The coaxiality is calculated based on the data obtained from the contact between the probe and the surface of the part. The measurement results obtained by using the above measurement methods can be relatively easily affected by various factors such as measurement devices, environmental disturbances and manual operations, which lead to lower accuracy of the final measurement results and more time waste. According to the research experience in the field of form and position error measurement, we have designed and built a set of coaxiality measurement experiments platform based on laser ranging technology with laser displacement sensors to measure the coaxiality of multi-specification bevel gear-spline compound gear shafts[7]. We put forward a non-contact optical measurement method to obtain the spatial geometric profile information of parts[8]. Laser scanning of complex parts for precise distances avoids probe measurement inaccuracies. The part is driven by a motor to rotate so as to obtain more stable data. Finally, the coaxiality error of the bevel gear relative to the spline for one compound gear shaft is evaluated, realizing the fast and accurate measurement of coaxiality.

1 Test Principle

The Chinese machinery industry standard "JB/T 7557—1994 coaxiality error detection"[9] has explained the basic measurement method of coaxiality in detail. The overall measurement process can be summarized as the following four steps in Fig.2.

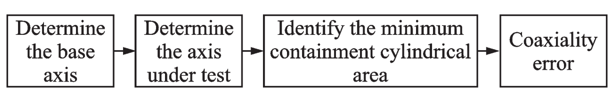


Fig.2 Basic process of coaxial error measurement

Based on the above-mentioned basic measurement method of coaxiality error, we use non-contact laser displacement sensors to obtain the information of each measurement element on the part to be tested by measuring the distance from the sensor to the surface of the part. The measurement scheme is shown in Fig.3.

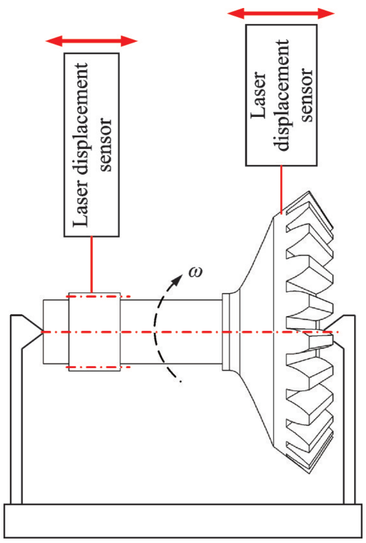


Fig.3 Schematic diagram of coaxial optical measurement scheme

During the measurement, the two laser displacement sensors measure the above spline part and the bevel gear part respectively while the compound gear shaft rotates at a constant speed ω. The distances from the sensors to the highest points of the two tooth top circles are within the range of the respective sensors which can move along the axis of the part to be measured. The proposed basic measurement process is shown as follows.

(1) Look for multiple sections to be measured, which are perpendicular to the rotation center axis in the spline part of the compound gear shaft.

(2) For a certain section, a series of distance values of measurement points on the section are obtained by a laser displacement sensor during a part of the rotation of the part.

(3) After data processing, the measured series of distance values are converted into the profile information of the section under the measurement coordinate system.

(4) Process the profile information of the section to obtain the coordinates of the center point of the section to be measured in the measurement coordinate system.

(5) Perform the above processing on the other sections of the spline part to obtain the coordinates of the center points of all the tested sections of the spline part.

(6) The coordinates of the center point of each section of the spline part are processed to obtain the reference axis equation of the coaxiality error evaluation.

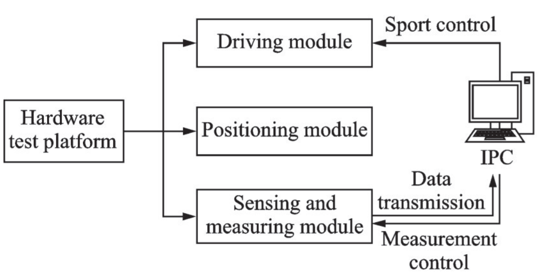
(7) Perform operations similar to steps(2—5) on the bevel gear part to obtain the positions of the center points of all the sections to be measured.

(8) According to the coaxiality evaluation criterion, determine the coaxiality error value of the bevel gear part relative to the reference axis of the spline part.

2 Measurement System Construction

2.1 Construction of hardware platform of measurement system

The overall structural design of the test system hardware platform is shown schematically in Fig.4. The test hardware platform can be divided into three parts: Driving module, positioning module and



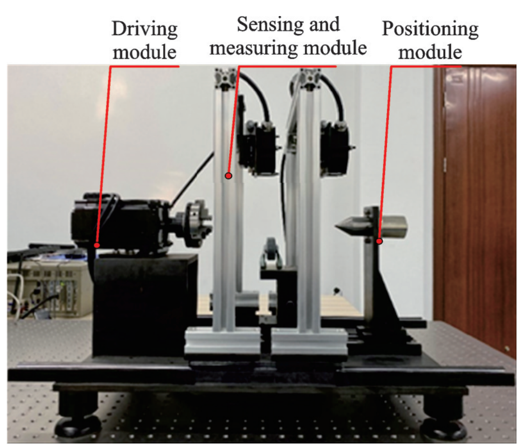


Fig.4 Overall structure of the test platform

sensing and measuring module. Among them, the driving module is responsible for driving the part to be tested, whose positioning and supporting depend on the positioning module. The sensing and measuring module is responsible for measuring the distance of the surface of the part and sending the measurement data to the industrial computer.

The positioning module and the sensing and measuring module are shown in Fig. 5. The overall structure of the positioning module includes the top tailstock, lifting support device and linear motion component. The lifting support device provides the main supporting force for the part to be tested, which is assisted by the top tailstock. Both of them are installed on the linear motion component. The position can be adjusted in the direction of the axis of the rotation center to meet the measurement requirements of parts of different length specifications. The sensing and measuring module mainly includes laser displacement sensors, one-dimensional translation stages, gantry brackets, and linear motion components. The triangle measurement principle of the laser displacement sensor is mainly using diffuse reflection measurement mode to obtain the distance[10-12].

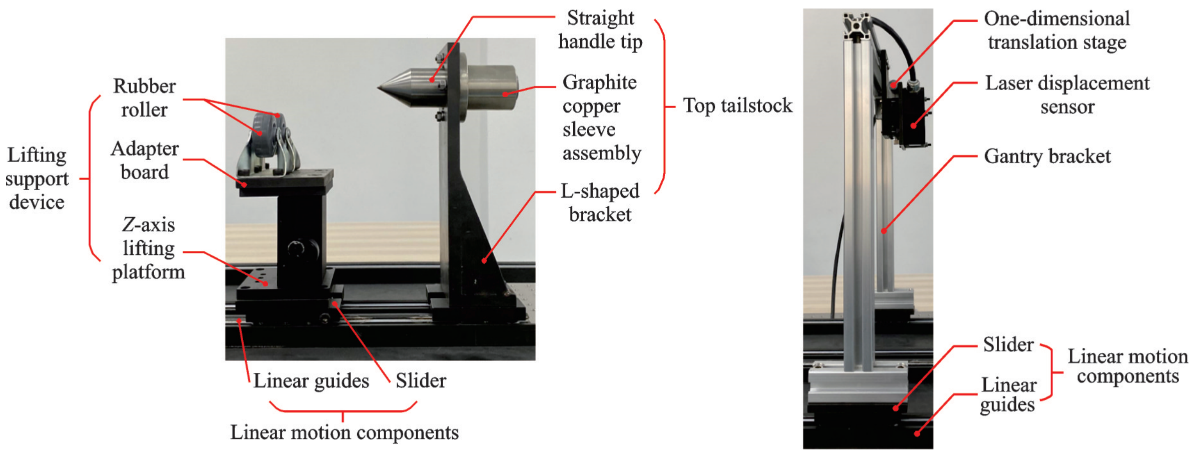


Fig.5 Positioning module and sensor measurement module

2.2 Construction of software module of measurement system

The host computer software of the measurement system is divided into five modules: User management module, system setting module, system calibration module, part measurement module and data processing module. The overall structure design is shown in Fig.6.

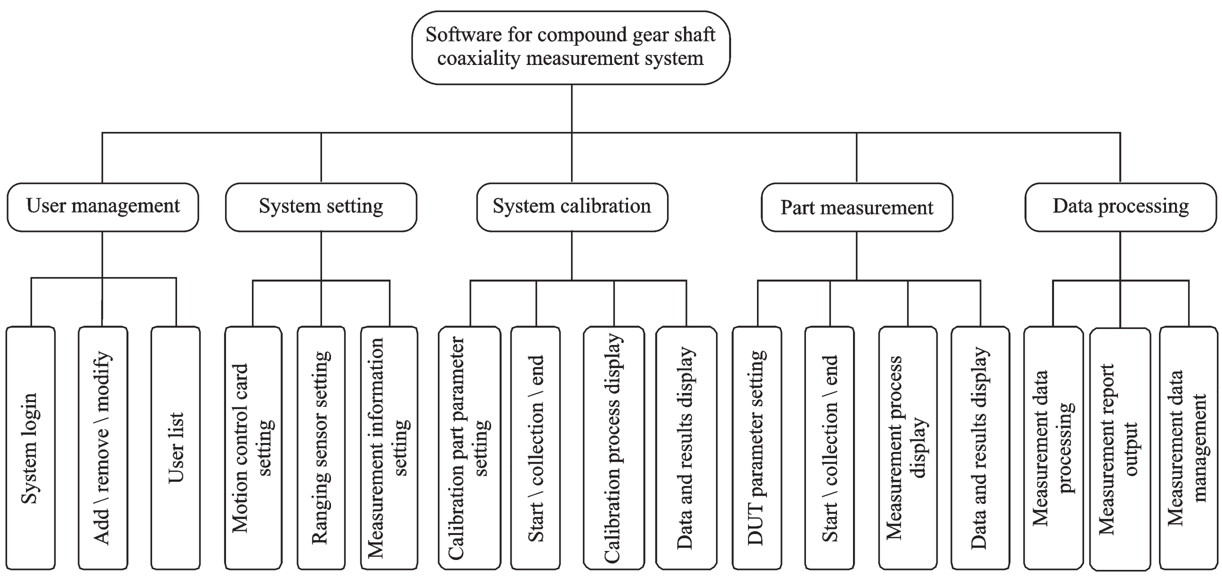


Fig.6 Overall structure design of the host computer software

The software test flow chart of the coaxial optical measurement system can be summarized as shown in Fig.7. After entering the measurement system, the system calibration is carried out firstly and then the part is measured. Finally, the measurement data is processed to determine whether the part is qualified.

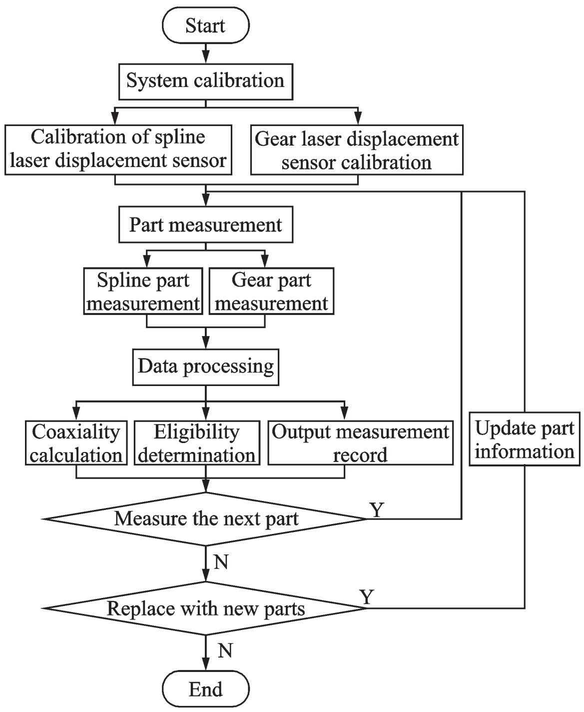


Fig.7 Test flow chart

2.3 System calibration

Due to installation errors, the laser is not vertically hit on the axis of the standard part, so we eliminate errors through system calibration. The calibration principle is shown in Fig.8. Assuming that the distance from the laser displacement sensor to the rotating center axis is d, and the offset distance of the sensor in the horizontal direction is ΔX. For a single laser displacement sensor, we use the axle diameters to calibrate the step axes of R and r. After measurement, the average distance obtained by the sensor is h_R and h_r. We can get the distance relationship as follows

$$\Delta X=\sqrt{r^2-\frac{[R^2-r^2-(h_r-h_R)^2]^2}{4(h_r-h_R)^2}} \tag{1}$$

$$d=h_r+\overline{BC}=h_r+\sqrt{r^2+\Delta X^2} \tag{2}$$

After calibration, the radius of the section circle is shown as

$$r_i=\sqrt{\Delta X^2+(d-d_i)^2} \tag{3}$$

where d_i represents the distance measured after calibration and r_i the radius of the actual measured part.

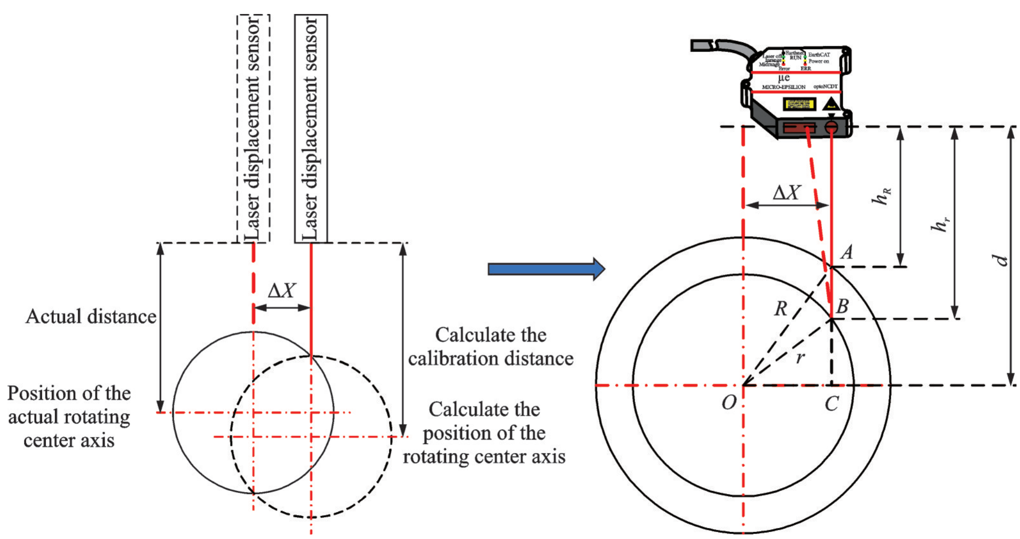


Fig.8 Principle of step axis measurement

2.4 Data processing and coaxiality assessment

By analyzing the positive profile data of spline and bevel gear, we find that the tops, roots, and sides of the teeth are distributed continuously and evenly at data points near the central position with little fluctuation. But the data points at the junction fluctuate relatively largely leading to poor continuity. In order to extract the center of the circle, we use distance difference threshold and scale threshold methods to strip data. When fitting the center of the ring, we need to remove the root circle data and only keep the top circle part. The plane point set convex package method[13] and the internal gradual approximation peripheral extraction method can both eliminate the root data. By comparing the two methods, the number of data retained before and after the top extract is shown in Table 1.

Obviously, approximation processing preserves valid data better. Therefore, we choose approximation method to process cross-sectional profile data. The results of bevel gear data are shown in Fig.9.

In order to obtain the coaxiality of the part, the base axis needs to be extracted. We use four methods to fit the center of the circle, which are least squares circle, minimum circumscribed circle, maximum inscribed circle and minimum zone circles[14-15]. After repeatedly measuring 10 sets of data for the bevel gear in Fig.10, we have found that the least squares circle fits the center of the circle with the smallest fluctuations.

There are three ways to process the data of the base axis, which are the minimum containment cylinder axis method, the least square midline method and the method of connecting head and tail center points. After comparison, we choose the minimum containment cylinder axis method to fit the base axis. Suppose that the axis passes through the point $O_0(x_0, y_0, 0)$, with the direction vector $L=(p, q, 1)$. The distance d_i from the center points $O_i(x_i, y_i, z_i)$ to the axis can be obtained by Eq.(4). Therefore, the radius of the minimum containment cylinder axis can be expressed as Eq.(5).

Table 1 The retained number of data before and after processing

Part to be tested	Raw data	Outlier processing	After the top data processed	
			Convex bag processing	Approximation processing
Bevel gear	20 000	8 125	312	4 330

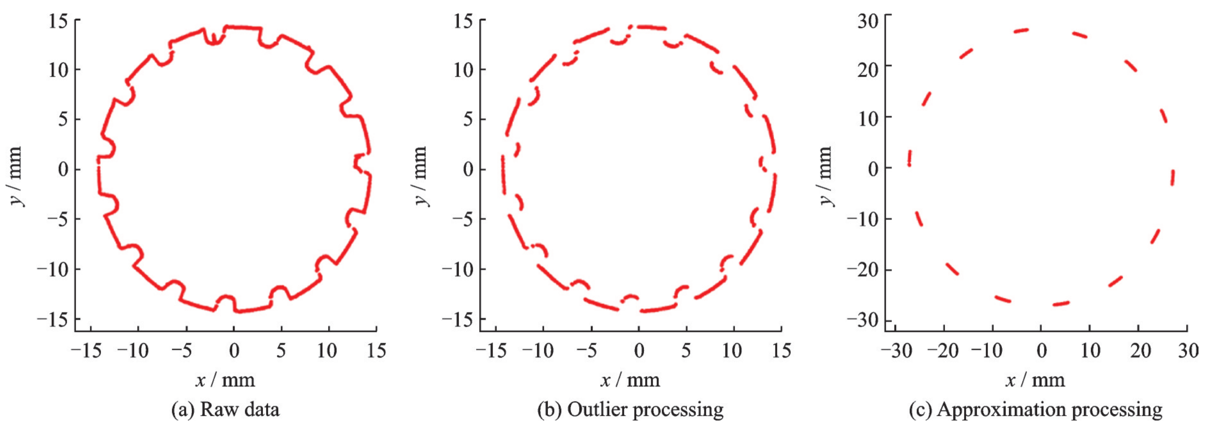


Fig.9 Results of bevel gear part of the top tooth extract processing

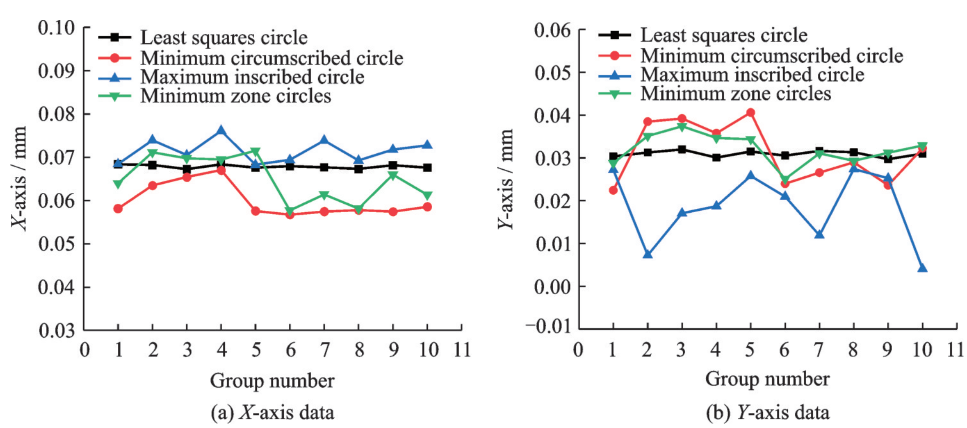


Fig.10 Change curves of the bevel gear

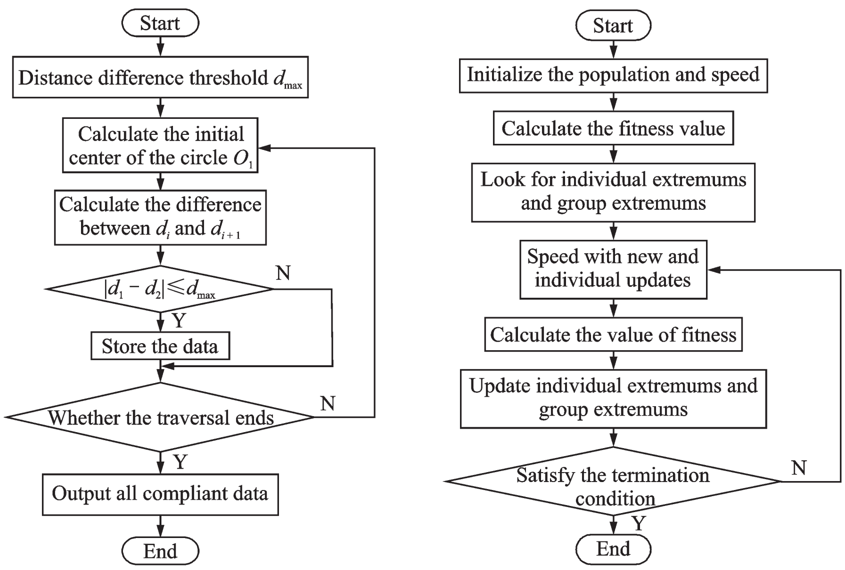
$$d_i = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2 + z_i^2 - \frac{[p(x_i - x_0) + q(y_i - y_0) + z_i]^2}{1 + p^2 + q^2}} \tag{4}$$

$$f(x_0, y_0, p, q) = \min(\max(d_i)) \tag{5}$$

The particle group algorithm is selected to solve the minimum inclusive cylindrical axis at the center of each section. Eq.(5) is used as the optimization target function of the particle group algorithm and the values of all parameters during the iteration are shown in Table 2. The gear shaft screening data flow and the particle group algorithm flow in the software are shown in Fig.11.

Table 2 Values of the particle group algorithm

Number of particles	Learning factor c_1	Learning factor c_2	Inertial weight ω	Maximum number of iterations	Argument dimension
30	1.494 45	1.494 45	0.729	2 000	4



(a) Section profile data filter (b) Particle group algorithm

Fig.11 Flowchart of data processing algorithm

The minimum inclusion area calculation is performed for each interface center point after obtaining the base axis equation. We take twice the maximum the distance from the reference axis as the coaxiality error.

3 Test and Analysis

3.1 System calibration test

The design dimension of the distance between the spline and bevel gear laser displacement sensor and the rotation center axis is 90 mm and the range of the sensor is 45—95 mm. In order to make the surface of the part to be measured within the range of the sensor, the radius of the stepped axis for calibration should be 0—45 mm. The actual calibration step axis is shown in Fig.12. We take their both average value for each of 10 sets of calibration results of the two sensors as the final calibration result. The calibration results are shown in Table 3. After the calibration, the data r_i in Eq.(3) obtained from the test is the radius value of the actual part.

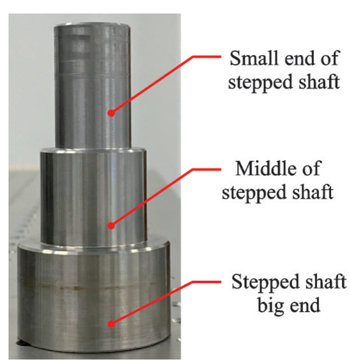


Fig.12 Ladder shaft for calibration

Table 3 System calibration test results

Sensor	Distance of rotation center axis d/mm	Offset distance in horizontal direction ΔX/mm
Spline laser displacement sensor	89.584	2.666
Bevel gear laser displacement sensor	89.663	0.902

3.2 Section measurement test

3.2.1 Single-section measurement test

We use the calibrated laser displacement sensor to perform distance measurement on three sections to obtain the profile information of the section to be measured. Then we calculate the coordinates of the center point of each section profile. The operation is repeated for 10 times. After analyzing the coordinate changes of the contour center of each section for the three sections to be measured on the cylindrical part of the compound gear shaft, we calculate the circle runout error of the data points of the tooth top contour for each group of cross-section profile data. The 10 measurement results of the spline part and the bevel gear part are shown in Fig.13. It shows that the fluctuation of the round runout error is small among them. The calculated results of the 10 groups are all within 0.01 mm, showing good repeatability.

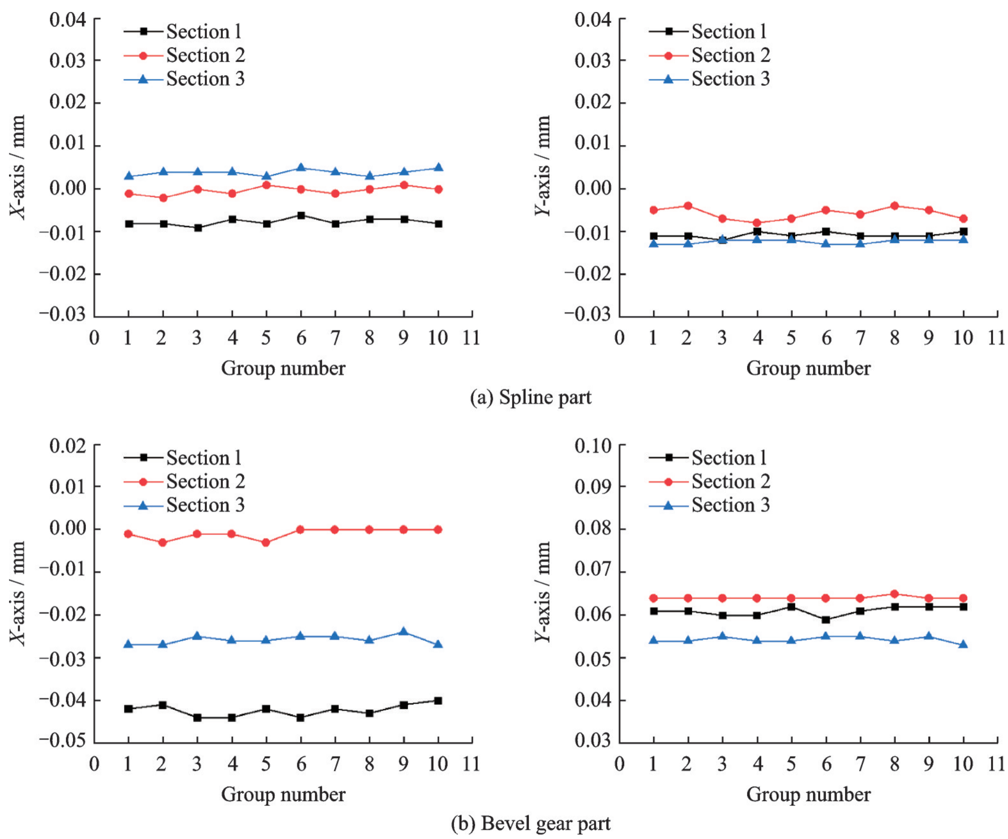


Fig.13 Normal section profile center coordinate change curves of the spline part and the bevel gear part cross section

3.2.2 Multi-section measurement test

According to the axial length of the flower key part and the gear part, we look for seven sections to be measured in the flower key part with 2 mm of the cross-section spacing as well as six sections to be measured of the bevel gear part with the same section spacing for compound gear shaft parts. Then we use the calibrated two laser displacement sensors to measure the distance between the spline part and the gear part to be measured to obtain the profile information of each measured section. After that the coordinates of the center point of each profile are calculated. According to the base axis fitting method, we calculate the minimum containment cylinder axis equation of the center point of each section of the spline part as the reference axis. Then we use the reference axis to evaluate the coaxiality error for the center points of the seven sections to be measured[16]. According to the minimum inclusion area coaxiality determination criterion, we then calculate the distance from the center point of each section of the bevel gear to the reference axis and take twice the maximum distance as the coaxiality error of the part. The above measurement process is repeated to get 10 sets of measurement tests. The coaxial error measurement results are shown in Fig.14. It shows that there is a certain fluctuation in coaxiality error with the range value of 10 measurement results is 0.065 mm.

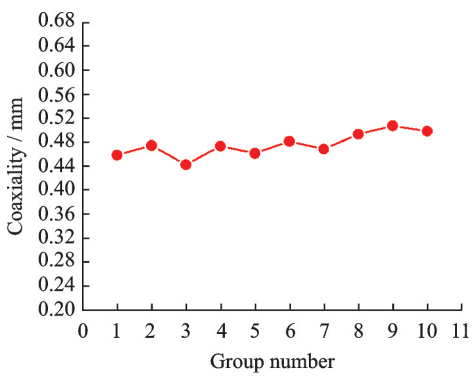


Fig.14 Curve of coaxiality error of compound gear shaft

3.3 Error analysis

By analyzing the possible influence of the hardware structure, data processing method and external environment of the measurement system on the coaxiality measurement process, various factors that may introduce errors into the measurement results are summarized as follows.

(1) Gross errors in measurement data

The data collection process of the sensor may be affected by he disturbance of the external environment which will result in outliers with large deviations in the cross-sectional profile of the part to be measured. Through the distance difference threshold and scale threshold methods, the effect of this abnormal data on subsequent data processing can be effectively removed.

(2) Errors from measurement equipment

The measurement error of the laser displacement sensor itself is 10 μm, which is determined by the manufacturing accuracy of the sensor. There is a gap between the roller and the rail shaft when the linear motion assembly is sliding. According to the existing experimental conditions in the laboratory, it is relatively difficult to process and assemble parts to meet the accuracy requirements of theoretical design.

(3) Errors caused by data processing methods

According to the results of the single-section circle center measurement test, the normal section profile processing method is used to process the profile information of the section in which the particle group algorithm is used to solve the minimum containment cylinder axis[17]. The initial value of each particle is random which makes the calculation result error.

(4) Errors caused by external factors

Environmental factors (such as temperature, vibration, electromagnetic interference, etc) and operations (personal factors) during the measurement process will affect the measurement data. We try to measure in a quiet, confined environment.

3.4 Test system performance parameters

The range of the coaxial optical measurement system test platform is mainly related to the range of the laser displacement sensor and the distance from the rotation center axis to the laser displacement sensor. The range of the two sensors is from 45 mm to 95 mm. According to the system calibration experiments, the distance between the spline laser displacement sensor and the rotation center axis is 89.584 mm with the bevel gear laser displacement sensor and the rotation center axis is 89.663 mm. Based on the above information, a schematic diagram of the measurement range is shown in Fig.15.

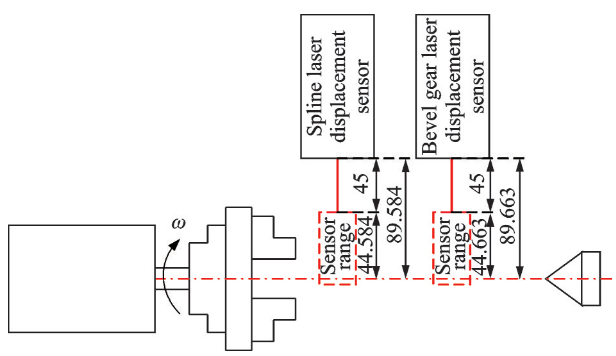


Fig.15 Schematic diagram of measurement range

Based on the above information, the coaxial optical measurement test platform is built for this project. The system range is shown in Table 4.

Table 4 Measuring system range

Parameter	Spline tooth tip circle diameter/mm	Bevel gear tip diameter/mm	Total length of the part under test/mm
Range	0—89.168	0—89.326	0—200

The measurement accuracy of the measurement system is evaluated and analyzed based on the measurement results of 10 sets of coaxiality errors. After bringing the measurement result in Eq.(6), we get $\varnothing 0.476$ mm as the measurement result $\overline{f}$. The third place after the decimal point of the coaxiality error measurement value is the estimated value, meaning that the measurement result of the measurement system can be accurate to the second place after the decimal point.

$$\overline{f} = \frac{1}{10}\sum_{i=1}^{10} f_i \tag{6}$$

The uncertainty evaluation and analysis of the measurement system is performed based on 10 sets of coaxiality error measurement results. After bringing 10 sets of measurement results in Eq.(7), we get 0.020 mm as the standard deviation of the measurement results. According to the Leyte criterion, no abnormal value appears in the measurement results. The type A uncertainty of the measurement system is $u=s=0.020$ mm.

$$s = \sqrt{\frac{1}{9}\sum_{i=1}^{10}\left(f_i - \overline{f}\right)^2} \tag{7}$$

4 Conclusions

(1) This paper introduces how to measure the coaxiality of a bevel gear-spline compound gear shaft by non-contact optical measurement method. According to the measurement process and principle, a measurement platform hardware as well as software platform are designed and constructed. The test flow of the entire measurement system is anylized to achieve rapid and accurate measurement and evaluation of coaxiality error.

(2) After the calibration, we get the laser offset ΔX of the sensor relative to the standard part axis. The distance difference threshold and scale threshold methods are used to eliminate outliers to reduce gross errors. After approximation processing, the top circle data is obtained to fit the center of the cross-sectional circle. The base axis is fitted by the particle group algorithm and then we get the final coaxiality error by processing the data in the minimum containment area. We obtain accurate coaxiality error after efficient processing.

(3) In the single-section measurement test, a normal section contour center measurement test and a round runout error measurement tests are performed for different parts of the part to be tested. We then get the range value within 0.01 mm. In the multi-section coaxiality measurement test, the distance measurement is performed between the spline part and the bevel gear part for the compound gear shaft. The coaxiality error of the bevel gear part with respect to the reference line of the spline part is from 0.45 mm to 0.50 mm. Among them, the range value is 0.065 mm. Finally, the error analysis of the measurement system is performed according to the test results.

References

[1] LU Y H, ZHANG J, LI X Y, et al. A robust method for adaptive center extraction of linear structured light stripe[J]. Transactions of Nanjing University of Aeronautics & Astronautics, 2020, 37(4): 586-596.

[2] KÜHNEL M, ULLMANN V, GERHARDT U, et al. Automated setup for non-tactile high-precision measurements of roundness and cylindricity using two laser interferometers[J]. Measurement Science and Technology, 2012, 23(7): 074016.

[3] JUN J, PARK Y, LEE J Y. Coincidence measurement system of concentricity and horizontality using a polarizing laser for unmanned assenbly of T-50 supersonic advanced trainer[J]. International Journal of Precision Engineering and Manufacturing, 2012, 13(10): 1759-1763.

[4] LI H W, LIANG Z Q, PEI J J, et al. New measurement method for spline shaft rolling performance evaluation using laser displacement sensor[J]. Chinese Journal of Mechanical Engineering, 2018, 31(4): 124-132.

[5] WANG Yingying, ZHANG Xuechang, LIANG Tao. Study on the coaxial error detection of piston rod based

on machine vision[J]. Mechanical Science and Technology, 2015, 34(12): 2-3.(in Chinese)

[6] YAN Minwei, ZHANG Yingjie, DAI Bochao. Research on coaxiality detection technology using laser sensors[J]. Journal of Xi'an Jiaotong University, 2017, 51(10): 27-32.(in Chinese)

[7] ZHANG X B, JIANG X Q, LI Z. A coaxiality measurement method for hole using non-diffracting beam technology[J]. Key Engineering Materials, 2005, 295/296: 283-288.

[8] GUO Yali, Han Yan. Non-contact measurement on coaxiality of column[J]. Transducer and Microsystem Technologies, 2009, 28(1): 103-105.(in Chinese)

[9] Ministry of Machine Building Industry of People's Republic of China. Coaxiality error detection: JB/T 7557-1994[S]. [S.l.]:[s.n.], 1994.(in chinese)

[10] WU W Q, PIRBHULAL S, ZHANG H Y, et al. Quantitative assessment for self-tracking of acute stress based on triangulation principle in a wearable sensor system[J]. IEEE Journal of Biomedical and Health Informatics, 2019, 23(2): 703-713.

[11] BRA U D, GRUDEN V, MO I J. A method for surface quality assessment of die-castings based on laser triangulation[J]. Measurement Science & Technology, 2008, 19(4): 045707.

[12] LU J, CAI Z, YAO B, et al. Error compensation and accuracy analysis of laser measurement system based on laser-beam calibration[J]. Optik, 2019, 200: 163272.

[13] CAO Lin, WANG Guangxia, WANG Weiqi, et al. A 3D model optimization method based on line features of oblique images[J]. Journal of Nanjing University of Aeronautics & Astronautics, 2020, 52(6): 980-988.(in Chinese)

[14] SUI W, DAN Z. Four methods for roundness evaluation[J]. Physics Procedia, 2012, 24(1): 2159-2164.

[15] JIN L, CHEN Y P, LU H Y, et al. Roundness error evaluation based on differential evolution algorithm[J]. Applied Mechanics and Materials, 2014, 670/671: 1285-1289.

[16] GUO Chongying, LIU Jianhua, TANG Chengtong, et al. Datum axis fitting for tolerances based on 3D convex hulls[J]. Optics and Precision Engineering, 2014, 22(12): 3247-3257.(in Chinese)

[17] ZHANG K. Research on coaxiality errors evaluation based on ant colony optimization algorithm[C]//Proceedings of Life System Modeling & Simulation International Conference on Bio-inspired Computational Intelligence & Applications. [S. l.]: Springer-Verlag, 2007.

Acknowledgements This work was supported by the National Natural Science Foundation of China (No.51975293) and Aeronautical Science Foundation of China (No. 2019ZD052010).

Authors Mr. **YE Zhibin** is a postgraduate student at Nanjing University of Aeronautics and Astronautics. His main research is focused on computer aided measurement and control research.

Prof. **LU Yonghua** received his Ph.D. degree in Mechatronic Engineering from NUAA in 2005. His main research is focused on intelligent detection and control, test systems, robots, sensors, etc.

Author contributions Mr. **YE Zhibin** gave the design idea, set up the model and analyzed the test results. Prof. **LU Yonghua** verified the reliability of the model. Mr. **TAN Jie** contributed to realizing the processing of hardware model and Mr. **LI Yanlong** contributed to writing software. Mr. **CHAI Zhong** assisted to complete the testing. All authors commented on the manuscript draft and approved the submission.

Competing interests The authors declare no competing interests.

(Production Editor: WANG Jing)

基于非接触式光学的复合齿轮轴同轴度测量系统研究

叶志斌[1], 陆永华[1], 谭　杰[2], 李雁龙[2], 柴　众[1]

(1.南京航空航天大学机电学院, 南京 210016, 中国; 2.国营锦江机器厂, 成都 610043, 中国)

摘要: 针对传统接触测量方法的低效率、高成本、低精度的弊端,提出了基于激光位移传感器的非接触式光学测量方法。根据同轴误差评价标准的有关规定和复合齿轮轴的结构特点,设计构建了一套配套软件系统和硬件测试平台。本文使用距离差阈值法和规模阈值法来消除异常数据。选择最小二乘法拟合圆心,并采用最小包容圆柱轴线作为复合齿轮轴同轴度评定的基准轴线。多截面测量试验表明,极差为0.065 mm,试验平均同轴误差为∅0.476 mm。

关键词: 复合齿轮轴;非接触式测量;激光位移传感器;同轴度;测量系统