Development of coaxiality measurement system of turbine components and stud standard parts

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Abstract: Turbocharger and gearbox were widely used in the precision machinery manufacturing industry. The dimensional accuracy of turbine components and stud standard parts was an important guarantee for the assembly accuracy of turbine components and gearbox, among which coaxiality was a key parameter for the dimensional accuracy of turbine components and stud standard parts. According to the demands of coaxiality measurement for turbine components and stud standard parts, a set of checking fixture was developed, and a software based on LabVIEW was built for the measurement. The coaxiality of stud standard M12 was measured by experiment and the uncertainty of measurement was evaluated. The experimental results show that the coaxiality error obtained from the four measurements is 6.3–6.5 μm, and the extended uncertainty reaches 2.6 μm. The results show that the developed coaxiality measurement system is suitable for the high precision measurement of the coaxiality of turbine parts and stud standard parts.

Key words: coaxiality measurement; turbine components; stud standard part; uncertainty

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涡轮部件及螺柱标准件同轴度测量系统的研制

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摘 要：涡轮增压器与变速箱在精密机械制造行业中应用广泛,涡轮部件及螺柱标准件的尺寸准确度是涡轮增压器和变速箱装配精度的一个重要保证,其中同轴度是涡轮部件及螺柱标准件尺寸准确度的一个关键参数,根据涡轮部件及螺柱标准件的同轴度测量需求,研制了一套涡轮部件及螺柱标准件同轴度的测量系统,并基于 LabVIEW 开发了测量软件。通过实验对螺柱标准件 M12 的同轴度进行测量并完成测量不确定度评定。实验结果显示四次测量得到的同轴度误差在 6.3~6.5 μm,扩展不确定度达 2.6 μm,结论表明:研制的同轴度测量系统适用于涡轮部件及螺柱标准件同轴度的高精度测量。

关键词：同轴度测量； 涡轮部件； 螺柱标准件； 不确定度

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0 Introduction

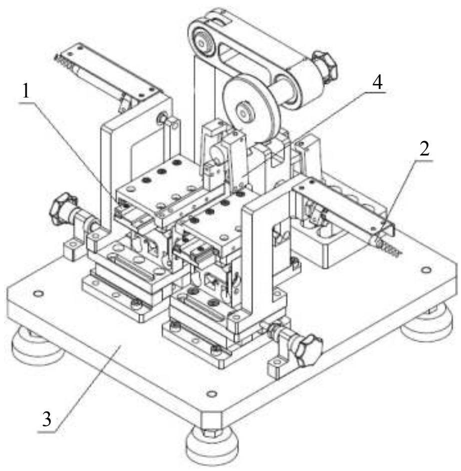
In recent years, with the development of the national economy and the transformation of industrial structure, as well as the increasing development of mechanical manufacturing, the manufacturers and customers of mechanical products are processing quality of mechanical products. Meanwhile, the requirements of assembly accuracy and the quality of products are higher[1]. Turbocharger and gearbox are widely used in mechanical industry, and stud standard parts are universally used in turbocharger and gearbox. In order to ensure the assembly accuracy of turbocharger and gearbox, it is necessary to ensure the dimensional accuracy of turbine components and stud standard parts, because coaxiality is an important parameter to measure the dimensional accuracy of turbocharger and gearbox[2].

Aiming at the blank of coaxiality measurement of turbine components and stud standard parts without center hole, a method of measuring coaxiality of turbine components and stud standard parts is applied in this paper. In order to measure the coaxiality, the testing fixture and using virtual instrument was designed. The testing fixture of coaxiality measurement instrument can accomplish the measurement of thread coaxiality and solve the traceability value problem of important parts in the mechanical industry.

1 Design of testing fixture system

The testing fixture of coxiality measurement of turbine parts and stud standard parts comprise the base, V type clamping mechanism, guide rail measuring mechanism and inductance probe[3].

The base is the foundation of the whole testing fixture. The V-type clamping mechanism and the guide rail measuring device are fixed on the base. The two inductance probes are fixed at the same height as the stud standard parts. The whole structure of the tester is shown in Fig. 1. When the coaxial degree of the tested standard part is measured with the testing fixture, the cylindrical part of the tested standard part is pressed on the V-shaped frame. When the rolling bearing drives the measured standard part to rotate along the circumference, the thread drives the stylus to move along the axis of the standard part with the speed of one pitch per cycle, the V-type clamping mechanism is made of cemented carbide. The standard parts of the stud have different specifications, according to the specification of the thread. Several kinds of optimum three-needle diameters are calculated to meet the requirement of coaxial measurement of stud standard parts[4].



1-guide rail measuring mechanism; 2-inductance probe;

3-base; 4-three-needle probe

Fig.1 Testing fixture for measuring coaxiality

In this paper, the differential inductive displacement sensor is chosen, and the type DG03 inductance probe, which is made by Sanmenxia Zhongyuan Measuring Instrument Co. Ltd., is used. The resolution is 0.1 μm, the measuring range is ±1.0 mm, and the sensitivity of output voltage is 70 mV/mm. the measuring force of the inductance probe is small. In the range of 0.55–0.75 N, the deformation is reduced by the measuring force, and the two inductive probes are fixed in the position of the same height as the tested standard parts and perpendicular to the axis of the tested standard parts[5].

2 Design of data acquisition system

The data acquisition system consists of the signal processing circuit, data acquisition card and computer software.the sensitivity of the sensor is 70 mV/mm, and the coaxiality of the measured standard parts is several microns, so the output voltage signal of the sensor is only a few millivolts. It is necessary to design a signal conditioning circuit to adjust the output signal of the sensor in order to amplify the output signal of the sensor. In this paper, a high precision operational amplifier is used to amplify the signal. The AD620 instrument amplifier is selected and the required magnification is obtained by two-stage amplifier.

The signal after the amplification circuit can be read by the data acquisition card. The data acquisition system selects USB5935 data acquisition card, which is based on the USB bus, can be directly inserted in the computer's USB interface, the data can be input into the computer for analysis and processing[6].

The signal output from the data acquisition card arrives at the computer and is displayed by LabVIEW software. This data acquisition system has designed a graphical display interface with LabVIEW to display the change curve of coaxiality measurement. The maximum value of absolute value after subtracting corresponding points of the two curves (the coaxial value of the tested standard parts) is shown. The producer/consumer mode in LabVIEW programming is adopted in this system. The producer cycle is data generation/acquisition and the data is generated and placed in the data buffer. When the consumer cycle is required for data display/analysis, data is pulled from the data buffer to perform relevant analysis operations [7].

The data acquisition system mainly includes two modules: data acquisition setup and data acquisition with result display. The data acquisition system includes channel setting, timing setting, and recording setting. Data acquisition setup is mainly for the channel of data acquisition system, connection terminal configuration, and maximum/minimum voltage. Timing set is mainly for the data acquisition system sampling clock source, sampling number, Sampling mode, sampling rate etc. The record setting is mainly set by the recording mode of the acquisition system and the path of the TDMS file used to record the data[8].

3 Measurement experiment and analysis

The main purpose of this experiment is to measure the stud standard part M12. The measurement is carried out in the laboratory of temperature (20 ±0.3) ℃ and humidity of 53% RH. In the actual measurement, according to the thread specification of the tested standard part, the measuring needle with the corresponding diameter is selected. And it is fixed on the guide rail measuring device. Adjusting the guide rail perpendicular to the axis of the tested standard parts, in order to ensure that the measuring needle has the appropriate measuring force. A small round bar with a cylindrical degree of fewer than 0.5 μm is fixed on the V-shaped frame. The measuring needle is pressed on the small round bar and the direction of the guide rail is adjusted so that the left and right guideways are bounded by LabVIEW in the course of the 20 mm travel. The maximum value of surface display is less than 1 μm, which can make the error of coaxiality measurement less than 1 μm because the reference axis of guide rail and stud standard part is not parallel. Then, the cylindrical part of M12 standard part of the tested stud is put forward[9]. Press it on the V-type frame, Put the needle in the thread, reset the device, drive the rolling bearing, make the measured standard part rotate evenly, and the difference between the right and left side of the inductance micrometer is taken as the coaxial error of the measured standard part. The average value is calculated as the result of the coaxiality measurement.

The measurement of standard stud M12 has been done for four times, and the experimental results are shown in Figs.2–5. The vertical coordinates in the figure are the difference between the values of the two sides of the inductance micrometer (t).

Figure 2–5 show that the t(max) obtained by four times measurement is in the range of 6.3–6.5 μm. The

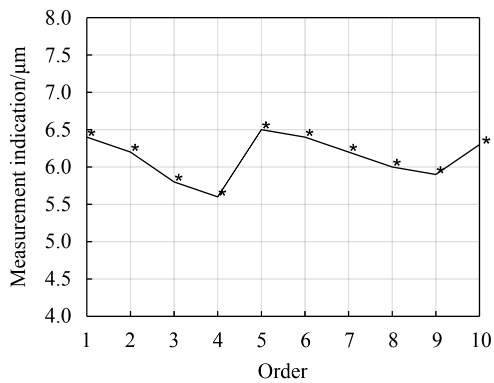


Fig.2 First measurement data

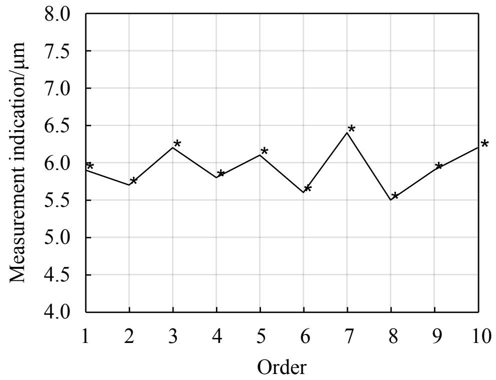


Fig.3 Second measurement data

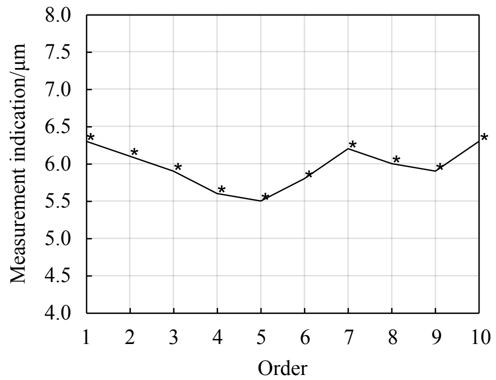


Fig.4 Third measurement data

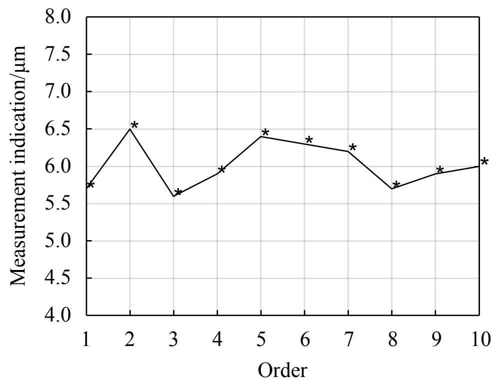


Fig.5 Fourth measurement data

experimental results show that the coaxial measuring instrument has good repeatability under the same experimental conditions[10].

4 Evaluation of measurement uncertainty

Measurement model

$$t = |M_a - M_b| \tag{1}$$

Where, t is coaxiality error; M_a is inductance sensor indication of the left side; M_b is inductance sensor indication of the right side.

The uncertainty source of input including:

(1) Standard uncertainty induced by repeatability of the coaxiality of turbine components and stud standard part $u(|M_a - M_b|)$;

(2) Standard uncertainty induced by resolution of inductance probe $u(\delta_{|M_a - M_b|})$;

(3) Standard uncertainty induced by indication error of inductance probe $u(\Delta |M_a - M_b|)$;

(4) Standard uncertainty induced by expansion coefficient difference $u(\delta_a)$[11];

(5) Standard uncertainty induced by temperature difference $u(\delta_t)$;

(6) Standard uncertainty induced by force measurement $u(F_{|M_a - M_b|})$;

(7) Standard uncertainty induced by shape error of three needle $u(x_{|M_a - M_b|})$;

(8) Standard uncertainty induced by non parallel reference axis of the guide rail and stud standard parts $u(\Delta P)$[12];

(9) Standard uncertainty induced by the reference axis which is out of vertical of the standard parts of the inductance probe and stud $u(\Delta S)$;

(10) Standard uncertainty induced by the measurement of the planeness of the interface due to the slight movement of the parallelogram mechanism up and down during the measurement $u(\Delta C)$[13];

(11) The uncertainty induced by the deviation between the measured value and the actual value due to the trace movement of the parallelogram mechanism in the measurement $u(\Delta D)$[14];

The standard uncertainty above are independent.

The Combined uncertainty is:

$$uc = \sum_{i=1}^{n} \sqrt{ui} = \sqrt{0.2^2 + 1^2 + 0.71^2 + 002^2} = 1.26\ \mu\text{m} \tag{2}$$

So the expanded uncertainty (k=2) is:

$$U = ku_c = 2 \times 1.26 = 2.52 \approx 2.6\ \mu\text{m} \tag{3}$$

Measurement uncertainty source and the summary of calculate results is shown in Tab.1.

Tab.1 Measurement uncertainty source and the summary of calculate results

No.	Measurement Uncertainty Source	ui	Evaluation type	Distribution type	ui/μm
1	Repeatability	$u(\lvert M_a-M_b\rvert)$	A	/	0.2
	Resolution	$u(\delta_{\lvert M_a-M_b\rvert})$	B	uniformiy	0.03
2	Indication error of inductance micrometer	$u(\Delta\lvert M_a-M_b\rvert)$	B	/	0.2
3	Temperature	$u(\delta_t)$	B	uniformiy	neglected
	Expansion factor	$u(\delta_\alpha)$	B	uniformiy	neglected
4	Force of measurement	$u(F_{\lvert M_a-M_b\rvert})$	B	uniformiy	neglected
5	Three-needle form error	$u(x_{\lvert M_a-M_b\rvert})$	B	Two-point	0.71
6	Installation error	$u(\Delta P)$	B	Two-point	1
		$u(\Delta S)$	B	uniformiy	neglected
7	Mechanism error	$u(\Delta C)$	B	uniformiy	neglected
		$u(\Delta D)$	B	uniformiy	neglected
	Combined standard uncertainty: u_c				1.26
	Expanded uncertainty(k=2): U				2.6

5 Conclusions

In this paper, the coaxiality measurement method of turbine components and stud standard parts is taken as the research object, the mechanical design and the software design of the data acquisition system for the coaxiality measuring tools of turbine components and stud standard parts are completed[15]. Then, the measured results of the designed turbine components and stud standard coaxiality measuring tools are verified by experiments. The experimental and measurement uncertainty evaluation results show that the uncertainty of the coaxiality measurement results is 2.6 μm, which reaches the expected goal.

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