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A New Measurement Method of Rotary Precision of Lathe Spindle

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Abstract. Rotary precision of the lathe spindle directly affects accuracy of the machined work-piece. With continuous improvement on requirements of rotary precision of the lathe spindle, a more accurate measurement method is needed to adopt to reflect actual shape precision of unprocessed part. Some advanced measurement principle and methods about rotary precision of the lathe spindle are researched, and also the measurement error is analyzed. The measurement result gotten by sensor concludes two parts, one is eccentric error caused by installation of the base ball, the other is rotary error of the lathe spindle. The eccentric error is separated by the way of filter, as well as the rotary error is quickly and correctly measured by unidirectional digital measurement. The rotary error is superimposed on a base circle generated by algorithm. The roundness error is assessed by MZC. At last, verifying the feasibility of the new measurement method by means of real experiment.

Introduction

Lathe spindle is an important part to determine the location of the work-piece or the tool and to transmit the main cutting campaign. And its rotary precision is a main factor to affect the machining accuracy, and is an important indicator to measure the lathe performance. The location of ideal rotation axis is fixed in space when lathe spindle is turning. The line-speed of rotation center is zero, furthermore, remaining points are all around the center in the form of circular motion. However, there are many factors which make the rotation center instable, for example, geometry accuracy of the lathe spindle and bearing, installation precision, and deformation generated by the force and heat [1]. The actual location of rotation center is always changing, and its variation may be periodic or random. Therefore, the average position of instantaneous centerline is often considered as the "ideal axis ". The movement is identified as the rotary axis error motion when spatial location of the instantaneously rotary axis deviates from the ideally rotary axis. Both the machining accuracy and surface quality of work-piece are affected by instability of the rotation center. It is helpful for users to evaluate the lathe quality and forecast the machining accuracy by determining and analyzing rotary precision of the lathe spindle. So it is one of the most important projects for studying lathe [2] to measure and research on rotary precision of the spindle.

Mathematical Model of Rotary Precision of the Lathe Spindle

A reference axis must be used to reflect the rotation axis since it is invisible. A high roundness ball is usually chosen as the base level when the rotary precision is measured. The installation of standard ball can be seen from Fig.1. Two sensors are deployed in radial position by an angle of 90. The screw of swing device can adjust installation eccentricity of the standard ball [3]. In fact, the signal detected by the sensor is complex. There are the following parameters in Fig.1.

O_o - Ideal rotation center; O_m - Geometric center of the standard ball;

O_r - Instantaneous rotation center; e - Installation eccentricity of the standard ball;

θ - Angular of error motion, when e is parallel to x axis, $\theta = 0$;

$r(\theta)$ - A instantaneously radial error motion (the vector with size and direction);

R_m - Radius of the standard ball; $s(\theta)$ -Shape error of the standard ball.

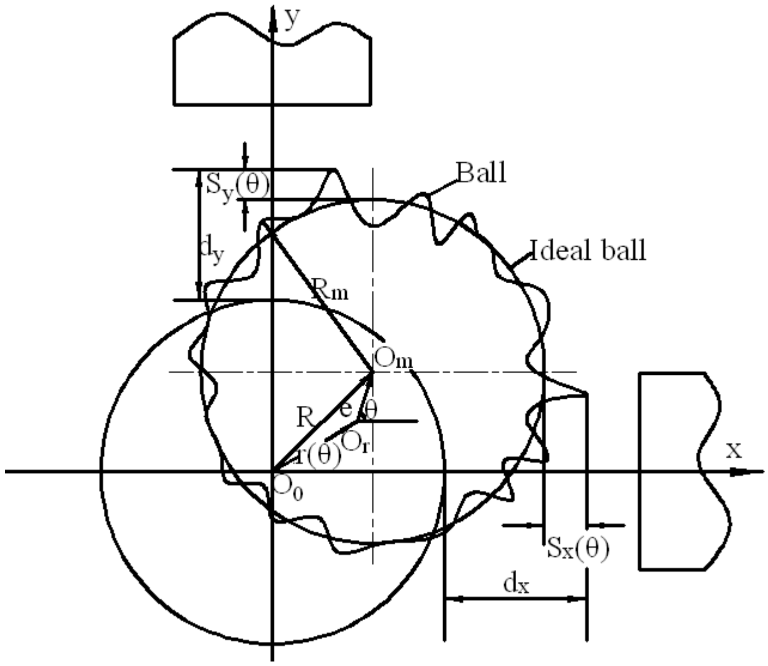

Fig. 1 Detection signal analysis of radial error

If the radius of the standard ball is much greater than the other two volumes, eccentricity and radial error, then output signals of the two sensors are:

$$dx = e\cos\theta + r_x(\theta) + s_x(\theta) \tag{1}$$

$$dy = e\sin\theta + r_y(\theta) + s_y(\theta) \tag{2}$$

It can be seen that $r(\theta)$ is needed in Eq.1 and Eq.2.

(1)The ball is considered as the standard ball when shape error of the ball is much less than the rotary error. Only in this way, $s_x(\theta)$ and $s_y(\theta)$ are ignored.

(2) d_x and d_y are defined as the trace of the standard ball center O_m instead of the trace of instantaneous rotation center O_r ,because eccentric error e is considered.

New Measurement Method of Rotary Precision of the Lathe Spindle

Conventionally Digital Measurement Method. The block diagram of conventionally digital measurement system is shown in Fig.2.

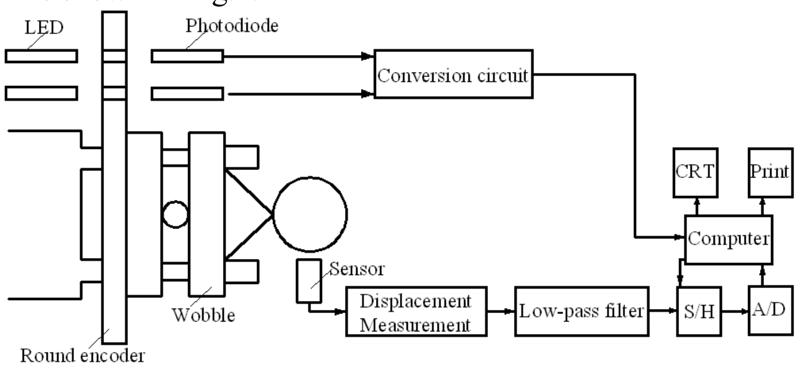

Fig. 2 The block diagram of conventionally digital measurement system

The eccentric error caused by installation of the base ball is gotten by sensor, and its frequency is the same as the speed of the spindle. The basic principle of digital measurement method is described in detail. The eccentric error is separated by digital signal processing technology, such as FFT, in order that the instantaneous rotation center is close to the real. The separated signal is superimposed on a base circle to form circular image. The radius of base circle is variable.

A holly round encoder is fixed in the chuck of the lathe spindle. A pulse signal will be produced when the hole faces to the photoelectric tube or not. There are many holes in the round encoder which are evenly distributed on the same circumference to control the sampling interval. And there is another single hole outside the circle to generate the starting signal of each turn. According to these signals, the computer could control the sampling interval of A/D and the starting signal of each turn. Displacement signal inverted into voltage signal is sent into low-pass filter to remove the interference of high frequency. The filtered signal is processed by the computer.

It is very simple to generate the base circle by algorithm. If the number of hole to control the sampling interval is N (such as N =256), then $X(I)$ can be gotten from: $X(I) = X(I) + A$. A is the radius of base circle. Each angle which corresponds to a sampling point can be gotten from: $Q = 2\pi / N$. $X(I)$ can be broken down into two vertical components through Eq.3 and Eq.4. Finally, the measured signal superimposed with the base circle is completed.

$$X(I) = X(I) \cdot COS(I \cdot Q) \tag{3}$$

$$Y(I) = Y(I) \cdot SIN(I \cdot Q) \tag{4}$$

Improved Digital Measurement Method. The Round encoder and photoelectric sensor are cancelled by the improved method. The improved digital measurement system is shown in Fig.3.

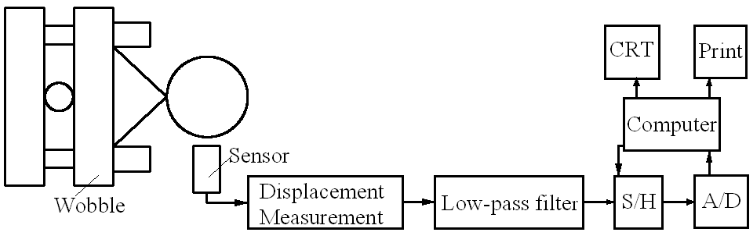

Fig. 3 The block diagram of improved digital measurement system

The reason for canceling the first column of photoelectric sensor is that the speed change is small during one circle. A set of error signal is analyzed by spectrum to get dominant frequency which is the frequency of error signal. The speed of athe can be calculated by using the dominant frequency.

The reason for canceling the second column of photoelectric sensor and the round encoder is that sampling points within one cycle can be gained from: $N_T = N / f$. N_T is sampling points within one cycle, N is the collected points in total, f is dominant frequency.

Experiment

Virtual instrument is perfectly combined the computer technology with the instrument technology. And the virtual technology is introduced into the measurement system of rotary precision of lathe spindle based on LabWindows/CVI. The measurement system consists of three parts: data acquisition card, signal conditioning circuit, virtual instrument system considering computer as hardware platform [4] [5]. Local installation diagram of this measurement system is shown in Fig.4.

Roundness errors [6] of rotary precision of the lathe spindle which are measured 30 times are listed in Table1 when the spindle speed is 360[r/min], 530[r/min] and 750[r/min]. According to the actual circumstance, ten groups of samples are taken as the analysis object to obtain a more accurate measurement. Rotary precision of this system is about 5[um] which can be seen from average value in Table 1. This measurement system meets the requirement of general accuracy [7].

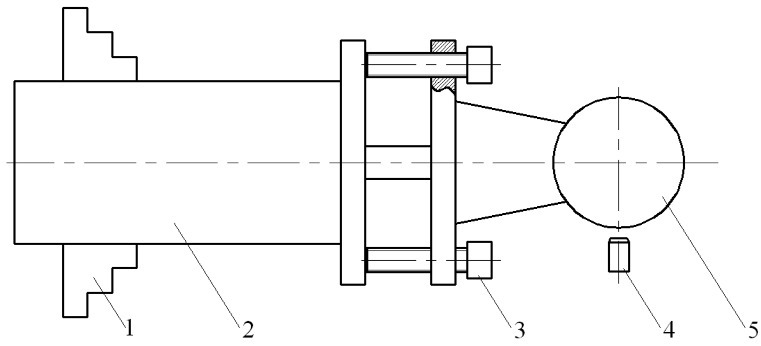

Fig. 4 Local installation diagram of this measurement system
1. Jaw chuck 2. Standard shaft 3. Adjustment screw 4. Eddy current displacement sensor 5. Standard ball

Table 1 Statistics of rotary error

Rotary Error / Laps	Rotary Speed		
	n=360[r/min] (fs=1024,N=1024)	n=530[r/min] (fs=1024,N=1024)	n=750[r/min] (fs=1024,N=1024)
The first lap	4.5476	4.6598	5.2977
The second lap	6.6499	4.8661	6.5076
The third lap	6.4483	5.3633	5.3618
The fourth lap	4.2509	4.6069	4.0771
The fifth lap	3.1978	3.7524	4.9929
The sixth lap	4.3257	4.8142	6.2955
The seventh lap	6.3785	4.9013	6.0382
The eighth lap	2.6179	4.9383	6.0303
The ninth lap	2.6392	3.6069	5.5751
The Tenth lap	3.1741	3.7647	4.9046
Average value	4.4227	4.5275	5.5081

Conclusions

The digital measurement method of rotary precision of lathe spindle is theoretically researched in detail. A new method is put forward to effectively separate eccentric error from rotary error. A kind of specific measurement method is set up through the above analysis. More accurate rotary precision of lathe spindle can be obtained in this digital measurement, therefore this method is feasible.

References

[1] K.J.H. AI-Shareef and J.A. Brandon: International Journal of Machine Tools and Manufacture, Vol. 30 (1990) No.3, p.431.

[2] G.K. Arora, C. Mallanna, B.K. Anantharaman and P. Babin: International Journal of Machine Tool Design and Research, Vol. 17 (1977) No.2, p.127.

[3] H.F.F. Castro: Measurement, Vol. 41 (2008) No.5, p.526.

[4] S. Lei: International Journal of Machine Tools and Manufacture, Vol. 42 (2002) No.6, p.653.

[5] E. Marsh and R. Grejda: Precision Engineering, Vol. 24 (2000) No.1, p.50.

[6] E.H.K. Fung, S.M. Cheung and T.P. Leung: Computers in Industry, Vol. 35 (1988) No.2, p.109.

[7] E. Okuyama, N. Nosaka and J. Aoki: Measurement, Vol. 40 (2001) No.1, p.64.