Research on Principle and Application of Laser Interferometer

Pingping Jia

Weinan Normal University, Weinan, Shaanxi, 710499, China

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Abstract: Laser interferometer has become the benchmark for linear measurement and compensation of precision machine tools. This paper takes the linear measurement of Renishaw ML10 laser interferometer as an example. Starting from the measurement principle of laser interferometer, the relationship between measurement distance and wavelength and pulse number is obtained. . The influence of environmental factors on measurement factors is described. The calculation formulas for positioning accuracy and repeat positioning accuracy are pointed out for specific linear measurements. And pointed out the problems that should be paid attention to during the measurement process.

1. Introduction

The laser interferometer is a high-precision measuring instrument based on the laser wavelength as the length measurement. With the appearance of the dual-frequency laser interferometer, it has become a high-precision mechanical production because of its stable performance, high detection accuracy and good data reliability. Standard instruments for calibration and compensation have been widely used in machinery manufacturing, metal cutting and aerospace [1-2]. In this paper, based on the measurement principle of laser interferometer, starting from the measurement principle and environmental factors, the accuracy measurement and compensation principle are deeply studied. The solution of positioning accuracy and repeat positioning accuracy data in linear measurement is explained. Has a certain practical significance.

2. Measurement principle

Laser interferometers are divided into single frequency and dual frequency. Single frequency laser interferometers are greatly affected by environmental factors and are generally used in laboratories in specific environments. The dual-frequency laser interferometer appeared in the 1970s. It uses the frequency change to measure the displacement. The displacement information is carried on the frequency difference of the sum. It is insensitive to the DC level change caused by the change of the light intensity, and has strong anti-interference ability. Used in a variety of conditions. Its working principle is as shown in Figure 1:

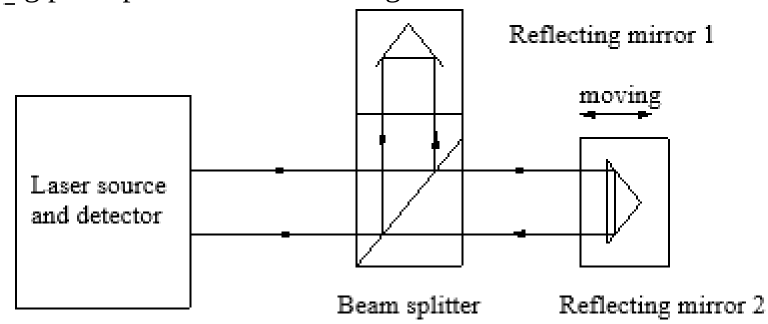

Fig.1 Schematic Diagram of the Laser Interferometer

During the detection, the pyramid mirror 1 and the beam splitter are simultaneously fixed on the bed, and the pyramid mirror 2 moves relative to the beam splitter. The laser source emits a laser

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beam of a single frequency, which is split into two beams by a beam splitter, and is respectively reflected by a pyramid cone. The mirror is reflected back into the beam splitter, creating beam interference in the detector. When the optical path difference changes, the detector can observe the signal change between the two ends of the constructive and destructive interference, and the change of the two optical path differences can be obtained, and the measured length is obtained [3-5].

The difference between the measured signal and the reference signal is the Doppler frequency difference. The number of pulses with a frequency in time is equivalent to the integral in the interval, ie:

$$N = \int_0^t \Delta f d_t \tag{1}$$

For $\Delta f = 2(\frac{v}{c}) f$,and $v = \frac{dl}{dt}$, $f = \frac{c}{\lambda}$,so:

$$N = \int_0^t \Delta f d_t = (\frac{2}{\lambda})\int_0^t dl = \frac{2l}{\lambda} \tag{2}$$

Measuring distance:

$$l = (\frac{\lambda}{2})N$$

The laser interferometer module has an environmental compensation system, which is used to collect the humidity, temperature and atmospheric pressure of the measurement site, and is used to adjust the wavelength of the laser beam. During the measurement process, the sensor collects the temperature, humidity and pressure data of the measurement site for the laser. The adjustment of the wavelength of the laser beam in the interferometer; at the same time, the compensation coefficient of the expansion effect of the artificial input object is determined by the actual material of the machine tool; finally, the standard temperature value is input, and the equivalent of the current measured value is equivalent to the standard temperature parameter. wavelength. The standard temperature is generally set to 20 °C. Indicates that the current measurement data is equivalent to the error under standard temperature conditions.

Fig.2 The Chart of Worksite

3. Test examples

The actual working condition measurement chart is shown in Figure 2 above. The machine tool is a full-closed machine tool, and the data feedback device is a grating ruler and its matching reading head. The laser interferometer is a Renishaw ML10 laser interferometer. When the data is measured, the pyramid mirror 1 is fixed together with the beam splitter, and is placed at one end of the bed. The pyramid mirror 2 is fixed on the moving end, and the outside is measured during the measurement. To minimize the effect, the pyramid mirror 2 should be placed as close as possible to the reading head. The wavelength and the number of pulses detected by the laser interferometer are determined during the detection. The data can be analyzed by obtaining the measured value. The calculation formula of the laser interferometer comes with the national standard, as follows [6]:

$$x_{ij} = p_{ij} - p_i$$

Where: the actual position of the moving part measured by the laser interferometer; the position that should be reached by the theory set in advance; the difference between the two. In the actual measurement process, multiple measurements (general measurement 3 times or more) are required to take the arithmetic mean; the difference between the theoretical value and the target position is the required compensation amount. The compensation data is input into the control system and the data is measured again. The compensation accuracy and repeat positioning accuracy after compensation are as follows:

$$s_i \uparrow = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(x_{ij}\uparrow - \overline{x_i}\uparrow)^2}\,;\; s_i \downarrow = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(x_{ij}\downarrow - \overline{x_i}\downarrow)^2} \tag{5}$$

$$R_i \uparrow = 4S_i \uparrow;\; R_i \downarrow = 4S_i \downarrow;\; R = \max(R_i \uparrow, R_i \downarrow) \tag{6}$$

$$A\uparrow = \max\left[\overline{x_i}\uparrow + 2s_i \uparrow\right] - \min\left[\overline{x_i}\uparrow - 2s_i \uparrow\right];\; A\downarrow = \max\left[\overline{x_i}\uparrow + 2s_i \uparrow\right] - \min\left[\overline{x_i}\downarrow - 2s_i \downarrow\right] \tag{7}$$

Where: $\uparrow$: indicates the direction trend from one end to the other (the symbol $\downarrow$ indicates the opposite movement trend);

S_i : an estimate of the unidirectional positioning standard uncertainty at a location;

R : One-way repeat positioning accuracy of a position;

A : Axis unidirectional positioning accuracy, the size of which is: $A = \max(A\uparrow, A\downarrow)$.

4. Conclusion

The linear measurement and compensation principle of Renishaw laser interferometer is discussed in detail. The relationship between measurement distance and pulse and wavelength number is obtained. The calculation method of positioning and repeat positioning during measurement is pointed out. There are many factors affecting the measurement accuracy of the laser interferometer in the linear measurement process. In order to obtain satisfactory accuracy, the lens group should be fixed at the same position as the reading head during linear measurement and compensation to achieve accuracy measurement and stability of compensation data. .

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