Transformation method from incremental angular displacement sensors to absolute angular displacement sensors

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ABSTRACT

This paper analyzes the characteristics of three typical angular displacement sensors, such as optical grating, inductosyns and time grating sensors, and a novel design method is presented. This method is based on the synthetic principle of electrical travelling wave. The precision of optical grating sensor is improved with the proposed method. Experiment results prove the valid of synthetic time-space orthogonal travelling wave, which realizes the transformation from the incremental sensors to absolute ones.

Keywords: incremental, absolute, angular, displacement sensors, Transformation method

1. INTRODUCTION

Incremental displacement sensors such as typical incremental optical grating sensors, employ non-modulation work principle, and the line number range from 100 to 0.1 million. The measurement precision of optical grating sensor improve with increasing its line number, therefore, the price is increased\[1\]. The absolute displacement sensors such as typical inductosyns, employ modulation work principle, and the pole number range from several tens to 720. The measurement precision of inductosyns sensor improve with increasing its pole number\[2\]. The cost of time grating angular displacement sensors is several thousands. Time grating sensors adopt movable coordinate system at constant speed to obtain travelling wave of electrical field. Using scanning time difference corresponding to position value, an absolute angular position can be measured with high precision and resolution. The current precision can reach ±0.6"\[3\].

A low precision incremental optical grating sensors with non-modulation work principle is converted into a high precision absolute angular displacement sensors with the modulation principle of inductosyns.

2. TRANSFORMATION METHOD FROM INCREMENTAL SENSORS TO ABSOLUTE SENSORS

A novel angular displacement sensors with new principles is proposed according to the combinations of the principles of incremental optical grating sensors, inductosyns and time grating sensors. Fig.1 illustrates the working diagram. The proposed sensors consist of normal incremental angular displacement sensor, Signal synthesis circuit and the signal processing circuit of time grating sensors. Two channel spacial orthogonal sinusoidal signals output from the normal
incremental angular displacement sensor can indicate periodical modulating signal of measured displacement. The two channel time orthogonal sinusoidal signals serve as the carrier signals. The two channel spacial and time modulating sinusoidal signals input the multiplier, the two channel modulating signals can be synthetized a channel electrical travelling wave, which is similar to the output absolute signals of inductosyns. After the phase comparison between the electrical travelling wave signal and a channel carrier signal, the phase difference between the two channel signals can be expressed with the number of the clock pulse with high frequency. After scale transformation, the angle can be measured.

As regarding such sensors, the output electrical signals do not indicate the displacement changes directly, but a pole for the modulating sensors. One pole is equivalent to to one grating line, thus a normal optical grating sensor with 2000 line number is equivalent to a modulating sensor with 2000 poles, which is the considerably high for modulating sensors. The precision of sensors are improved with increasing number of poles. The reasons are as following: in the first place, the more pole number of sensors, the smaller angular value. Thus, the pulse equivalent is smaller, the resolution and precision will be improved. Secondly, the more pole number of sensors, the pitch is smaller, the ratio of gap and pitch increase. The amplitude of error components of high harmonic wave will decrease. Therefore, the precision will be improved. Finally, due to the equilibrium function of tandem circuits, manufacturing and size errors will be decreased [4][5][6].

3. ELECTRICAL CIRCUITS DESIGN

A GBZ05 optical grating sensor designed by the institute of optics and electronics of the chinese academy science is employed as target. Such optical sensor has the 2000 lines. The peak-peak of the output spatial orthogonal signal are 4V, which is served as the modulating signal. The expression of the two channel signal are as following equation(1) and equation(2):
\[ u_1 = U \sin \frac{2\pi x}{W} \]  \hspace{1cm} (1)
\[ u_2 = U \cos \frac{2\pi x}{W} \]  \hspace{1cm} (2)

3.1 Generating time carrier signal circuits

A channel sine carrier signal can be generated with the crystal oscillator, the complex programmable logic device (CPLD), the digital analog converter and the amplifier. A reference voltage signal can be obtained with the voltage reference chip. The peak-peak value of sinusoidal signal of carrier signals can be adjusted by configuring operational amplifier. After the phase shift processing circuits, the peak-peak of the output time orthogonal signal are 4V. The expression of the two channel signal are as following equation(3) and equation(4):

\[ u_a = E \sin \omega t \]  \hspace{1cm} (3)
\[ u_b = E \cos \omega t \]  \hspace{1cm} (4)

The fig.2 shows the electrical diagram.

3.2 Generating travelling wave circuits

The two channel spacial and time modulating sinusoidal signals input the two input of the multiplier. The output signal of the multiplier is the modulated standing wave signal, the two channel modulating signals can be synthetized a channel electrical travelling wave, which is similar to the output absolute signals of inductosyns. After the phase comparison between the electrical travelling wave signal and a channel carrier signal, the phase difference between the two channel signals can be expressed with the number of the clock pulse with high frequence. After scale transformation, the angle can be measured.

The phase comparison between the electrical travelling wave signal and a channel carrier signal, difference between the two channel signals can be expressed with the number of the clock pulse with high frequence. After scale transformation, the angle can be measured. The expression is as following equation(5) and equation(6):
\[ u_a = U_a \sin \omega t \cos 2\pi \frac{x}{W} \]  \hspace{1cm} (5) \\
\[ u_b = U_b \cos \omega t \sin 2\pi \frac{x}{W} \]  \hspace{1cm} (6)

The equation (5) is the multiply result of equation (2) and equation (3). The equation (6) is the multiply result of equation (1) and equation (4).

The above two signal are applied to the added circuit consisting of the operational amplifier and the resistance. The output signal of the added circuit is electrical travelling wave. The expression is as following equation (7):

\[ u = U_m \sin(2\pi \frac{x}{W} + \omega t) \]  \hspace{1cm} (7)

The travelling wave and one channel time carrier wave signal are applied into the signal processing circuits for time grating sensors, the measured angular value can be obtained. The function of the signal processing circuits of time grating sensors is phase comparison for two channel input signals. The phase difference between the two channel input signals can be indicated by pulse number with high frequency. After scale transformation, the angle can be measured. The fig. 3 shows the electrical diagram.

4. EXPERIMENT

The experiment devices are shown in fig. 4. The experiment device consists of upper layer, middle layer and lower layer. The upper layer is an optical grating sensor with 2000 line number. The middle layer is german Heideain optical encoder RON886 with precision ±1″. The lower layer is the rotatry table, which is placed on platform. The rotatry table and the two optical grating sensors are installed concentricly. The rotational force is offered by the rotatry table. The high precision Heideain optical encoder is served as the measuring standard. The electrical travelling wave are shown with oscilloscope in fig. 5. The shown electrical travelling wave represent the phase changes during the movement.
5. CONCLUSIONS

The measurement principles of similarity and the differences among the optical grating, inductosyns and time grating sensors are analyzed, and a novel sensor is presented. The results prove the valid of the proposed method. The difference between the optical sensor and the proposed sensors are as following: the equal spatial pitches are not served as measurement standard, but to generate two channel spatial simple harmonic wave. Therefore, the line number of sensors become pole number of sensors. The difference between the inductosyns and the proposed sensors are as following: the electrical travelling wave is not generated by rotating magnetic field induced by the conductor, but the accumulation of the two channel standing wave. Such proposed sensor has the characteristic of low cost, high precision and intelligence.
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7. REFERENCES
