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Permanent Magnet Tracking Position Sensor

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Abstract

In view of the disadvantages of traditional position sensor, a novel permanent magnet tracking position sensor is proposed. The hall component is used to convert the magnetic signal reflecting the shaft velocity and position into an electrical signal by the construction and optimization of magnetic field. And then the resolver-to-digital conversion is carried out by arctangent so as to obtain the signals of shaft position and velocity.

Keywords: *permanent magnet, resolver-to-digital conversion, position sensor*

1. Introduction

In the motor control system, the position sensor is generally needed to provide the information of the rotor position and velocity in order for the motor position and velocity control, so the position sensors become an important component of the motor control system. At present, the photoelectric encoder is a common position sensor [1, 2]. The position sensor is widely used in many fields. With the increase of the demand of position detection in most fields, the traditional position sensors are unable to meet the special requirements of several applications because of their inherent defect. In this paper, a permanent magnet tracking position sensor is designed. The designed sensor is better than the photoelectric encoder in environmental suitability, and has simple structure and fabrication process, so it can replace the photoelectric encoder.

2. Tracking Position Sensor Principle and Design

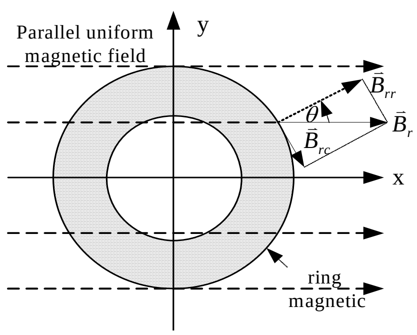

Figure 1. Cross Section of the Cylindrical Magnet Steel in a Uniform Magnetic Field

2.1. The Basic Principle of Tracking Position Sensor

The cylindrical or ring magnetic steel is placed in a parallel uniform magnetic field to be magnetized, and the axis of the magnetic steel is made vertical to the direction of the magnetic field, as shown in Figure 1. In the ideal state, the surface of the magnetic steel is magnetized to

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a bipolar magnetic field, whose residual magnetic induction intensity can be decomposed into the radial and tangential components, as is shown in Equation (1) and Figure 1.

$$\vec{B}_{rr} = \vec{B}_r \cos\theta \qquad \vec{B}_{rc} = \vec{B}_r \sin\theta \tag{1}$$

From Equation (1), the radial magnetic field of magnetic steel surface changes with the cosine law, with which the permanent magnet tracking position sensor is designed. Two orthogonal hall components are placed on the same circumference in the periphery of the magnetic field. The hall components sense the radial magnetic field and generate a voltage signal reflecting the changes of the magnetic field. The angular position information and even the speed information of the rotating magnetic field is obtained by solving the arctangent value of two orthogonal cosine voltage signals [3].

2.2. The Construction of Space Magnetic Field

Magnetic materials include isotropic and anisotropic materials. After being magnetized, the magnetic properties of the anisotropic materials are better and the remanence on the surface of the magnet is more than the isotropic materials. However, a direction of magnetic orientation is considered when the anisotropic material magnet is being magnetized. Only when the direction of external magnetic field is consistent with the direction of magnetic orientation, would it can achieve the best magnetizing effect, while the magnetizing effect of the isotropic magnet is always uniform in every direction. Thus, the anisotropic materials are more applicable to the parallel magnetizing of the bipolar magnet steel in this design so as to increase the air-gap length of the tracking position sensor, while the isotropic materials are more applicable to the radial charge magnetism of multipolar magnet steel.

The ring or cylindrical magnet steel of anisotropic materials need to be magnetized in the parallel magnetic field, where the direction of the parallel magnetic field should be consistent with the magnetic orientation direction of the magnet steel, as Figure 2 shows.

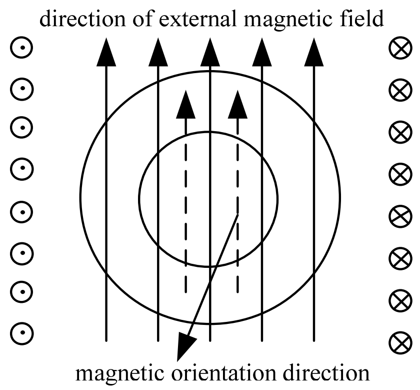

Figure 2. General View of Parallel Magnetizing

In the ideal state, the space distribution of magnetic lines for a magnetized ring magnet steel is shown in Figure 3, where the magnet steel is 6mm in out-diameter, 3mm in in-diameter and 3mm in height, and In the positive half period and negative half space, the magnetic field distribution of the positive half cycle and the negative half cycle are exactly symmetrical. The waveforms of radial and tangential magnetic field are shown in Figure 4, on a circumference whose center is the center of the magnet steel with the radius of 6.6mm. In the ideal state, there is no relative position deviation between the magnetic steel and the hall component and between the hall components, so the amplitude of the radial magnetic field the hall component is sensitive to is the same as the amplitude of the tangential magnetic field the hall component is insensitive to, and the phase difference between them is only 90°.

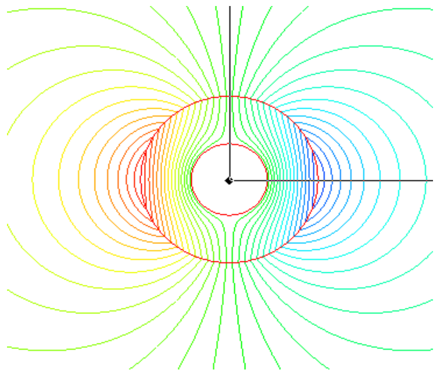

Figure 3. Space Distribution of Magnetic Lines of Magnetic Steel

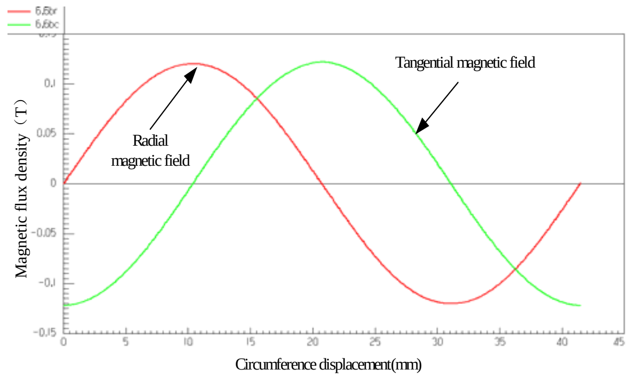

Figure 4. Radial and Tangential Magnet Field when R=6.6mm

2.3. The Optimation of Magnetic Field

In the design of permanent magnet tracking position sensor, there is generally position deviation in the axial direction for the installation of hall elements, as shown in Figure 5. In this case, the magnetic field sensed by the hall elements is different. Certain measures must be taken to minimize the error of the sensed magnetic field because of the evitable installation deviation. The error can be decreased by putting the ring core on the periphery of hall elements. The optimaion of axial magnetic field of the core is analyzed qualitatively by the software ANSOFT.

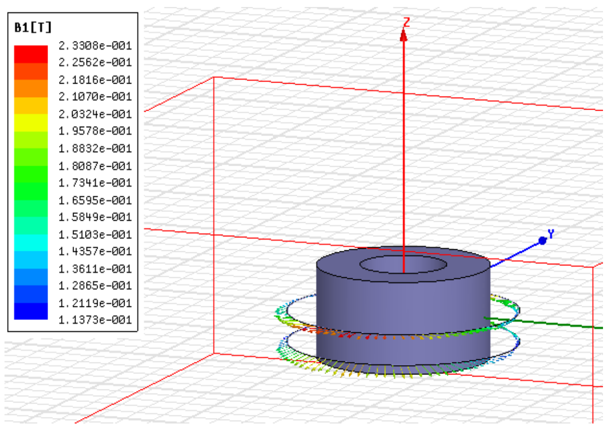

Figure 5. Distribution of Magnetic Field in Different Axial Positions on a Circumference with R=5.5mm

Suppose the position deviation of hall elements only exists in the axial direction of the surface of magnetic steel. In the outside of magnetic steel with the outer diameter of 6mm, the inner diameter of 3mm and the height of 3mm, one hall elements is placed on a circumference whose center is the axis center of the magnet steel with the radius of 5.5mm, while the other hall elements is placed on a circumference whose center is 1mm away from the axis center of the magnet steel with the radius of 5.5mm. The distribution of magnetic field intensity vectors on the surface of hall elements is shown in Figure 5. The Z-axis component of magnetic field intensity on a circumference of the axis center of the magnet steel is zero, but it is not zero on any other circumference. Thus, the projects of magnetic field intensity vectors in X-Y plane are not equal, that is, the project of magnetic field intensity on a circumference whose center is 1mm away from the axis center is much smaller than that on a circumference whose center is the axis center, as shown in Figure 6.

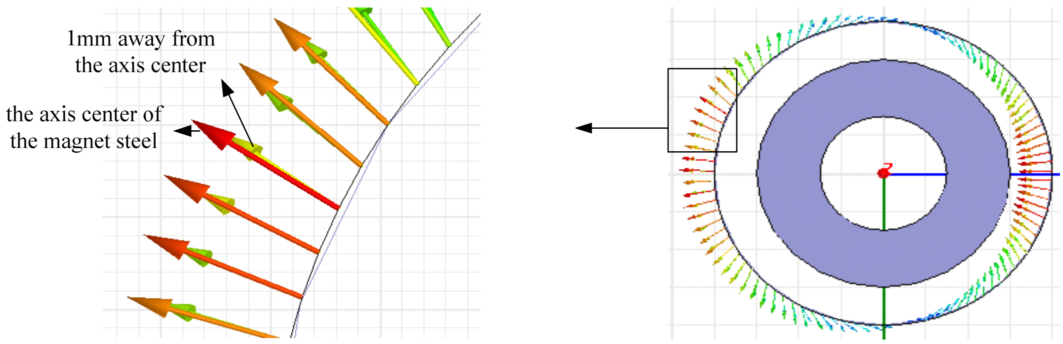

Figure 6.Top View of Magnetic Distribution in Different Axial Positions on a Circumference with R=5.5mm

Distribution of magnetic field intensity vectors in different axial positions on two circumferences is shown in Figure 7, where the ring core is placed in the outside of magnetic steel. The projects of magnetic field intensity vectors in X-Y plane are shown in Figure 8, where the project deviation is significantly decreased after the iron core is placed, and the error of magnetic field component sensed by the hall elements is effectively weakened. Thus, besides the method to improve the installation deviation, the method to apply the ring core can decrease the axial deviation and obtain a good performance.

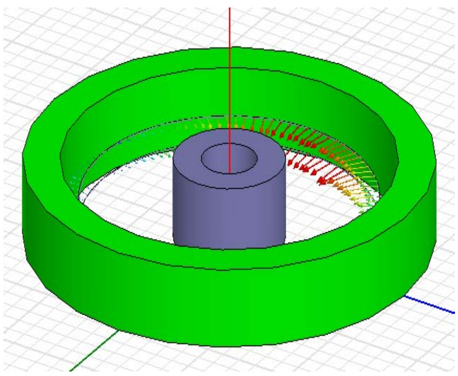

Figure 7. Distribution of Magnetic Field in Different Axial Positions on a Circumference with R=5.5mm (with iron core)

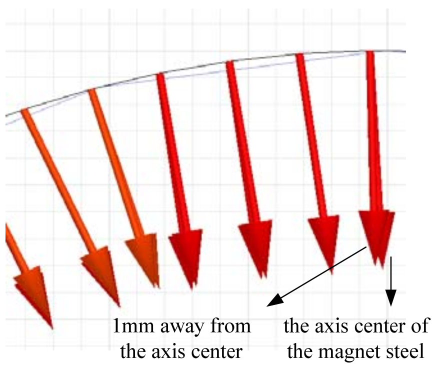

Figure 8. Bottom View of Magnetic Distribution in Different Axial Positions on a Circumference with R=5.5mm (with iron core)

2.4. The Arctangent Method based Resolver-to-Digital Conversion

In this paper, the original signal of the position sensor is decoded by the arctangent method [4]. The implement method of arctangent is to solve the phase angle according to the input sine and cosine signals, that is, to solve the arctangent value of the sine and cosine signals, $\tan^{-1}\left(\frac{V\sin\theta}{V\cos\theta}\right)=\theta$, so as to get the position angle θ. We can get more accuracy angle position by the analysis on stable error [5] and dynamic error [6] and error compensation. Figure 9 shows the circuit structure of resolver-to-digital conversion with the arctangent method.

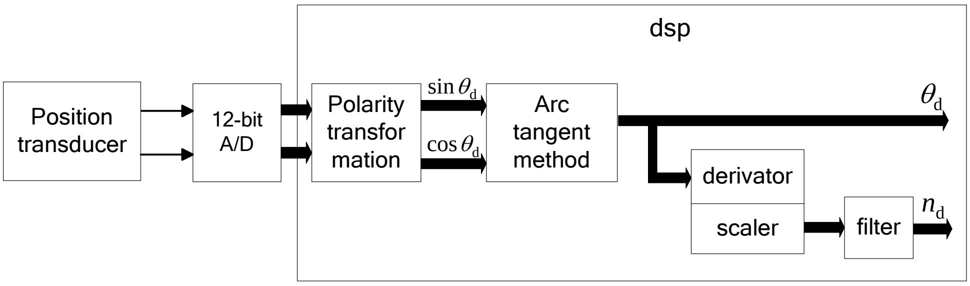

Figure 9. Circuit Structure of Arctangent

3. Experimental Results and Application

Two orthogonal linear hall sensors sense the magnetic field components which results from two-pole ring magnetic steel and thus output two phase orthogonal cosine voltage signals, as shown in Figure 10. It can be seen from the tested waveforms that the two signals is completely orthogonal with the phase difference of 90^0, which will be then decoded to obtain the position signal.

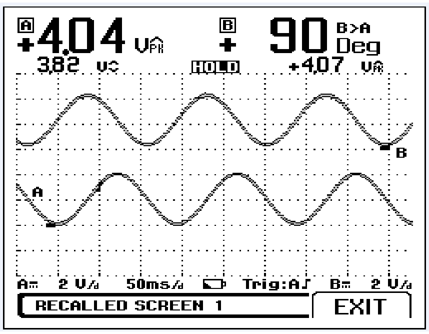

Figure 10. Waveforms of Output Signals of Hall Sensors

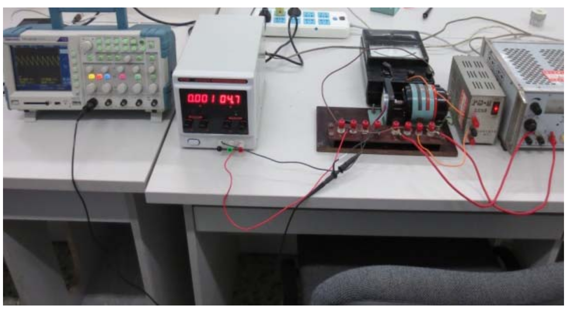

Figure 11. Test Platform of Position Sensor

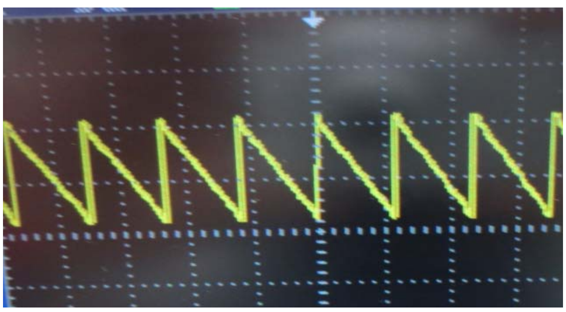

Figure 12. Test Waveform of Angular Position

The experimental platform is established for the test of the tracking position sensor, as shown in Figure 11. The output waveform of angular position for the hall effect based tracking position sensor is shown in Figure 12. The curve between the rotation speed and the armature voltage of DC motor for the designed tracking position sensor is shown in Figure 13, where the separately excite DC motor with the rated exciting current of 0.3A and the rated speed of 2400r/min is used.

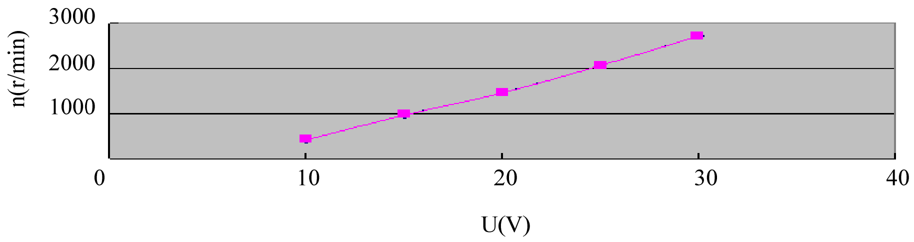

Figure 13. Curve between the Rotation Speed and the Armature Voltage of DC Motor

4. Conclusion

A novel tracking position sensor is designed which provides a new solution for the speed and position measurement of motor control system. The experiment and application results show that the resolution and precision of the designed position sensor can completely meet the requirements of the motor control system, and can replace the photoelectric encoder with the same resolution and precision, so it is of great practicality in engineering.

Acknowledgement

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