Research on Polar Anisotropic Molding Yoke Shape to Reduce Dead Zone of Ring Type Bond Magnets

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The safety window motor for preventing accidents in which an automobile window is pinched is based on the principle that a ring type bond magnet is attached to the lower part of the rotor of the motor to detect the magnetic flux and detect the position. At this time, a dead zone of ring type bond magnet is generated between the N pole and the S pole of the ring-type bond magnet and the hall sensor does not detect the magnetic flux in this section. When the range of this dead zone is large, the region where the magnetic flux can be detected is limited, so that accurate position detection is impossible. In this paper, we provide the proposed model of a polar anisotropic molding yoke with a magnetic flux-concentrated structure for the dead zone reduction plan of ring type bond magnets. Since the conventional polar anisotropic molding yoke is magnetized by applying a magnetic field directly to the ring type bond magnet with a permanent magnet of the molding yoke, it is not possible to apply a magnetic field beyond the performance of the permanent magnet of the molding yoke. So, to reduce this dead zone, this paper designed a model that could be molded with a high air gap flux density by inserting a magnetic flux concentration core, and the thickness of the inner and outer teeth and the direction of the magnetic field applied to the permanent magnet were used as the design variable. In this paper, the results were analyzed through finite element analysis and the validity of this paper was verified.

***Index Terms*— bond magnet, dead zone, hall sensor, polar anisotropic molding yoke**

I. INTRODUCTION

Recently, as the demand for robots and the supply ratio of renewable energy have increased, the usage of electric motors and generators has increased. Therefore, sensors required for detecting the position of the rotor has also increased [1]. Of these, the safety window motor for preventing accidents in which an automobile window is pinched is based on the principle that a ring type bond magnet is attached to the lower part of the rotor of the motor to detect the magnetic flux and detect the position [2], [3]. At this time, a dead zone, which is a section where the magnetic flux is very weak, is generated between the N pole and the S pole of the ring-type bond magnet and the hall sensor does not detect the magnetic flux in this section. When the range of this dead zone is large, the region where the magnetic flux can be detected is limited, so that accurate position detection is impossible. In this paper, we provide the optimum model of a polar anisotropic molding yoke with a magnetic flux-concentrated structure for the dead zone reduction plan of ring type bond magnets for accurate control of electric motors and generators [4], [5].

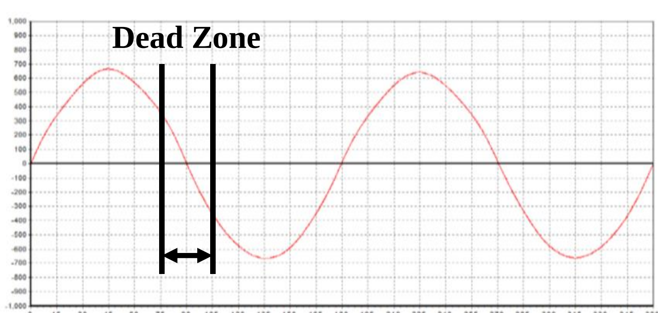

Fig. 1. Dead zone in waveform measured with a gauss meter.

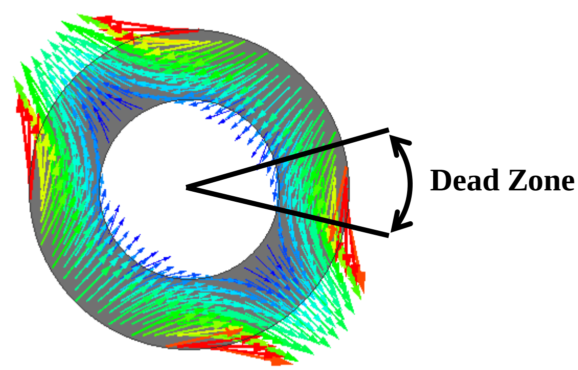

Fig. 2. Dead zone of polar anisotropic ring type bond magnet.

II. RELATED THEORY

Since the conventional polar anisotropic molding yoke is magnetized by applying a magnetic field directly to the ring type bond magnet with a permanent magnet of the molding yoke, it is not possible to apply a magnetic field beyond the performance of the permanent magnet of the molding yoke [6].

Therefore, if a soft magnetic core is inserted between a permanent magnet of the conventional model, a ring type bond magnet can be molded using a higher magnetic flux density than the conventional model, and thus the performance of the molding yoke can be improved. The magnetic flux concentration type structure that allows the magnetic flux generated from the permanent magnet of the molding yoke to be concentrated is related to the magnetic flux concentration factor. And it can be expressed by the following equation (1).

$$C_\phi = \frac{A_m}{A_g} \tag{1}$$

A_m is the cross-sectional area of the magnet, and A_g is the cross-sectional area of the air gap. This means that when the magnetic flux density in the air gap is larger than the magnetic flux density from the magnet surface, the greater the magnetic flux passing through the magnet, the more concentrated the magnetic flux. Therefore, if the magnetic flux-concentrated structure is used, when a magnetic field is applied, the air gap flux density can be higher than that of the conventional model, and the dead zone of the ring type bond magnet can be reduced.

III. Analysis & Result

In the case of the conventional model, the structure is such that a magnetic field is directly applied to a very different ring type bond magnet with a permanent magnet. Therefore, the magnetic flux does not penetrate deeply into the magnet, and a large dead zone is generated. The shape showing the direction of the magnetic field of the permanent magnet of the conventional model is shown below.

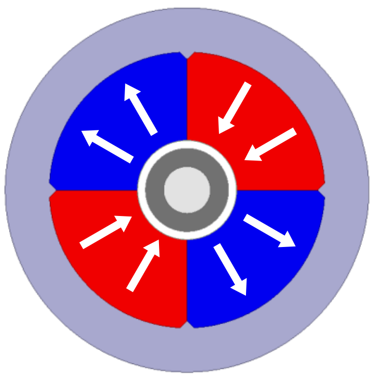

Fig. 3. Conventional model

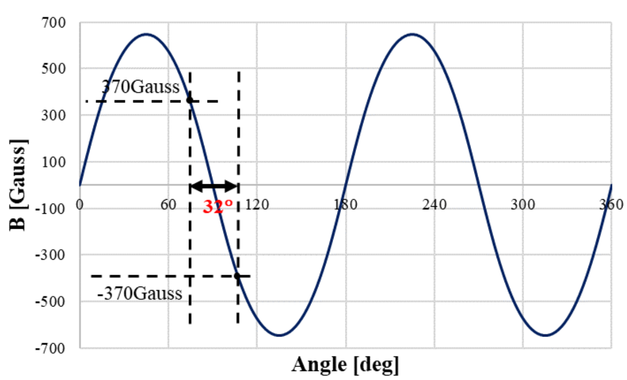

Fig. 4. Magnetic flux density waveform of the conventional model

By inserting the magnetic flux concentration core from the conventional model, we designed an improved model so that it can be molded with a high magnetic flux density. As shown in Fig. 4, the thickness of the inner and outer teeth and the direction of the magnetic field applied to the permanent magnet were used as the design variable. In this paper, the results were analyzed through finite element analysis. The design variable of inner and outer teeth thickness was set range of 0mm to 12mm and the angle degree of the magnetic field applied to the permanent magnet was set the range of 0° to 90°.

TABLE I
Specifications for Conventional Model

Parameter	Value	Unit
Ring type bond magnet	HM-1220KD	-
Permanent magnet	N45EH	-
Back yoke	SUS304	-
Inner pin	SUS304	-
Pole	4	-
Yoke inner diameter	53	mm
Yoke outer diameter	70	mm
Ring magnet inner diameter	8	mm
Ring magnet outer diameter	15	mm

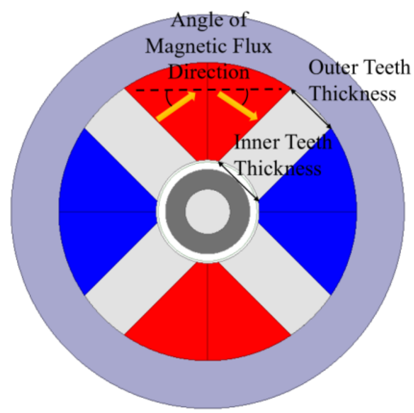

Fig. 5. Variable settings

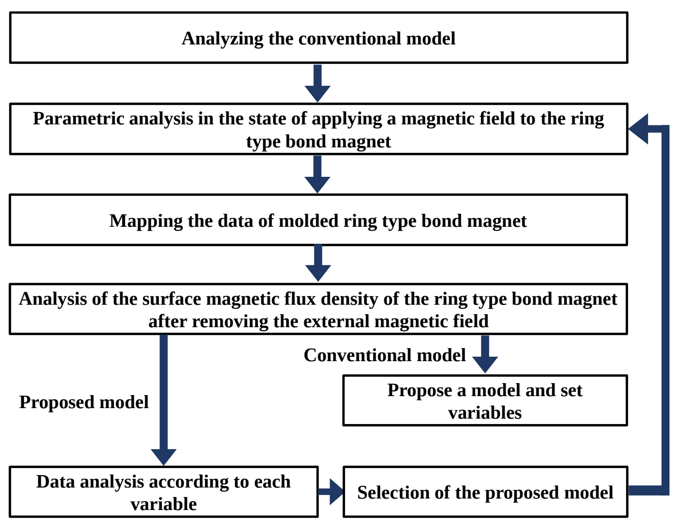

Fig. 6. Process for improving polar anisotropic molding yoke

A. Air gap flux density according to magnetization angle

Fig. 6 shows the change in air gap flux density according to the magnetization direction when the inner teeth thickness is 11mm and the outer teeth thickness is 0mm. Analyzing this result, when the angle of the magnetization direction is too large or too small, the magnetic flux leaks to the permanent magnet and the outside. So it can be confirmed that the maximum air gap flux density is generated around 40°.

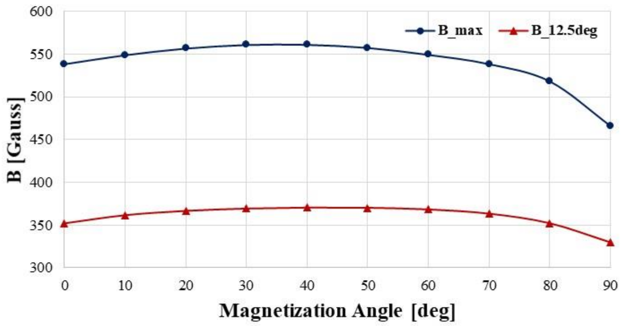

Fig. 7. Magnetic flux density according to magnetization direction

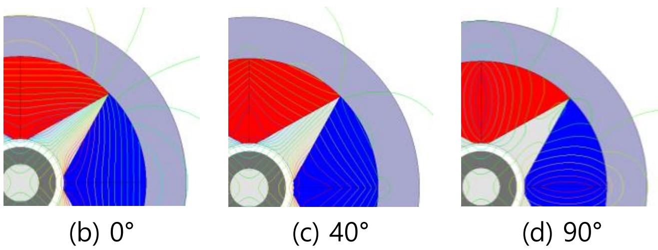

Fig. 8. Magnetic flux density according to magnetization angle

B. Air gap flux density according to the thickness of the inner teeth

Fig. 8 shows the change in air gap flux density according to the thickness of the inner teeth when the angle of the magnetization direction is 40° and the thickness of the outer teeth is 0mm. Analyzing the results at 12.5° where the dead zone occurs in a ring type bond magnet, the magnetic flux leaks to the adjacent core when the thickness of the inner teeth is too large. So it can be confirmed that the magnetic flux is most concentrated on the pole of the ring type bond magnet when the

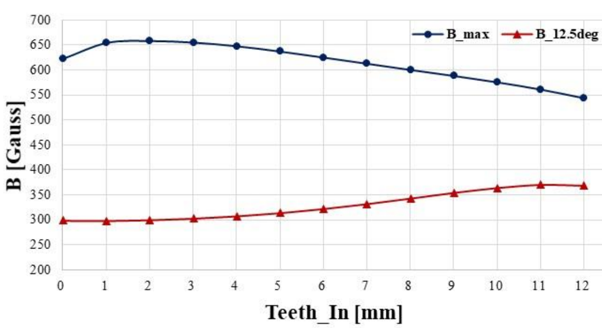

Fig. 9. Magnetic flux density according to inner teeth

thickness of the inner teeth is 11mm.

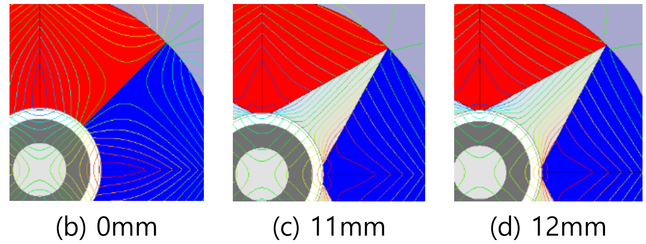

Fig. 10. Magnetic flux density according to inner teeth thickness

C. Air gap flux density according to the thickness of the outer teeth

Fig. 4 shows the change in air gap flux density according to the thickness of the outer teeth when the angle of the magnetization direction is 40° and the thickness of the inner teeth is 11mm. Analyzing the result, it is confirmed that when the thickness of the outer teeth is 0mm, the magnetic flux leaked to the outside is minimized and the maximum air gap flux density is generated.

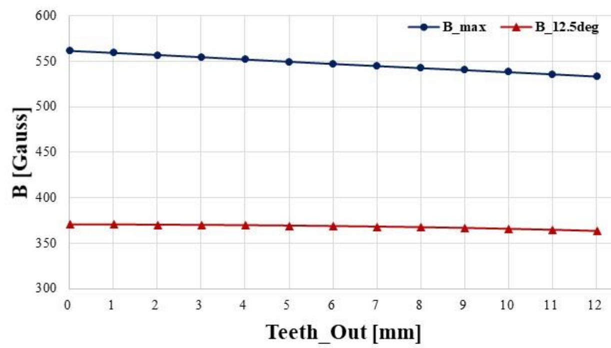

Fig. 11. Magnetic flux density according to outer teeth

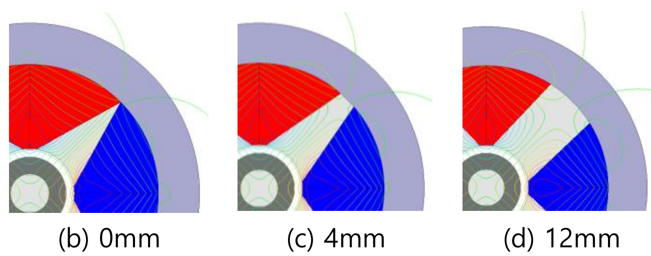

Fig. 12. Magnetic flux density according to outer teeth thickness

Through the analysis, we were able to obtain the optimum model that can be molded to the highest magnetic flux density when the angle of the magnetization angle is 40 °, the inner teeth thickness is 11 mm, and the outer teet thickness is 0 mm. The proposed model is shown below.

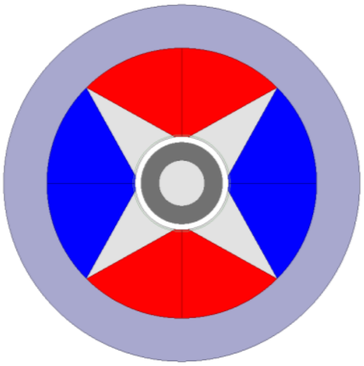

Fig. 13. Proposed model

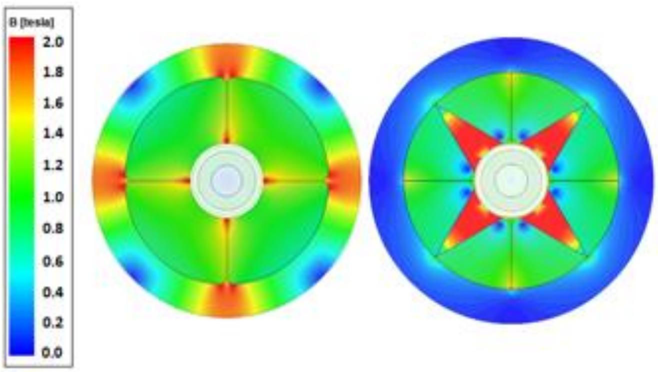

Fig. 14. Magnetic flux density of conventional & proposed model

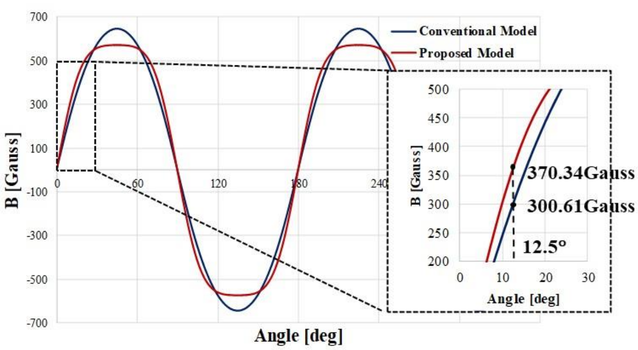

Fig. 15. Magnetic flux density of conventional & proposed model

Fig. 14 is a comparison waveform of the air gap flux density of the proposed model and the conventional model. The proposed model has a 23% increase in air gap flux density compared to the conventional model. As a result, dead zone decreased by about 22%.

IV. Manufactured Model

We asked a company to manufacture the proposed model for selection and confirmed that the performance of the ring type bond magnet manufactured using the magnetic flux-concentrated polar anisotropic molding yoke was improved over the conventional molding yoke. After applying a magnetic field to the ring type bond magnet, the yoke was pulled out, and then the Gauss meter was separated by 1 mm to measure the magnetic flux density in the Normal direction. The waveform of the actual model was measured and the data was analyzed.

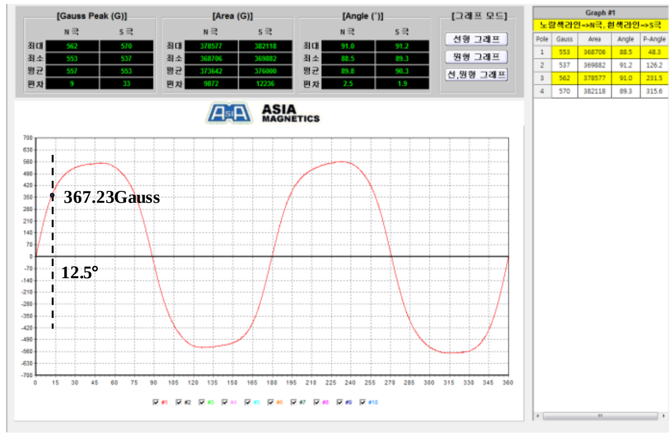

Fig. 16. Waveform measured with a Gauss meter

In the case of the manufactured model, it was measured at 367 Gauss at 12.5 °, and it was verified that it is possible to magnetize with higher magnetic flux density than the ring type bond magnet manufactured using the conventional model and to reduce the dead zone.

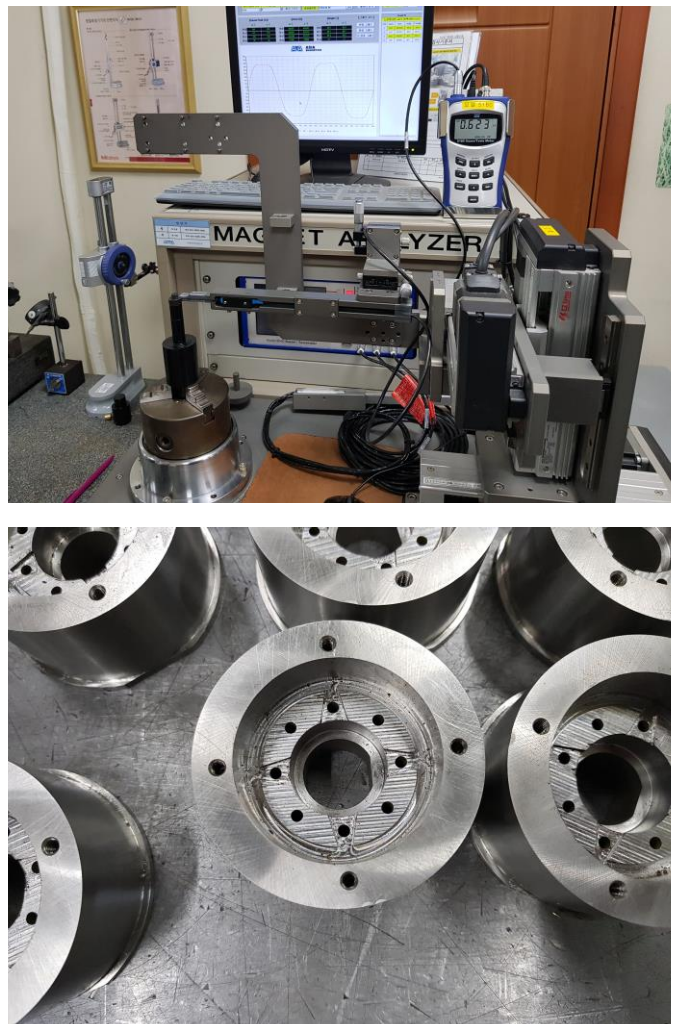

Fig. 17. The physical model

V. Conclusion

In this paper, a flux-concentrated core was inserted to reduce the dead zone range of the ring type bond magnet. As a result, it is possible to reach a higher air gap flux density than the conventional model. Finally, the validity of this paper was verified through the finite element analysis method. Based on this, it is expected that the market share of the safety window can be expanded, and further, the technological competitiveness of domestic sensor industries can be improved.

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