1. INTRODUCTION

- Motors equipped in the vehicle must satisfy high power in confined spaces. Since high power density is required, BLDC using permanent magnets is mainly used. The permanent magnet type synchronous motor of the IPM type has a wide operating range through weak magnetic flux control, and has a high torque using reluctance torque.

- Dysprosium (Dy) and Terbium (Tb) used in permanent magnets are expensive. Dy or Tb is essential for automotive motors that operate at high temperatures. Higher, $H_{r}$, as number of increases the performance of thermal characteristics in permanent magnets. If used rare earth grain boundary diffusion (GBD), rare earth (Dy) diffuses inward along the grain boundaries of the magnet. This results in a high anisotropic magnetic field along the grain boundaries. Even in using relatively less rare earth (Dy), it has the same coercive force ($H_{r}$) as the reference permanent magnet. Grain diffusion (GBD) apply rare earth Dy to the sintered magnet surface. After application, heat treatment several times above 900 °C. In this process, it has a high anisotropic magnetic field. Has the same effect as Dy of 3% in the permanent magnet manufactured by conventional method. Little figure in Fig. 2, shows the diffusion along the grain boundary on the sintered permanent magnet surface. The right side shows the grain boundary diffusion taken with a scanning electron microscope (SEM).

2. Analysis of the Grain boundary diffusion and demagnetization

- Fig. 3 shows the J-H and B-H curves of GBD permanent magnets and reference permanent magnets. The operating temperature is a value for 100 °C, 140 °C. At 100 °C, the $H_{r}$ of GBD was -16.25 [kOe] and the $H_{r}$ of the reference permanent magnet was -11.1 [kOe], showing a greater value of approximate 31%. The $H_{r}$ of GBD at 140 °C is -10.9 [kOe] and the reference magnet is -9.8 [kOe], which is 11% smaller.

- Equation shows the residual magnetic flux density(Br(T)), coercive force(Hc(T)) of the magnet according to driving temperature. The residual flux density temperature coefficient β [%/°C], coercive force temperature coefficient β [%/°C] show negative values. T0 is the reference temperature

$$B_r(T) = B_r(0) \cdot [1 + \alpha (T - T_0)]$$

$$H_c(T) = H_c(0) \cdot [1 + \beta (T - T_0)]$$

3. Simulation and experiment

- Fig. 5 shows the magnet flux density according to reference permanent magnet and GBD permanent magnet, operating temperature 100 °C (Max. B 1.2[T]) (a) Non_segmented magnet (b) Segmented magnet (c) 7segmented magnet

- The simulation was performed by applying a current seven times the maximum current (Irms = 168 A). The current phase angle was set to 92 deg representing the maximum reduction rate. Fig. 6 shows the magnet flux density according to segmented reference permanent magnet and GBD permanent magnet. It shows the magnetic flux density after receiving the effect of the armature reaction. The more blue, the lower the magnetic flux density

- Fig. 7 shows the demagnetization ratio according to Ref.magnet and GBD magnet

- Fig. 8 shows the model shape and experiment setting

- Efficiency mag(GBD) comparison of Simulation data and experiment Data shows the test environment. The data was analyzed by conducting experiments by connecting control inverter and analysis equipment. GBD permanent magnet is currently in production and will be tested later

Conclusion

- In this paper, we analyzed the characteristics of the perma-nent magnet synchronous motor (IPMSM) using reference per-manent magnets and rare earth grain boundary diffusion (GBD) permanent magnet. This magnet has less rare earth (Dy, Tb) and higher coercive force (Hc). A permanent magnet with the same performance can be used at a lower cost. In addition, the demagnetization characteristics of the permanent magnets were compared. Because of the high coercivity, the grain boundary diffusion (GBD) has a high resistance to hot demagnetization. GBD main-tains higher magnetic flux density than reference permanent magnet at the same temperature. When the segmented permanent magnet were used, the demagnetization characteristics of the permanent magnets were improved, but no significant difference was ob-served at high temperature. Data analysis was conducted by simulation, and motor output was verified by test.