Development of Dy free NdFeB anisotropic bonded magnet with high performance

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1. Introduction

The need for lighter motors in increasing automobile fuel efficiency is high and NdFeB anisotropic bonded magnets with high magnetic performance and freedom of design are effective in realizing motor size and weight reductions. The magnetic powder used in NdFeB anisotropic bonded magnets is manufactured by the d-HDDR process utilizing the high temperature reaction between NdFeB and hydrogen[1)]. This bonded magnet has five times higher magnetic force than standard ferrite one and its near-net-shape characteristic enable easy application to motors. The anisotropic bonded magnet has been used for downsized / lightweight seat motors. The coercive force was improved by grain boundary diffusion treatment of Nd-Cu-Al alloy into NdFeB magnetic powders after d-HDDR treatment [2)] instead of Dy addition. This alloy forms Nd-rich grain boundaries and isolates the crystal grains after diffusion process. As a result, it intercepts the magnetic interaction between the crystal grains and leads to increase of the coercive force up to 20kOe. Currently, this anisotropic magnetic powder was molded to bonded magnet with high performance by compression molding and injection molding magnet with mixture of several resins.

2. Compression molding magnet

The magnetic properties of NdFeB bonded magnet was easily decreased due to oxidation under using atmosphere. We successfully developed a magnet powder coating technology leading to improved reliability of the bonded MAGFINE magnets towards an automotive specification level of flux loss below 5% after 1000h exposure at 150deg.C. This coating layer was created on the magnetic powder surface with thickness of approximately 200nm (Fig.1). This powder has good stability under the oxidation atmosphere compared to conventional MAGFINE powders without coating.

During the compression molding, the NdFeB magnetic powders were pressed under high pressure of 9ton/cm^2 and induced the damage of powder cracking. This leads to degradation in magnetic performance, in particular the squareness ratio. A compound made of d-HDDR magnet powder coated with resin, fine SmFeN powder and lubricant can produce molded blocks with a high density of 6.0 g/cm^3 at a low molding pressure of 1 ton/cm^2. In addition, by enabling molding at a low pressure, the loss of squareness of the magnet powder was reduced to 0.5%. From the above, through kneading and the addition of fine powder and lubricant, the surface treatment of d-HDDR magnet powder achieved high density magnets at a low molding pressure and a compound capable of controlling the reduction in loss of squareness(Fig.2).

3. Injection molding magnet

Two type resins of Polyamide 12 (PA12) and Poly Phenyl Sulphide (PPS) are used for anisotropic injection-molding magnet of MAGFINE. The PA12 type injection-molding magnet has good remanence Br up to 8.7 kG, however, low reliability under high temperature over 120deg.C. On the other hand, the PPS-type magnet has low Br up to 7.4 kG, however, high reliability under high temperature and some solvents. This difference is caused from physical characteristics of binder resin such as resin polarity, melting viscosity, and so on. The authors selected the polar-type polymer with higher melting point compared with polyamide 12 and similar viscosity as polyamide 12 in order to develop the injection-molding magnet with both high performance and high reliability at high temperature. The alignment ratio of magnetic powder in magnet was increased under the increase of resin polarity. During magnetic powder alignment, the melted resin was expanded to magnetic powder homogeneously due to high affinity with magnetic powder surface. It decreased the powder surface friction with magnetic powders and leaded to high alignment ratio. From this, we successfully developed injection-molding magnet with Br=8.3kG by using selected polymer binder (Fig. 3).

Reference
1) Y.Honkura, Proceeding of 19th International Workshop on Rare Earth Permanent Magnets and Their Application, Beijing, CHINA 2006, pp. 231-239.
2) C.Mishima,K.Noguchi, et.al. Proceeding of 21st Workshop on Rare Earth Permanent Magnets and their Applications, Bled Slovenia 2010, pp 253.

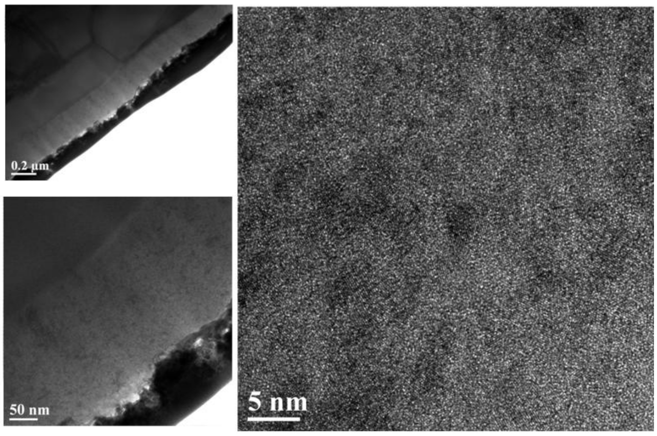

Fig.1. TEM observation results of magnetic powder surface with surface coating.

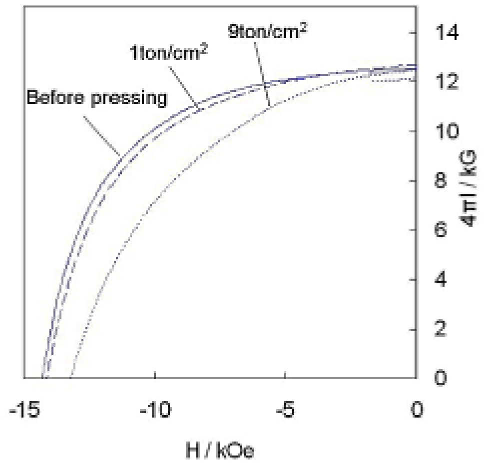

Fig.2. Demagnetization curves before and after molding.

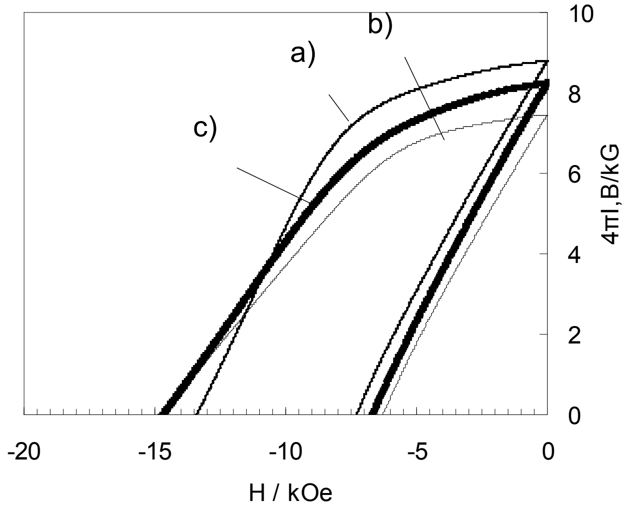

Fig.3. Demagnetization curves of injection molding magnets with a) PA12 binder, b) PPS binder, and c) selected-polymer binder.