Accurate measurement of hysteresis curve for Nd-Fe-B sintered magnet with superconducting magnet-based vibrating sample magnetometer

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Introduction

In recent years, there has been growing interest in the developments of a new measuring system for the hysteresis curve of large voluminal rare-earth magnets. There still remain some problems such as decrease in the maximum field (H_m), the magnetization distortion, and the drift in the hysteresis graph (HG) method, and the eddy current effect in the pulsed-field magnetometer (PF) method [1-3]. Therefore, we made the most use of a superconducting magnet (SCM)-based vibrating sample magnetometer (VSM). We compared the SCM-VSM method with the HG and PF methods to obtain accurate magnetic properties of Nd-Fe-B sintered magnets with very high coercivity (H_{cJ}) (≥ 2.1 MA/m).

Experiment

The sample was magnetized with an H_m of 5.6 MA/m. The inner diameter of SCM used for NbTi wire is 50 mm. The time for the measurement of a hysteresis curve was approximately 2.5 h. The applied field (H_{ex}) uniformity within 0.1% was 14 mm diameter sphere volume in the center of SCM. Magnetization (J) was calibrated at 1.0 MA/m by using the saturation magnetization of a Ni (99.9%) whose size was the same as that of sample. H_{ex} was calibrated by the nuclear magnetic resonance. The accuracy was better than ±1% after calibration for both J and H_{ex}. Particular attention was paid to accurate correction of demagnetizing field (H_d) for the cylindrical sample with diameter (D) of 10 mm and length (L) of 14 mm using a magneto-metric demagnetizing factor (N_m) depended on the differential susceptibility (dJ/dH_{ex}) [3, 4].

Results and Discussion

It was essential that the longer L of the sample be magnetized uniformly for these methods [3]. Fig. 1 shows the hysteresis and dJ/dH_{eff} curves of Nd-Fe-B sintered magnet with L-to-D ratio (L/D) of 1.4 for the SCM-VSM method, where H_{eff} is the effective field. These curves were corrected for the H_d. The definition of N_m was generally limited to $dJ/dH_{ex} \approx 0$. However, N_m was considered to be the functions of L/D and dJ/dH_{ex} [4]. The values of dJ/dH_{ex} in the hysteresis curves were 0.01-5.40 Tm/MA (= 10^{-6} H/m) in the study. N_m of the cylindrical sample with L/D = 1.4 for the SCM-VSM method is obtained by $0.240 - 0.037\log(1 + dJ/dH_{ex})$ on the condition of $0 \leq dJ/dH_{ex} \leq 10$ [4]. Table 1 shows the magnetic properties obtained from these methods for Nd-Fe-B sintered magnet. The squareness (H_k/H_{cJ}) obtained from PF method was much smaller than that of SCM-VSM method. It was suitable for the measurement of hysteresis curve for large voluminal rare-earth magnet.

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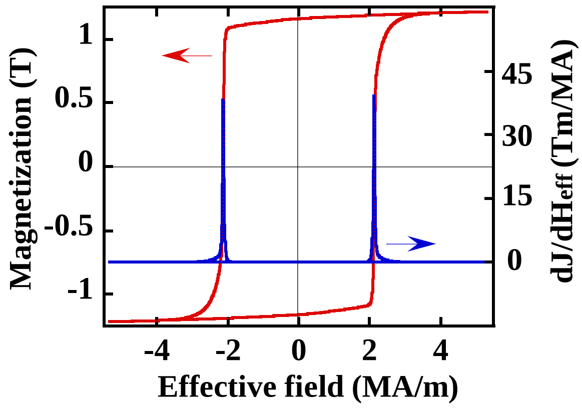

Fig. 1 J-H_{eff} and dJ/dH_{eff} curves of Nd-Fe-B sintered magnet.

References

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Table 1 Magnetic properties of Nd-Fe-B sintered magnet (D = 10 mm, L = 14 mm) measured by PF, HG, and SCM-VSM methods.

Method	Correction	J_m / B_r (T)	H_{cB} (MA/m)	H_{cJ} (MA/m)	H_k / H_{cJ}	$(BH)_{max}$ (kJ/m^3)	dJ/dH_{eff} near H_{cJ} (Tm/MA)
PF	Ref. [3]	1.22 / 1.15	0.89	2.10	0.919	256	17
HG	Ref. [3]	1.21 / 1.18	0.90	2.03	0.941	268	12
SCM-VSM	Eq. of N_m	1.22 / 1.16	0.90	2.13	0.963	263	38