

THE INFLUENCE OF THE POSTSINTERING TREATMENT ON THE MAGNETIC PROPERTIES FOR (Nd,Dy)(Fe,Al)B PERMANENT MAGNETS

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Abstract: The paper present the results obtained studying the influence of the annealing treatment on the magnetic properties and microstructure of the (Nd,Dy)(Fe,Al)B, with different compositions. These studies showed for the Nd₃₀Dy₅Fe_{bal}Al_{0.4}B₁ permanent magnets a substantial increasing of the coercivity after annealing treatment.

Key words: NdFeB magnets, postsintering treatment, magnetic properties, applications

1. INTRODUCTION

The improvement of the coercivity, of the temperature coefficient for the coercive field, the corrosion resistance is active research areas in the field of Nd₂Fe₁₄B based magnets [1]. High performance permanent magnets with an intrinsic coercive field, $jH_c > 20$ kOe and energy density product $(BH)_{max} > 31.5$ MGOe exhibit a complex multiphase microstructure. The grain size of sintered magnets and alignment of the grains strongly depend on processing parameters. The formation and distribution of the phase is mainly determined by the composition of the magnets [2,3].

The coercivity is intimately connected with a total anisotropy field H_A via the relation [4]:

$$jH_c \sim cH_A - N_{eff}M_s/\mu_0 \quad (1)$$

where c and N_{eff} are constants related to grain structure and grain boundary. The microstructure is related to the alignment of magnetic monodomain particles, nature and size of the defect regions in which nucleation / or pinning of the domain wall takes place. The microstructural parameter N_{eff} is the effective demagnetising factor. The μ_0 is the permeability of vacuum.

Therefore, the jH_c is governed by the three factors from this equation: the magnetic anisotropy field of the main hard phase, the spontaneous magnetisation of the main phase, microstructure and grain boundary. For the actual magnets $c < 1$, because of imperfect grain orientation and grain boundary defects and for that to explain why the actual magnets

1	Sintered	10.80	10.00	13.25	10.55	27.15	7.41
	Annealed	10.75	10.00	17.60	14.60	26.15	7.41
2	Sintered	12.55	11.50	19.10	16.00	36.20	7.50
	Annealed	12.48	11.50	>24.0 0	19.60	35.95	7.50
3	Sintered	12.20	11.50	18.85	16.00	35.30	7.49
	Annealed	12.20	11.45	>24.0 0	19.60	35.10	7.49

The effect of annealing at 630°C/2 h on the magnetic properties for $\text{Nd}_{33.65}\text{Dy}_{2.5}\text{Fe}_{\text{bal}}\text{Al}_{0.8}\text{B}_1$ and $\text{Nd}_{26.76}\text{Dy}_{5.8}\text{Fe}_{\text{bal}}\text{Al}_{0.4}\text{B}_1$ magnets are shown in Fig. 1 and 2, respectively. The magnets with high Nd content - 33 wt. % - and lower Dy content - only up to 2.5 wt. % Dy, shows a maximum $jH_c \sim 17.6$ kOe, also jH_c increase with 32 % comparatively as sintered jH_c value.

The annealing of the alloys with lower Nd content (27 ... 29 wt. %) and the same high Dy content (5.82 wt. %), resulted, also in a substantial increase of the intrinsic coercive field, $\sim 33, 4$ %. The maximum value for jH_c was obtained of around ~ 25.2 kOe.

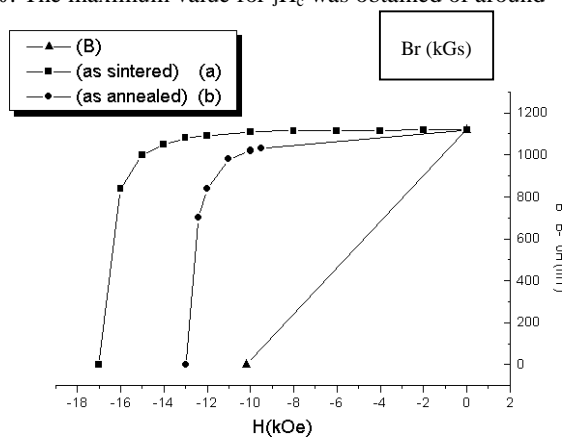


Fig.1 - The demagnetisation curves for $\text{Nd}_{33.65}\text{Dy}_{2.5}\text{Fe}_{\text{bal}}\text{Al}_{0.8}\text{B}_1$ magnets
a) after sintering b) after annealing

For the $\text{Nd}_{27}\text{Dy}_{5.8}\text{FeAl}_{0.4}\text{B}_1$ magnets (A + B alloys), obtained by “two alloys” method, the magnetic properties after sintering and after annealing also, are easily higher, comparatively those, obtained for the type B alloys, magnets, especially for the $B_r \sim 12.55$ kGs and $(BH)_{\text{max}} \sim 36.20$ MGOe.

These values are different for the type A - alloy magnets, $\text{Nd}_{33}\text{Dy}_{2.5}\text{Al}_{0.8}\text{B}_1$ (wt. %) with 11.4% lower H_k/jH_c ratio, between sintered and annealed, A - alloy magnets, corresponding $H_k/jH_c = 0.79 \dots 0.88$.

Br (kGs)

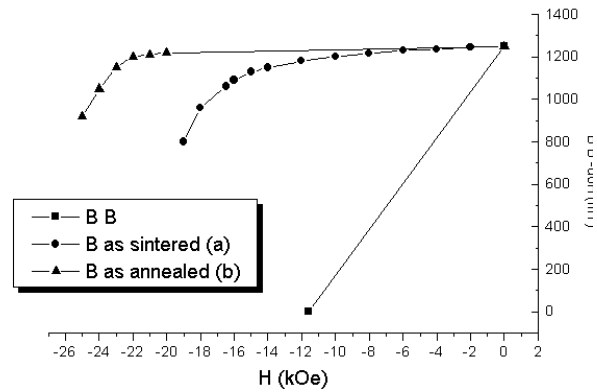


Fig. 2 - The demagnetisation curves for $\text{Nd}_{26.76}\text{Dy}_{5.8}\text{FeAl}_{0.4}\text{B}_1$ magnets
a) after sintering; b) after annealing

4. APPLICATIONS OF NdFeB PERMANENT MAGNETS IN AERONAUTICAL INDUSTRY

Magnetic circuit with high energy NdFeB has been used in special devices in aeronautical industry, but their have special condition for maintenance: life time in hours, life time in years, function in cumulated conditions.

In different type of magnetic circuit with advantage and disadvantage, the best work point is for NdFeB, but working temperature for this is lower (see Fig. 3).

Aeronautical industry use magnetic bearing system for the turbo pump of the Space Shuttle Main Engine and other type; the permanent magnets provide suspension, the electromagnets provide control; use magnetic levitation; and perhaps all types of electrical drive with permanent magnets. The necessity is to protect and makes work all the magnetic circuit in case of exterior perturbation, for example at extreme temperature, not expansive and with low maintenance, for long time.

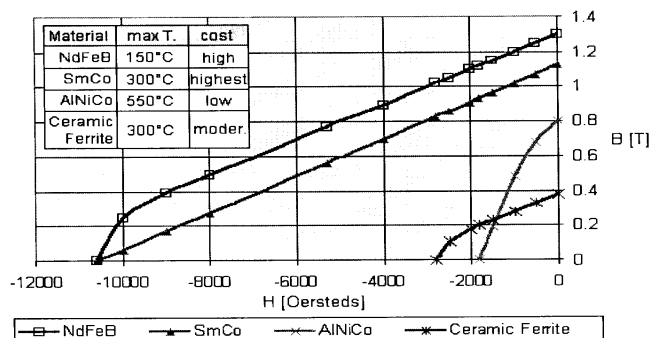


Fig 3 - Comparison of working temperature for different magnetic materials

5. CONCLUSIONS

The improvements seen in intrinsic coercivity of the $\text{Nd}_{33}\text{Dy}_{2.5}\text{Fe}_{\text{bal}}\text{Al}_{0.8}\text{B}_1$, $\text{Nd}_{29}\text{Dy}_{5.82}\text{Fe}_{\text{bal}}\text{Al}_{0.4}\text{B}_1$ and $\text{Nd}_{27}\text{Dy}_{5.82}\text{Fe}_{\text{bal}}\text{Al}_{0.4}\text{B}_1$, after annealing at $630^\circ\text{C}/2\text{h}$, have been confirmed and they appear to be due to a change in the morphology of the Nd rich phases along grain boundaries. That, resulting in a uniform distribution of the intergranular Nd rich phase and for the favorable distribution for the reducing direct exchange interactions and also reduce the long range magnetostatic between the hard magnetic grains, so that lead to increase of intrinsic coercivity. Were obtained the high value of $jH_c > 24 \text{ kOe}$ for the (Nd,Dy)(Fe,Al)B with lower Nd content (Nd ~ 27 ... 29 wt. %) and constant content Dy ~ 5.82 wt. %.

Study of magnetic stability for permanent magnet increase the performance for magnetic circuits who used, finally this special circuits come in applications like weapon with electromagnetic pulse, treatment in electromagnetic field, treatment in magnetic field (produce by the powerfully permanent magnet), etc.

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