LASER CUTTING OF RARE-EARTH NdFeB PERMANENT MAGNETS

[1]Igor BELYAEV, [1]Dmitry SEROV, [1]Andrey KIREEV, [2]Alexandr KUTEPOV, [3]Alexandr LYUKHTER, [3]Alexey ZHOKIN, [3]Vladimir RYKOV, [4]Natalia KOLCHUGINA

[1]Vladimir State University named after A.G. and N.G. Stoletovs, Vladimir, Russian Federation, belyaev-iv54@yandex.ru

[2]JSC RPA "Magneton", Vladimir, Russia, sales@tdmagneton.ru

[3]Vladimir Engineering Center for the Use of Laser Technologies in Mechanical Engineering, 3699137@gmail.com

[4] Baikov Institute of Metallurgy and Materials Science, Russian Academy of Sciences, Moscow, Russia, imet@ultra.imet.ac.ru

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Abstract

The possibility of laser cutting of rare-earth NdFeB permanent magnets is studied. An industrial Navigator KS-5VDM1-3 laser complex (VNITER, Russia) is used. Blanks of sintered permanent magnets intended for cutting were 10, 4.5, 3, and 2 mm thick. The cutting was performed in air. The used cutting conditions ensure the cutting of a blank for one pass. The cutting rate was varied in wide range. The magnetic properties of studied blanks were determined via measuring the magnetization reversal curves recorded before and after cutting. Changes in the alloy structure during laser cutting were estimated by X-ray diffraction analysis. The decrease in the magnetic properties during laser cutting was found to depend on the blank thickness. The thinner the magnet blank, the lower the decrease in its magnetic properties. The causes for the decrease in the magnetic properties of NdFeB permanent magnet blanks during laser cutting are local changing the phase composition of alloy and decrease in the degree of texture of blanks. The losses of magnetic properties can be minimized by optimization of laser cutting conditions.

Keywords: Rare-earth magnets, laser cutting, phase composition, magnetic properties

1. INTRODUCTION

Permanent magnets NdFeB are widely used in civil, special, and military equipment and in medicine as well. Among available industrially important permanent magnets, the NdFeB magnets exhibit the highest level of magnetic characteristics [1-3]. The preparation technology of these permanent magnets is multistage. **Figure 1** shows a schematic diagram of the standard preparation technology of NdFeB magnets.

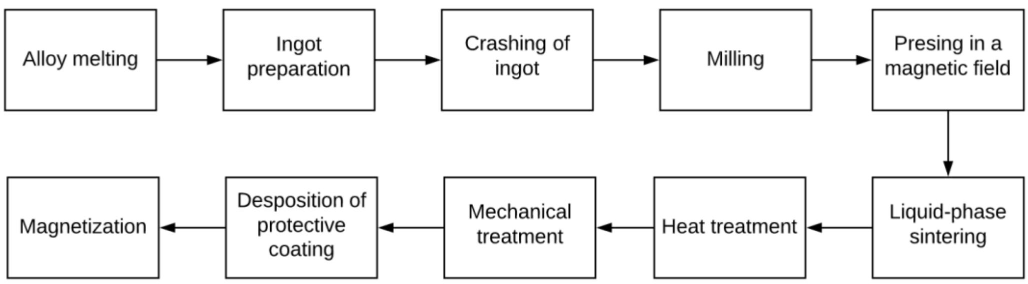

Figure 1 Schematic diagram of standard preparation technology of sintered NdFeB magnets

The manufacturing cost of NdFeB permanent magnets is rather high. To decrease the cost, many modern manufacturers realize incomplete (reduced) technological cycle. Such manufacturers purchase sintered magnet blanks (produced in other special plants) and begin the own production cycle from the mechanical treatment. Under these conditions, it is of interest to use the laser cutting of blanks since this cutting method exhibits the high performance and can be easily automatized [4,5].

The present study is aimed at the investigation of the effect of laser cutting of sintered NdFeB magnet blanks on the magnetic properties of permanent magnets manufactured from these blanks.

2. MATERIALS AND METHODS

For the investigation, we used blanks of sintered textured permanent magnets; the alloy composition comprises 34 % Nd, 1.5 % Dy, 3% Co, 1.15 % B and Fe – balance. The used blanks were in the form of plates 2, 3, 4.5, and 10 mm in thickness. The blanks were subjected to laser cutting. After cutting, the obtained blanks have single cutting plane. Measurements of the magnetic properties were performed for all cut blanks. Simultaneously, the magnetic properties of blanks, which were not subjected to cutting, were measured.

The laser cutting was performed using a Navigator KS-5VDM1-3 industrial laser complex (VNITER, Russia) equipped with a LS-3 ytterbium fiber laser with a capacity of 3 kW. A specially developed accessory was used to fix the blanks. In all cases, the capacity of laser radiation was 2 kW. The used cutting rate ensures the possibility to cut a blank in one pass. The alloy in the cutting zone was cooled with compressed air.

The magnetic properties were measured via continuous recording magnetization reversal curves using a Permagraph C-300 setup (Magnet-Physik Dr. Steingrover GmbH, Germany).

The phase composition of the alloy was studied by X-ray diffraction analysis using a D8 Advance diffractometer (Bruker AXS, Germany) and CuK_α radiation. The X-ray diffraction patterns were processed using TOPAS software. The samples were studied before the treatment of them with laser irradiation and after the treatment (in this case, the cutting plane was studied).

Table 1 Magnetic properties of sintered NdFeB blanks before and after laser cutting

Sample thickness, mm	Cutting rate mm/min	Sample state	Magnetic properties			
			B_r,T	Hc_b, kA/m	Hc_j,kA/m	(BH)max, kJ/m^3
10		**Before l/c**	**1.174**	**896.5**	**1779**	**263.1**
	450	After l/c	1.052	746.8	1788	194.8
4.5		**Before l/c**	**1.178**	**906**	**1592**	**267.7**
	1800	After l/c	1.171	818.5	1675	240
	2000	After l/c	1.09	782	1718	216
	2200	After l/c	1.17	844	1686	249
3		**Before l/c**	**1.2**	**918**	**1618**	**276**
	3000	After l/c	1.15	826	1630	243
	4000	After l/c	1.13	816	1620	234
2		**Before l/c**	**1.2**	**914**	**1620**	**275**
	5000	After l/c	1.12	823	1653	237
	7000	After l/c	1.14	833	1704	243

Note: l/c corresponds to laser cutting

3. RESULTS AND DISCUSSION

The cutting of blanks was accompanied by flashing; however, no pyroeffects were observed.

The magnetic properties of cut blanks were measured. Simultaneously, magnetic properties of control blanks (which were not subjected to laser cutting) were measured. **Table 1** shows the magnetic properties of blanks before and after laser cutting.

As is seen from **Table 1**, all magnet blanks retain their magnetic properties after laser cutting, although the level of magnetic properties, except Hcj, decreases. The decrease in the magnetic properties depends on the blank thickness. The losses of magnetic properties as a function of the blank thickness are shown in **Figure 2**.

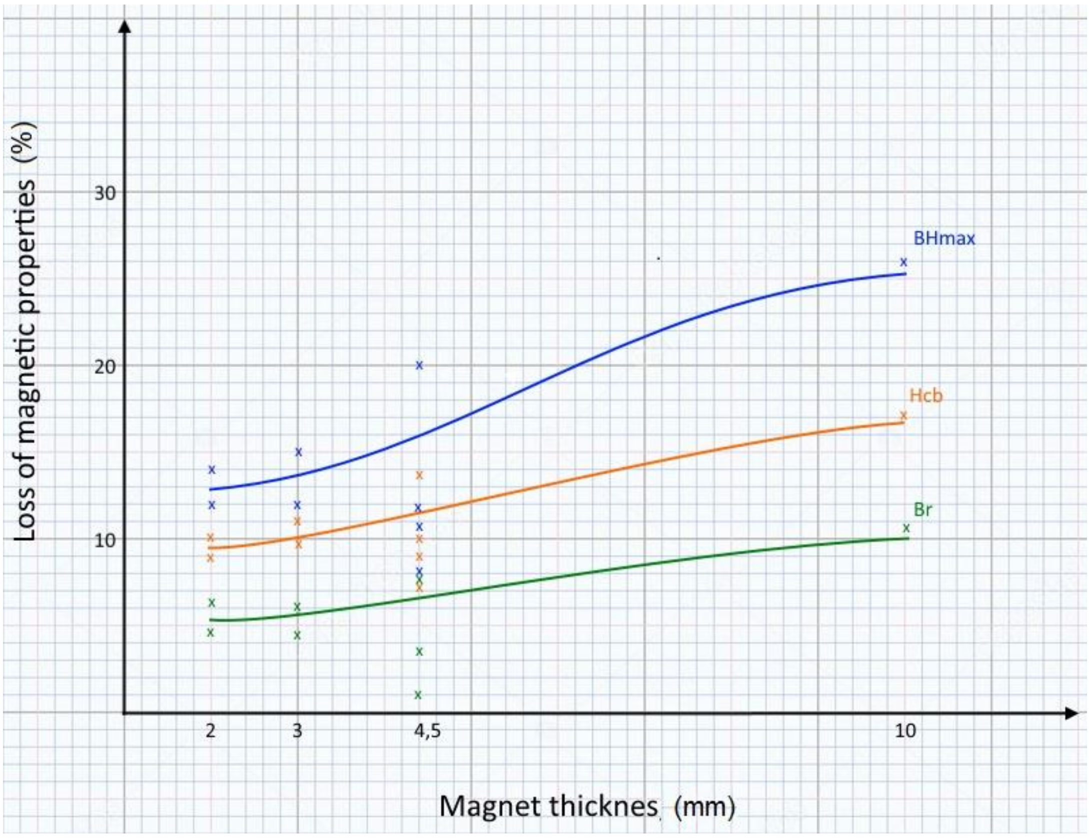

Figure 2 Dependences of losses of the magnetic properties of NdFeB permanent magnets on the blank thickness during laser cutting

The X-ray diffraction study of the blank surface after laser cutting showed that, under the action of laser irradiation in the cutting zone, changing the phase composition takes place. In the alloy layer adjacent to the cutting plane, the content of the main magnetic $Nd_2Fe_{14}B$ phase decreases and iron and neodymium oxide inclusions appear. This is likely to be the main cause for the decrease in the magnetic properties during laser cutting of the blanks. The other cause for the decrease in the magnetic properties consists in the disturbance of the anisotropy of magnetic-crystalline structure (texture). This fact is indicated by the decrease in the squareness of magnetization reversal curve after laser cutting (**Figure 3**).

It is seen from **Figure 3** that the magnetization reversal curve (1) is characterized by the high squareness as compared to that of curve (2). The correlation between the squareness of magnetization reversal curve and degree of anisotropy of magnetic-crystalline structure (texture) is well known in the physical materials science [6,7].

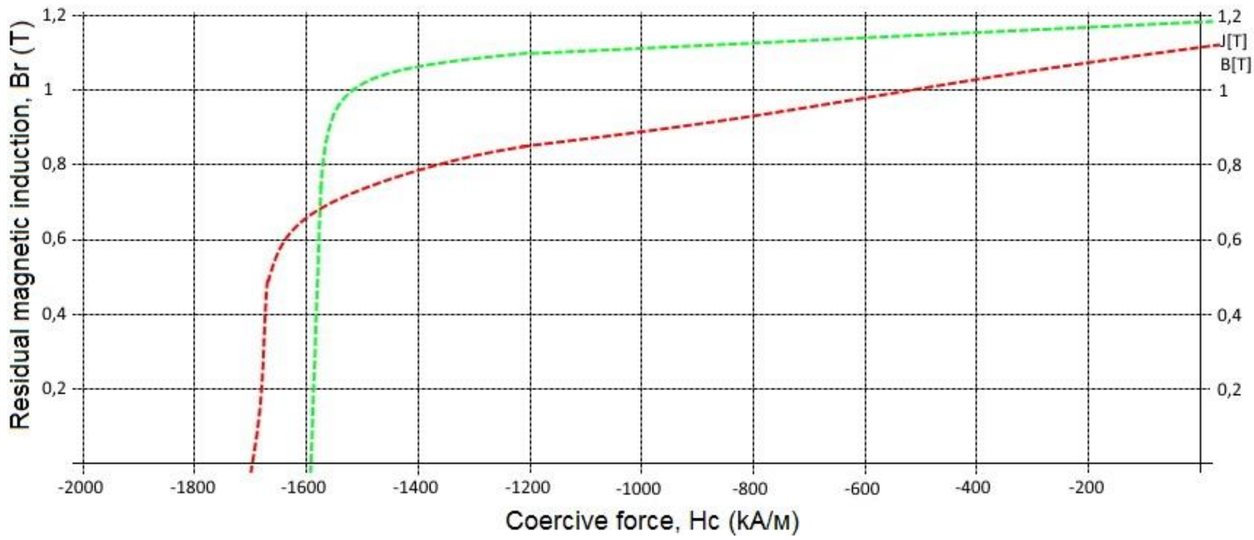

Figure 3 Magnetization reversal curves for NdFeB magnet blanks 4.5 mm thick (1) before and (2) after laser cutting at a rate of 2000 mm/min.

4 CONCLUSION

The laser cutting of compacted sintered blanks of NdFeB permanent magnets leads to the decrease in the Br, Hc_B and (BH)max magnetic parameters. The value of the decrease depends on the magnet blank thickness. The thicker the magnet blank, the higher the decrease in the Br, Hc_B and (BH)max values after laser cutting. However, on the contrary, the Hc_j value increases.

The causes for the decrease in the magnetic properties of the NdFeB permanent magnets after laser cutting consist in local changing the phase composition of alloy and decreasing the degree of anisotropy of magnetic-crystalline structure of compacted sintered blanks.

In order to realize the laser cutting of NdFeB permanent magnet blanks to 10 mm in thickness without significant decrease in their magnetic properties, it is necessary to optimize the technological conditions of laser cutting of the blanks.

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