ASPECTS REGARDING MECHANICAL PROCESSING OF STEELS FOR MAGNETS, NDFEB BASED

PHD. ENG. MELANIA TĂMAŞ, "ION NECULCE" NATIONAL COLLEGE, BUCHAREST,EMAIL: MELANIAT2@YAHOO.COM

PHD. ENG. DOINA ENE, "I. SOCOLESCU" TECHNICAL ARCHITECTURE COLLEGE, BUCHAREST, EMAIL: DOINAENE@YMAIL.COM

Abstract: *This paper presents experimental research concerning the behavior on cutting by turning of steels for magnets NdFeB based. In this context, cutting by rough turning of steels magnet neodymium and boron ferrite based were performed. Turning processing with the values of the cutting parameters recommended by European Union and Sandvik Coromant company rules, taking into account the chemical composition of the processed material and cutting tool were performed. The tables have been drawn up with different values of the cutting parameters. By comparing these data it can be concluded that steels for permanent magnets, NdFeB based have acceptable behavior, the process by rough turning. A full assessment of the optimization of the cutting by turning process of steels for permanent magnet, NdFeB base will result from subsequent experimental research that will take into account the wear of cutting tools and quality (roughness) of processed surface.*

Keywords : permanent magnets, metallographic structure, roughness, turning processing

Introduction

The Neodymium (Nd), a main magnets component has been first commercially used in 1927 as glass dyes, especially for laser lens and today it remain a popular such additive due reddish-purple color, which confer fluorescent effects, capable to change in accordance with the type of lights [1a] Also this has extremely high power applications, such as experiments in inertial confinement fusion. Neodymium, not found naturally in metallic form or unmixed with other rare earth lanthanide type elements represent one of the most important element due to it's contribution for „neo" alloys for magnets since first 1982, and commercially available in 1984 [2a, 3a]. Nevertheless, 3.6 billion years can be considered the beginning of rock-forming meteorite found in Antarctica, which may contain traces of fossil life on Mars.

Fig. 1b) Rare earth magnets, NdFeB based

The high density alloy sintered magnets (fig 1b), NdFeB based have the highest values of residual induction (B_s max = 1,41 T), high coercive force (H_c = 1260 kA/m) and maximum energy product (BH_{max} = 240 kJ/m^3), respectively. They are relatively hard to produce, very brittle and sensitive to corrosion, difficult to be mechanically processed due to low service temperature (80^0C) and also low Curie temperature (310^0C). The most important thing is the wide range of application in different industrial field that require strong permanent magnetic field, ten times higher than of ferrite magnets [5a].

In this article, some experimental researches regarding mechanical processing of such "neo" magnets, consisting of cutting by roughing turning, has been carried out

The variable parameters are: number of turns (speed) of turning machine (RPM): n, rot/min, advance of cutting tool: f (mm/rot), speed: v, (m/min), cutting depth: a_p, (mm).

METALLOGRAPHIC STRUCTURE AND METHOD FOR PRODUCING OF MAGNETS NDFDB BASED

From the point of view of the chemical composition on the basis of NdFeB permanent magnets are alloys of various elements (neodymium, iron, boron, cobalt, and various percent of dysprosium and praseodymium). Various percentages of dysprosium and praseodymium are added in recipe magnet alloy to improve corrosion resistance and intrinsic coercive force of magnet.

A typical recipe for obtaining alloy based NdFeB permanent magnets is shown in Table 2.1.

Table 1 Main elements of permanent magnets NdFeB based [6]

Main elements of NdFeB magnets	Weight percent (wt.%)
Neodymium (Nd)	29% - 32%
Iron (Fe)	64.2% – 68.5%
Boron (B)	1.0% - 1.2%
Aluminium (Al)	0.2% - 0.4%
Niobium (Nb)	0.5% -1%
Dysprosium (Dy)	0.8% -1.2%

The most common, commercial magnets NdFeB based, are sintered magnets type and has very strong values of magnetic induction and better performance than other types of magnets respectively. Manufacturing process of NdFeB magnets is based on the following steps:

- Separation / Refining: rare earth oxides with high purity separated and refined in furnaces / electrolytic ovens;
- Measuring materials: neodymium, iron, boron and other additives are measured in accordance to the chemical composition of the recipe proposed;
- Creating of alloy by furnace melting: measured elements are mixed and fed to a vacuum induction furnace and then melted to create the alloy;
- Spraying the alloy into fine particles: After mixing the alloy thus obtained is pulverized into fine particles, with the average diameter of microns size. To avoid oxidation, the fine particles obtained are protected by placing into argon or nitrogen environments;
- Pressing of particles in a magnetic field: The particles are placed into a confinement and pressed into a magnetic field to give a preferred direction of magnetization. Through this process a magnetic anisotropy is obtained.
- Sintering / aging of "green": The workpiece pressed receives heat treatment in a sintering furnace. Green magnet density prior to sintering of the magnet is about 50% of the

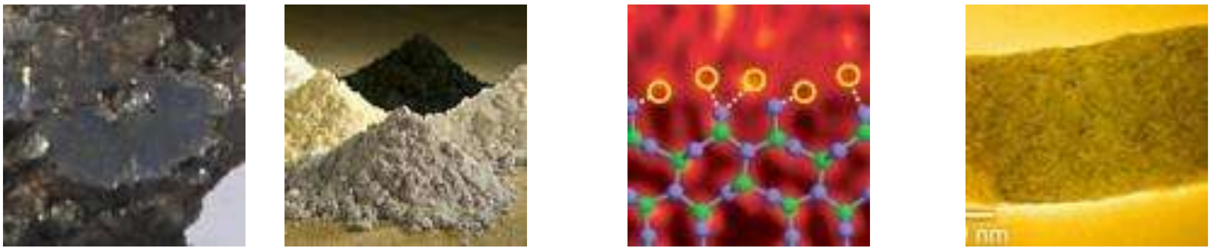
true density after sintering. Through this process, the magnet volume is reduced by about 50%;

- Final processing and plating: At this stage, a final processing of magnet, such three different plating with Ni-Cu-Ni or other different elements it is made.

- Inspect magnetic properties: key magnetic measurements: saturation induction, residual induction, coercive field and maximum energy product. Only magnets which have passed this inspection are sent to subsequent processes, including machining and assembly.

For increasing of corrosion resistance and strengthen the brittle magnets are triple plated with different coatings such as: nichel –cooper –nichel again, zinc, tin, epoxy, silver and gold. The gold plated magnets are actually quadruple plated with nickel, copper, nickel and a top coating of gold [7].

Figure 2 presents metallographic microstructure of rare earths elements that could be found in “neo” magnets mixed alloys.



a) Praseodymium *b) Samarium* *c) Lanthanum* *d) Cerium*

Fig. 2. Metallographic microstructure of rare earths elements as additives for magnets [8].

Experimental results obtained to cutting by turning of technologic samples

Samples of magnetic steels NdFeB alloy based were machined by turning roughing to identify their behavior under dynamic conditions. Turning roughing cutting through technological samples has been performed on a centered turning machine properly together with roughness tester MITUTOYO-SJ-210 with feeler, thermography camera THERMACUM SC 640, signal amplifier KISTLER type 5070, 3-axis (Fx, Fy, Fz) dynamometer KISTLER, acquisition board KISTLER and data acquisition Dynoware [9-11]. The Table 2 shows the parameter values of cutting conditions of samples turned at a constant cutting roughing depth by varying of cutting number of turns.

Table 2 Parameters values of cutting conditions at a constant cutting depth

MATERIAL: magnetic steel with neodymium	Vikers Hardness: 570 HV
Tool: cutting tool	
CUTTING CONDITIONS: Good M.U. Stabilitaty	
Cutting: continuous	
TOOLS USED: CM Plates: (standard metallic carbide)	
Type: SN 3-111	

Advance f [mm/rot]	Number of turns n [rot/min]	Speed ν [m/min]	Diameter d [m]	Thermal film	Cutting depth a_p [mm]
0,09	92	0,00578	0,02	S1 - New 0002	0,3
	184	0,01156		S4 - New 0005	
	380	0,02386		S7 - New 0008	
0,18	92	0,00578	0,02	S2 - New 0003	0,3
	184	0,01156		S6 - New 0006	
	380	0,02386		S8 - New 0009	
0,28	92	0,00578	0.02	S3 - New 0004	0,3
	184	0,01156		S6 - New 0007	
	380	0,02386		S9 - New 0010	

In Table 3 are presented the parameter values of cutting conditions of samples turned by varying the cutting roughing depth at a constant cutting number of turns.

Table 3 Parameter values of cutting conditions at variable cutting roughing depth

MATERIAL: magnetic steel with neodymium	Vikers Hardness: 570 HV
Tool: cutting tool	
CUTTING CONDITIONS: Good M.U. Stabilitaty	
Cutting: continuous	
TOOLS USED: CM Plates: (standard metallic carbide)	
Type: SN 3-111	

Advance f [mm/rot]	Number of turns n [rot/min]	Speed ν [m/min]	Diameter d [m]	Thermal film	Cutting depth a_p [mm]
0,09	184	0,01156	0,02	S4 - New 0005	0,3
				S10 - New 0013	0,6
				S11 - New 0015	0,9

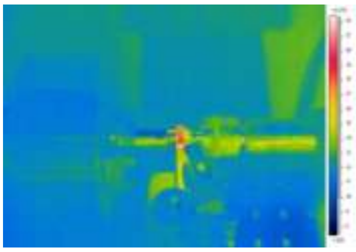
The Table 4 presents parameters values of roughing turning for technologic samples where maximum temperature, during process are registered.

Table 4 Parameters values of cutting conditions with different temperatures during process

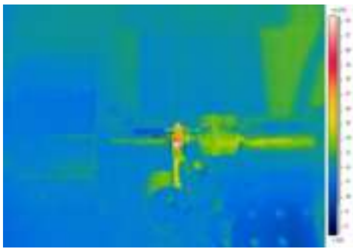
MATERIAL: magnetic steel with neodymium	Vikers Hardness: 570 HV
Tool: cutting tool	
CUTTING CONDITIONS: Good M.U. Stabilitaty	
Cutting: continuous	
TOOLS USED: CM Plates: (standard metallic carbide)	
Type: SN 3-111	

Advance f [mm/rot]	Number of turns n [rot/min]	Temperature $T[^0C]$	Thermal film	Cutting depth a_p [mm]
0,09	92	22,4	New 0002	0,3
	184	31,5	New 0005	
		200	New 00013	0,6
		100,5	New 00015	0,9
	380	386,5	New 0008	0,3
0,18	92	22,4	New 0003	
	184	54,5	New 0006	
	380	599,5	New 0009	
0,28	92	22,4	New 0004	
	184	54,5	New 0007	
	380	551,4	New 00010	

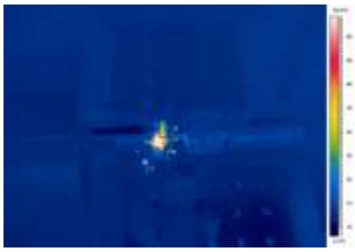
The figures 3a-e present different thermal effects obtained during cutting process. These are recorded with a specialized infrared thermal THERMACAM SC 640. It is easy to observe that the temperature increase direct proportionally with of number of turns and the advance of cutting tool [12-16].



a) ample S1 - New 0002

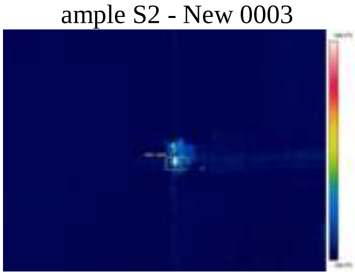


b) ample S2 - New 0003

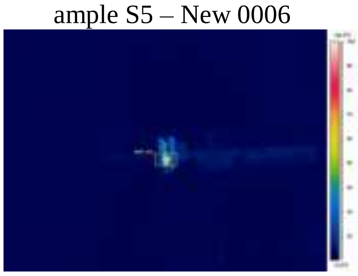


c) ample S5 – New 0006

d) ample S6 – New 0007



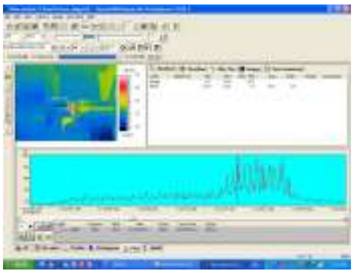
e) ample S10 – New 0013



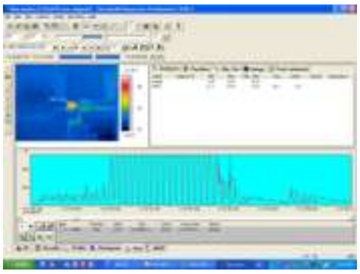
f) ample S11 – New 0015

Fig.4 Thermal effects that occur during the process of turning, observed with infrared camera THERMACAM SC 640.

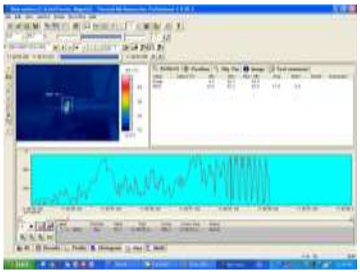
The figures 4 presents the diagrams with variation of maximum temperature values during cutting process.



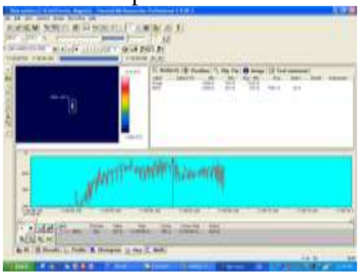
a) ample S1 - New 0002



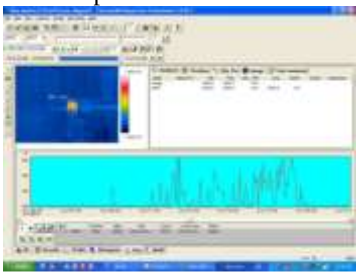
b) ample S2 - New 0003



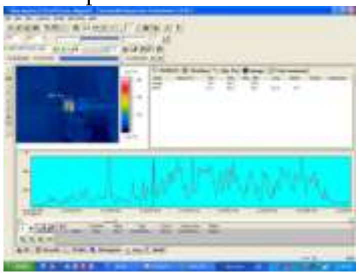
c) ample S5 – New 0006



d) ample S6 – New 0007



e) ample S10 – New 0013



f) ample S11 – New 0015

Fig. 3.2 Diagrams with variation of maximum temperature values during cutting process.

CONCLUSIONS

Steels for magnets NdFeB based are hard and brittle. Processing conventional machine tools of this kind of magnets is inadequate because the hardness and granular-crystalline structure does not allow the use of diamond tools, which is abrasives. This is due to the fact that the particles can burn during processing.

Processing these steels is recommended in non-magnetized state by heating them. After cutting processing can be magnetized to saturation.

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