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INFLUENCE OF TEMPERATURE ON OPERATION CHARACTERISTICS OF ELECTRICAL MACHINES WITH PERMANENT MAGNETS

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Abstract: The paper deals with the solution of the nonlinear magnetic field in a synchronous reluctance machine with permanent magnets. Nowadays, the permanent magnets made from rare earth are preferred. The properties of these magnets are depended on the temperature. There was modelled the operation characteristics T = f (t) – torque T, temperature t. For calculation, a FEM – based software was used. Results of the solution are discussed in conclusion.

Keywords: Synchronous reluctance machine, finite elements method, torque, rare earth.

1 Introduction

A permanent magnet (PM) can produce magnetic field in an air gap with no excision winding and no dissipation of electric power. External energy is involved only in changing the energy of magnetic field, not in maintaining it.

The use of permanent magnets (PMs) in construction of electrical machines brings the following benefits:

- no electrical energy is absorbed by the field excitation system and thus there are no excitation losses which means substantial increase in the efficiency.
- higher torque and/ or output power per volume than when using electromagnetic excitation,
- better dynamic performance than motors with electromagnetic excitation,
- better dynamic performance than motors with electromagnetic excitation

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- simplification of construction and maintenance
- reduction of prices for some types of machines

There are three classes of PMs currently used for electric motors:

- Alnicos (Al, Ni, Co, Fe);
- Ceramics (ferrites), e.g., barium ferrite $BaOx6Fe_2O_3$
- Rare-earth materials, i.e., samarium –cobalt SmCo and neodymium-iron-boron NdFeB - table 1.

This article deals with evaluation dependence of the static torque on the temperature. For calculation the synchronous reluctance machines with permanent magnets (RSM with PM) was used. Some machines work by higher temperature thus the knowledge of machine response – decrease of H_C and torque, is needed.

2 Properties of permanent magnets

Demagnetisation curves of the above PM materials are given in Fig. 1.

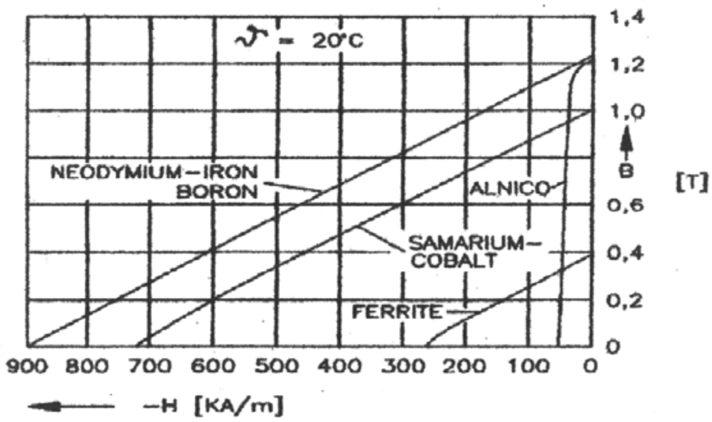

Fig. 1 Demagnetisation curves for different permanent magnets

Demagnetisation curves are sensitive to the temperature. Both B_r and H_c decrease as the magnet temperature increases, i.e.,

$$B_r = B_{r20}\left[1+\frac{\alpha_B}{100}(\vartheta_{PM}-20)\right] \tag{1}$$

$$H_c = H_{c20}\left[1+\frac{\alpha_H}{100}(\vartheta_{PM}-20)\right] \tag{2}$$

where θ_{PM} is the temperature of PM, B_{r20} and H_{c20} are the remanent magnetic flux density and coercitive force at 20°C and $\alpha_B < 0$ and $\alpha_H < 0$ are temperature coefficients for B_r and H_c in %/°C, respectively.

Table 1.

	ND-31HR Nd - based	ND-31SHR Nd - based	ND-35R Nd - based	Vacomax 240HR Sm_2Co_{17}
B_r [T]	1.14 to 1.24	1.08 to 1.18	1.22 to 1.32	1.05 to 1.12
H_c[kA/m]	828 to 907	820 to 899	875 to 955	600 to 730
μ_r [-]		1.05		1.22 to 1.39
α_B		-0.10		-0.03
α_H		-0.50		-0.15

3 Formulation of the problem

The cross-section of the RSM with PM (Fig. 2) is divided into several parts:

- Ω_1 – the subdomain of the iron, B-H curve
- Ω_{2-9} – subdomains of the stator winding (tab. 2), $J_C = 2{,}7 A/mm^2$

Table 2.

Slots		1	2	3	4	5	6	7	8	9	10	11	12
Coils	up	0	0	J_C	J_C	J_C	J_C	0	0	$-J_C$	$-J_C$	$-J_C$	$-J_C$
	down	0	J_C	J_C	J_C	J_C	0	0	$-J_C$	$-J_C$	$-J_C$	$-J_C$	0

Slots		13	14	15	16	17	18	19	20	21	22	23	24
Coils	up	0	0	J_C	J_C	J_C	J_C	0	0	$-J_C$	$-J_C$	$-J_C$	$-J_C$
	down	0	J_C	J_C	J_C	J_C	0	0	$-J_C$	$-J_C$	$-J_C$	$-J_C$	0

- Ω_9 – the subdomain of the air, $\mu_r = 1$.
- Ω_{10} – the subdomain of the rotor iron, $B = f(H)$,
- Ω_{11} – the subdomain of the permanent magnets , parameters in tab. 1
- Ω_{12} – the subdomain of the shaft, $\mu_r = 800$
- boundary Γ: $\boldsymbol{A} = 0$.

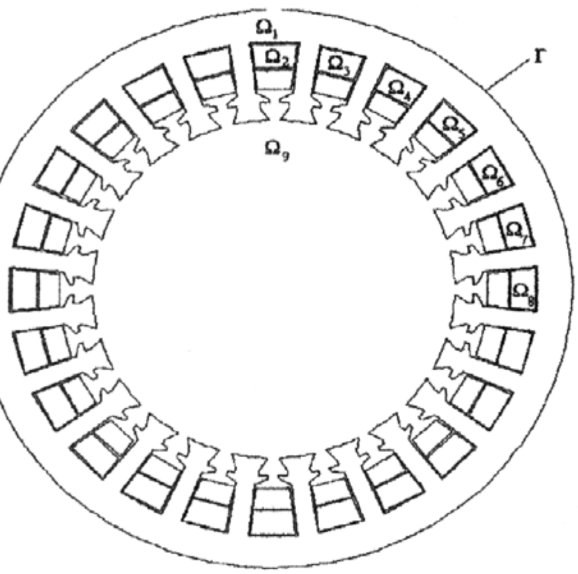

Fig. 2. Cross section of the stator

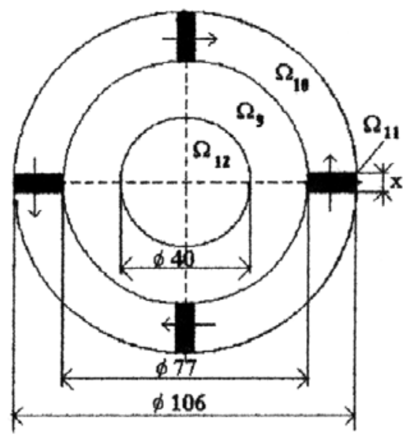

Fig. 3. Cross section of the rotor

4 Example of calculation

For solving of the task – operation characteristics T = f (t) – torque T, temperature t - was used the FEM-based program - FEMM. Fig. 4. shows the dependence of H_C on the temperature. The static torque was determined for one position of the rotor.

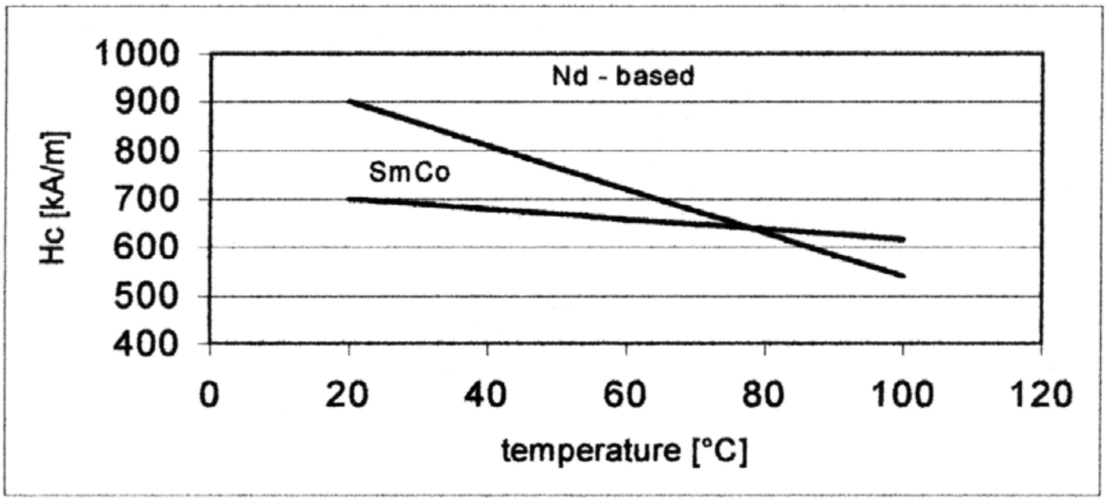

Fig. 4. Dependence H_C on the temperature.

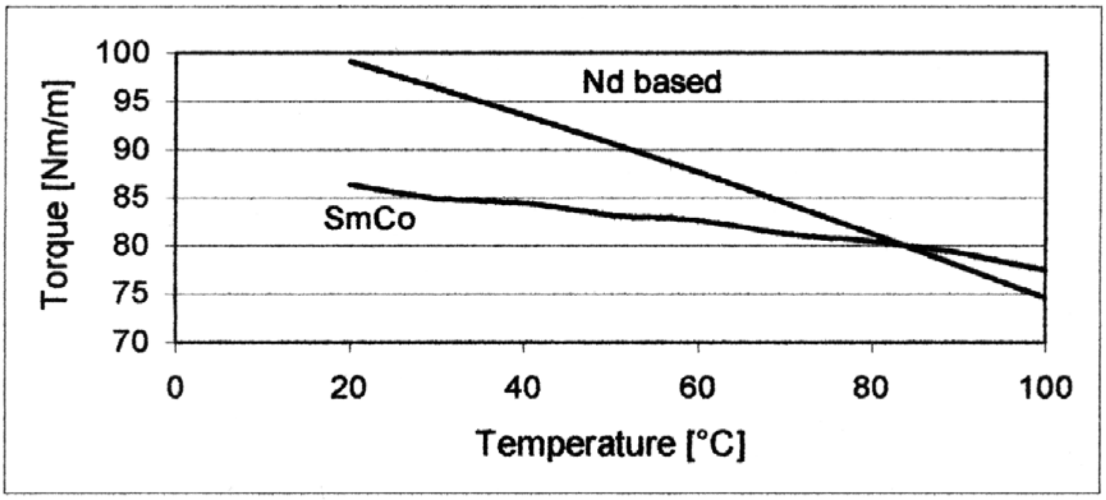

Fig. 5. Operation characteristic T = f (t)

5 Conclusion

Dependence of the static torque on the temperature is very significant. The decrease of the static torque is as many as 25% in range 20°C – 100°C, for Nd based magnets. Properties of the Nd based magnets are more depended on the temperature, however they have higher H_C at usual temperatures in comparison with SmCo magnets.

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[3] manual FEMM