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COGGING TORQUE REDUCING IN ELECTRIC MACHINE BY POLING MODIFICATION OF MAGNETIC CIRCUIT

*The paper presents results of permanent magnet electric machine's magnetic circuit simulating research by using Comsol program. During researches the structure of rotor had been modifying by changing pole pitch width angle – adjacent pole pitches took the angle dimension (30° – **α**) and (30° + **α**). The aim of research was determining the optimal value of parameter **α**, for which cogging torque takes the smallest value but the electromagnetic torque value is not changing. Conclusion from the research results proves that by application two of different pitches poles in rotor the cogging torque can be decreased about 30%.*

1 INTRODUCTION

In field of slot-shape electric machines the primary cause of existing vibration is significant irregularity of magnetic reluctance in air gap, which generates cogging torque. In previous author's papers [2] there are presented results of slot-shape machines examination, in which the magnetic wedges with adequate magnetic permeability for reducing cogging torque had been using. Reducing of irregularity of magnetic reluctance in air gap was a task for magnetic wedges. In article [1] authors show the way of reducing cogging torque by changing structure of electric machine's magnetic circuit without loading additional elements (e. g. magnetic wedges). It is done by nonsymmetrical locating of permanent magnet placed on the rotor. In present paper another way is proposed – decreasing of cogging torque has been reached by making adequate rotor with using two different width of pole pitches. The width of pole pitch have alternately the angle dimension (30° – **α**) and (30° + **α**). The researches carried out by using program Comsol consists of: determining cogging torque, electromagnetic torque and magnetic flux density in the center of air gap distribution when the parameter **α** takes the value from 0° to 10°. On this base the optimal value of parameter **α** was assigned.

2 NUMERICAL MODEL OF TESTED MACHINE

In figure 1a) the magnetic circuit of electrical machine, which had been subject of presented research, was shown. It is a 12-poles cylindrical machine with half-closed

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slots and permanent magnet (with dimension $\boldsymbol{b_{PM}}$ = 40 mm and $\boldsymbol{c_{PM}}$ = 7,5 mm) field excitation. The inner radius of stator is $\boldsymbol{R_s}$ = 57,5 mm, but the outer – $\boldsymbol{R_r}$ = 56,5 mm, the thickness of air gap – $\boldsymbol{\delta}$ = 1 mm and active length of machine – $\boldsymbol{l}$ = 30 mm. Figure 1b) presents field model of machine, where the arrows show the direction of permanent magnets magnetization, which are placed radial convertible with ferromagnetic field concentrators.

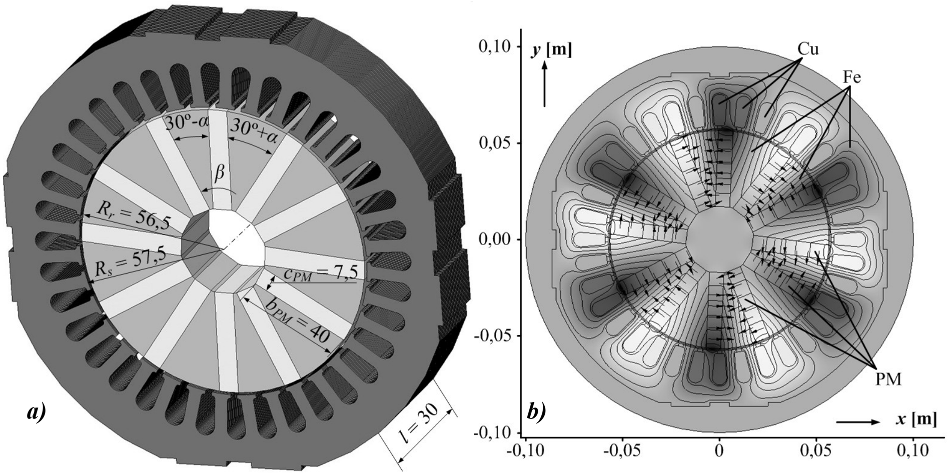

Fig.1. Magnetic circuit of an examined electrical machine: a) – 3D view, b) – field model

During research an assumption it has been made that the residual flux density of using permanent magnets is $\boldsymbol{B_r}$ = 1,23 T, but its' the relative magnetic permeability $\boldsymbol{\mu_{PM}}$ = 1,03. During the researches the parameter $\boldsymbol{\alpha}$ was changed from 0° to 10°, after that distribution of cogging torque of one cog pitch with step of 1° from $\boldsymbol{\beta}$ = 0° (balance point of rotor) to $\boldsymbol{\beta}$ = 10° (next balance point of rotor) has been determined. Next the value of electromagnetic torque $\boldsymbol{T_e}$ has been assigned for current density in windings $\boldsymbol{j}$ = 5 A/mm^2 and the magnetic flux density distribution in the middle of air gap in state without current for adjacent pole pitch has been assigned too.

3 RESULTS OF RESEARCH

On figure 2a) distributions of cogging torque $\boldsymbol{T_c}$ in dependence of parameter $\boldsymbol{\alpha}$ were illustrated. The figure 2b) shows value of electromagnetic torque $\boldsymbol{T_e}$ and average value of cogging torque $\boldsymbol{T_{cav}}$ in function of parameter $\boldsymbol{\alpha}$. Distributions of magnetic flux density have been shown in figure 3a) – for pitch poles (30° – $\boldsymbol{\alpha}$), in this case values of magnetic flux density are multiplied by -1 for better comparison with values in second type of pitch poles, 3b) – for pitch poles (30° + $\boldsymbol{\alpha}$). The table 1 shows results of research: average $\boldsymbol{T_{cav}}$ and relative $\boldsymbol{t_c}$ values of cogging torque, electromagnetic torque $\boldsymbol{T_e}$, relative electromagnetic torque $\boldsymbol{t_e}$ and average values of magnetic flux density $\boldsymbol{B^-_{yav}}$ and $\boldsymbol{B^+_{yav}}$ in the middle of the air gap on arc from $\boldsymbol{\gamma}$= 0° to $\boldsymbol{\gamma}$= 30°.

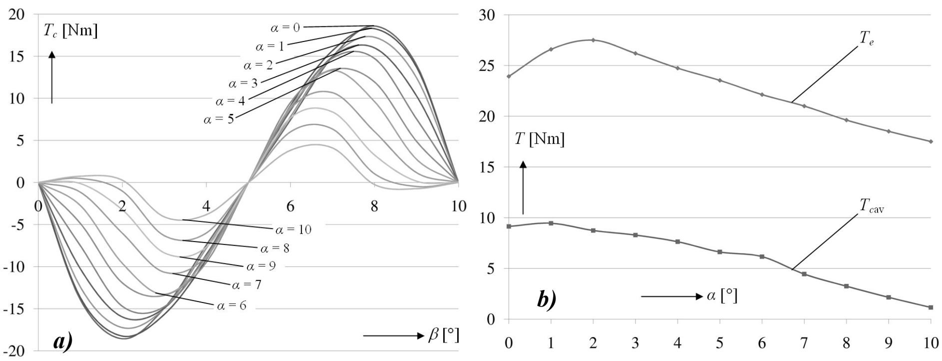

Fig.2. Torques in machine: a) – cogging torque distributions,
*b) – electromagnetic torque for **j** = 5 A/mm^2 and cogging torque in function of parameter **α***

Tab. 1. Results of simulating researches

No.	***α*** [°]	***T**cav* [Nm]	***t**c* [%]	***T**e* [Nm]	***t**e* [%]	B^-_{xav} [T]	B^-_{xav} [%]	B^+_{yav} [T]	B^+_{yav} [%]
1.	*0*	*9,1*	*100*	*23,9*	*100*	*-1,27*	*100*	*1,26*	*100*
2.	*1*	*9,5*	*103*	*26,6*	*111*	*-1,26*	*100*	*1,26*	*100*
3.	*2*	*8,7*	*96*	*27,5*	*115*	*-1,25*	*99*	*1,26*	*100*
4.	*3*	*8,3*	*91*	*26,2*	*109*	*-1,25*	*99*	*1,25*	*99*
5.	*4*	*7,6*	*83*	*24,7*	*103*	*-1,24*	*98*	*1,23*	*98*
6.	*5*	*6,6*	***72***	*23,5*	***98***	*-1,23*	*97*	*1,22*	*96*
7.	*6*	*6,2*	*67*	*22,1*	*92*	*-1,21*	*96*	*1,19*	*95*
8.	*7*	*4,4*	*49*	*21,0*	*88*	*-1,19*	*94*	*1,17*	*93*
9.	*8*	*3,2*	*35*	*19,6*	*82*	*-1,16*	*92*	*1,16*	*92*
10.	*9*	*2,1*	*24*	*18,5*	*77*	*-1,14*	*90*	*1,13*	*90*
11.	*10*	*1,2*	*13*	*17,5*	*73*	*-1,12*	*88*	*1,10*	*87*

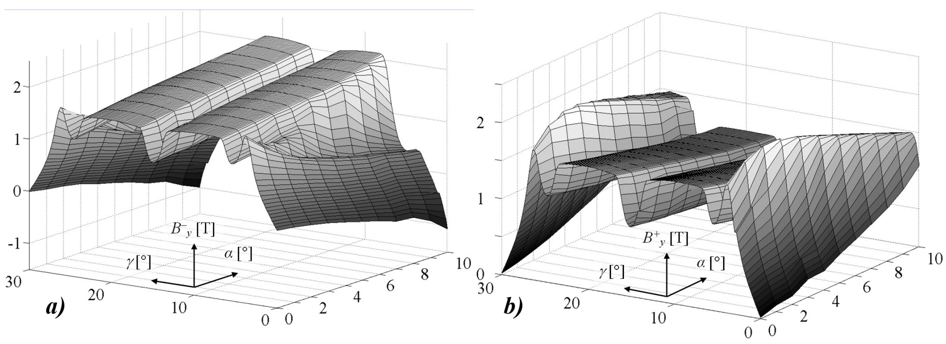

*Fig.3. Magnetic flux density distributions: a) – $\boldsymbol{B}^-_{yav}$ – magnetic flux density for poles 30°–**α***
*b) – $\boldsymbol{B}^+_{yav}$ – magnetic flux density for poles 30°+**α***

4 CONCLUSIONS

As a result of research is conclusion that the cogging torque in electric machines with two different dimensions of pole pitches can be reduced by changing magnetic circuit structure of rotor. In tested model with using pitch poles which dimensions are alternately 25° and 35° ($\boldsymbol{\alpha}$ = 5°) the cogging torque can be decreased about 30% with little loss of electromagnetic torque – only about 2%.

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5 REFERENCES

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ZMNIEJSZENIE MOMENTU ZACZEPOWEGO MASZYNY ELEKTRYCZNEJ Z MAGNESAMI TRWAŁYMI POPRZEZ ZMIANĘ STRUKTURY OBWODU MAGNETYCZNEGO

Referat prezentuje wyniki badań symulacyjnych obwodu magnetycznego maszyny elektrycznej z magnesami trwałymi przy użyciu programu Comsol. Podczas badań modyfikowana była struktura wirnika, poprzez zmianę szerokości kątowej podziałek biegunowych – sąsiednie podziałki biegunowe przyjmowały na przemian wymiar kątowy (30°– $\boldsymbol{\alpha}$*) oraz (30 °+* $\boldsymbol{\alpha}$*). Celem badań było wyznaczenie najlepszej wartości parametru* $\boldsymbol{\alpha}$*, dla którego moment zaczepowy przyjmie najniższą wartość przy zachowaniu wartości momentu elektromagnetycznego. Z badań wynika, że przy zastosowaniu dwóch różnych podziałek biegunowych w wirniku można uzyskać zmniejszenie momentu zaczepowego o ok. 30%.*