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The Influence of Pole Pair Number and Magnets' Width on Mechanical Torque of Magnetic Coupler with Rounded Permanent Magnets

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Abstract – In this paper it is researched the influence of permanent magnets' width and number of pole pairs on the mechanical torque of magnetic coupler with rounded magnets. The mechanical torque is calculated applying the program QuickField. For given magnetic coupler it is found the most suitable design taking into account the number of pole pairs and magnets' width.

Keywords – Magnetic coupler, magnetic force transmission, mechanical torque, permanent magnets, QuickField.

I. INTRODUCTION

A magnetic coupler is a mechanism, used to transfer the mechanical torque without contact of both half couplings, using attraction and repulsion forces from permanent magnets on the half couplings (Fig. 1). Magnetic coupler (MC) consists of two parts: inner 4 and outer 5 half coupling. The couplings are made of *Steel 3* and on them are placed the permanent magnets (PM) 6. PMs most often are made of rear earth alloys as neodymium-iron-boron (Nd-Fe-B) or samarium-cobalt (Sm-Co).

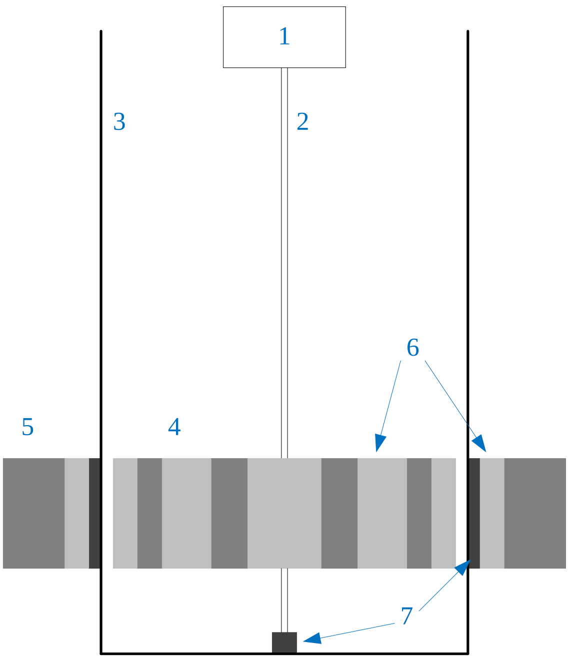

Fig. 1. Magnetic coupler in a design with mototr.
1 – motor; 2 – shaft; 3 – tube of stainless steel; 4 – inner half coupling; 5 – outer half coupling; 6 – permanent magnets; 7 – teflon box.

The MCs are used in pumps, compressors and liquid mixers. In Fig. 1 is given the MC in a design with motor for mixing liquids.

In this paper is analyzed a MC with rounded PMs made of rear earth alloy Nd-Fe-B (Fig. 2).

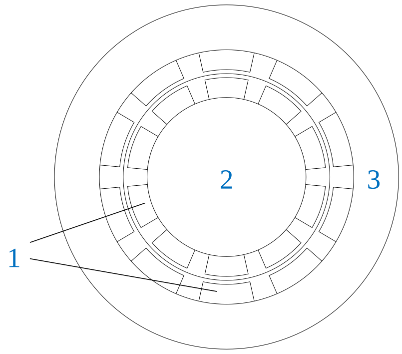

Fig. 2. Cross-section of MC with rounded PMs.
1 – PMs; 2 – inner half coupling; 3 – outer half coupling.

It is analyzed the influence of pole pairs number and PMs' width. The number of pole pairs p is changed from 1 to 10 with a step equal one. The influence of PMs' width is expressed with a proportionality coefficient β. The coefficient β is obtained from (1):

$$\beta = \frac{\alpha_{PM}}{(\alpha_{PM} + \alpha_{\delta})}, \quad (1)$$

where α_{PM} is the PM's angle with which understand the PM's width and α_{δ} is the angle of airgap between two PMs next to each other (Fig. 3).

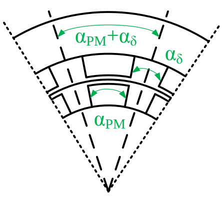

Fig. 3. The definition of PM's angle and angle of airgap.
α_{PM} – angle of PM; α_{δ} – angle of airgap between two PMs which are next to each other.

The coefficient β is changed from 0.6 to 0.9 with a step equal 0.1.

The dimensions of MC are given in Fig. 4.

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Volume 28

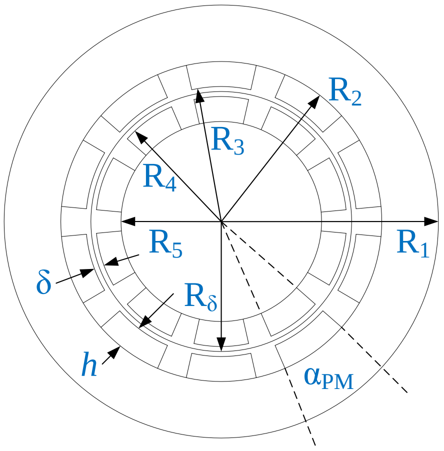

Fig. 4. Dimensions of MC.
R_1-R_5 – radiuses; R_δ – radius of airgap's middle circle ; δ - airgap; h – PMs height; α_{PM} – angle of PM

One more dimension, which varies, is the radius R_1 of outer circle of the outer half coupling (Fig. 4). It is not taken into account as variable because it has to be changed according to outer half coupling's yoke's height:

$$h_{yoke} = \frac{\pi \cdot R_2 \cdot \beta}{p} \cdot \frac{B_{PM}}{B_{steel}}. \qquad (2)$$

In (2) *p* is the pole pair number, B_{PM} is the residual induction of PM equal 1.28 (T) and B_{steel} is the induction of outer half coupling's yoke, which is made of *Steel 3* and the induction is equal 1.6 (T). Thus it is taken into account the saturation in the outer half coupling [1].

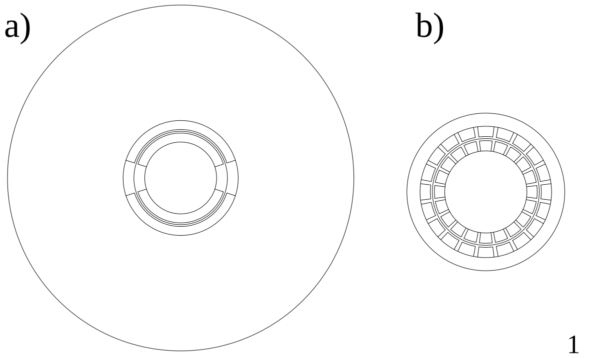

Fig. 5. The cross-sections of MCs with different pole pairs number *p*.
a – *p* = 1; b – *p* = 10.

The influence of pole pairs number *p* is shown in Fig. 5. As lower is the number *p*, as higher is yoke's height h_{yoke}. If after calculations yoke is smaller than 5 millimetres, it anyway is taken equal 5 mm. The height of PMs is equal for all MCs. The coefficient *β* is 0.8 in Fig. 5.

II. MECHANICAL TORQUES OF MC

The mechanical torques of the MCs are calculated applying the program QuickField [2]. For the calculations are used such PM's parameters:

- Residual induction B_r = 1.28 (T);
- Coercive force H_c = 860 (kA/m);
- Relative permeability μ_* = 1.184.

The airgap is defined as air and its relative permeability is μ_{0*}=1. The base of inner and outer half couplings is made of *Steel 3* and thus is defined by magnetization curve [1].

The mechanical torque is the parameter, with which are compared different MCs. The mechanical torque is calculated by contour made by the circle of airgap's middle with radius R_δ, according to [3], [4].

In Fig. 6 are given the curves of mechanical torque for pole pair number *p* = 10. The curves are parabolic.

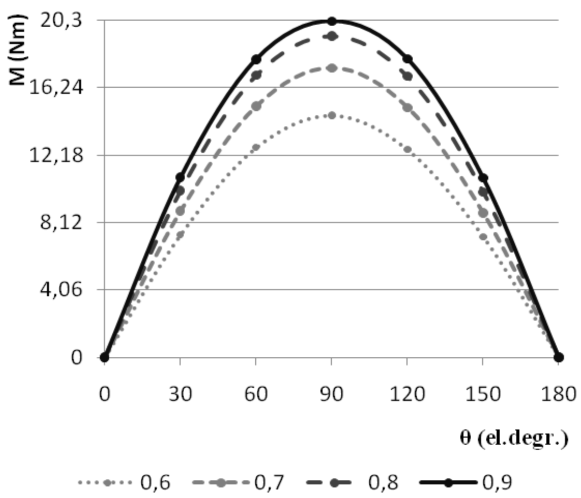

Fig. 6. Curves of mechanical torque for *p* = 10 by different proportionality coefficients *β* (0.6, 0.7, 0.8 and 0.9).

When the number of pole pairs decreases the curves become closer to trapeze form (Fig. 7), particularly at *β* = 0.9.

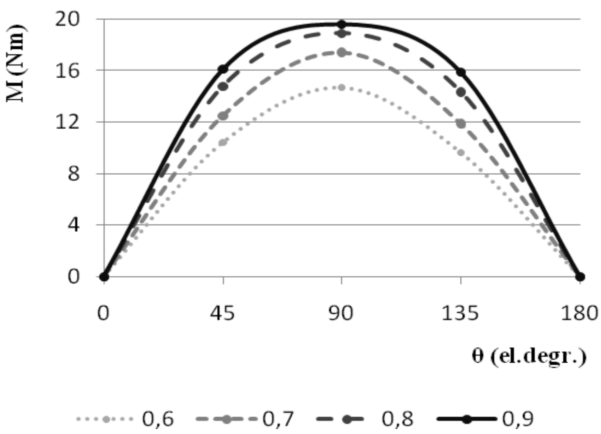

Fig. 7. Curves of mechanical torque for *p* = 4 by *β* (0.6, 0.7, 0.8 and 0.9).

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Volume 28

Special case is when pole pair number is 1 (Fig. 8).

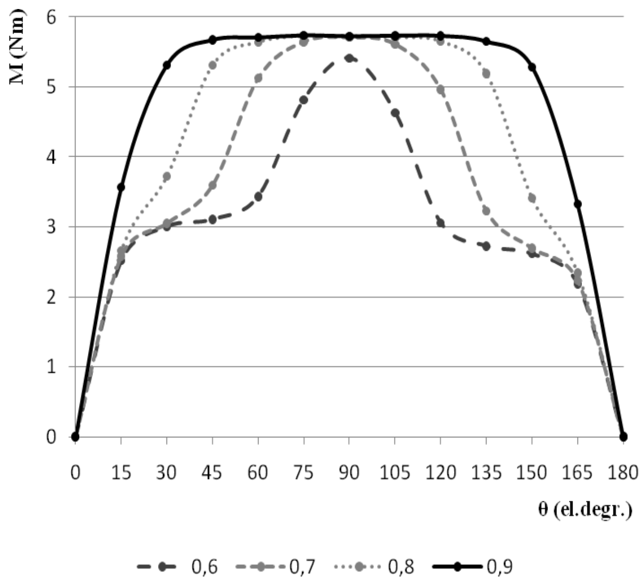


Fig. 8. Curves of mechanical torque for *p* = 1 by *β* (0.6, 0.7, 0.8 and 0.9).

In this case the curve for *β* = 0.9 is very close to the trapeze form. But for *β* = 0.6 the curve of mechanical torque has a mixed function.

These changes can be explained by the length of PMs. As wider is the PM, as longer is the zone of interaction forces between the PMs on both half couplings and thus the mechanical torque has longer (at more turning angles θ) it's maximal value. Also in contraire situation (*β* = 0.6) – as shorter are the PMs, as smaller there is the zone of interaction forces. The magnetization is more tended to corners, then in such geometry, when PM on inner and outer half coupling meets (attracts) with each other by corners, then there is a peak of mechanical torque.

III. POLE PAIR NUMBER AND MAGNETS' WIDTH INFLUENCE ON THE MECHANICAL TORQUE

To easier compare different MCs, is used the maximal value of mechanical torque. In Fig. 9 is given the connexion between the maximal mechanical torque M_{max} and the pole pair number *p* by different coefficients *β*.

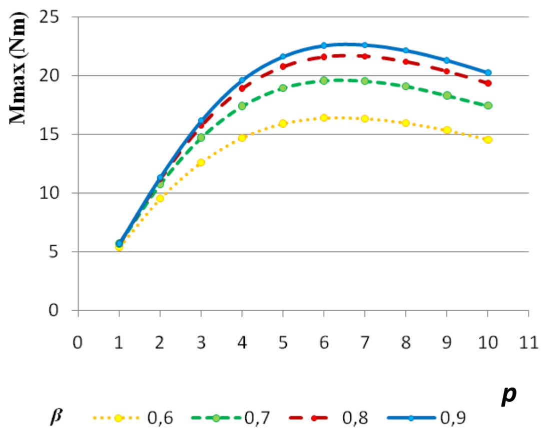


Fig. 9. The relevance $M_{max}=f(p, \beta)$.

The highest maximal mechanical torques are when the coefficient *β* is equal 0.9 and when the pole pair number is *p* is 6 or 7. These two cases – *p* = 6, *p* = 7 – have to be looked up closer.

In Fig. 10 are given the curves for these cases. From this graph the curves are divided into two parts (Fig. 11, a and b).

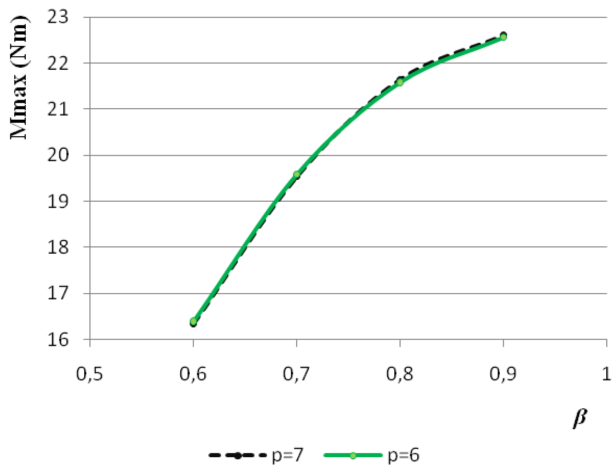
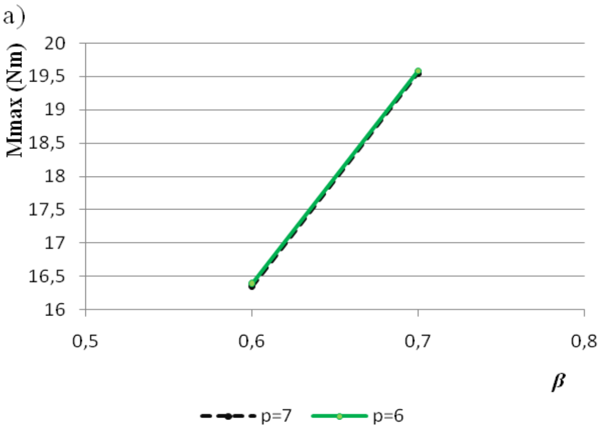


Fig. 10. M_{max} for pole pair numbers p = 6 and p = 7 by coefficient *β*.

a)



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Volume 28

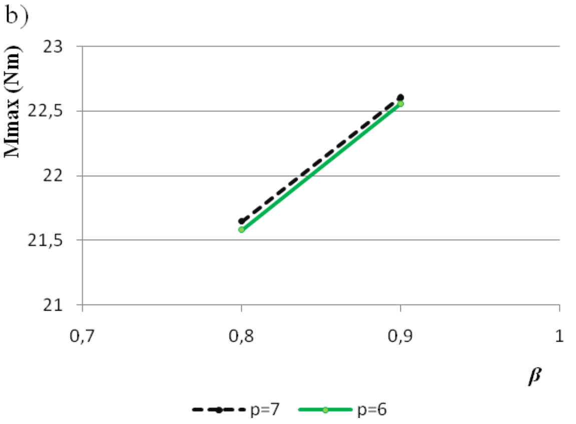

Fig. 11. M_{max} for pole pair numbers p = 6 and p = 7. a) – β = 0.6 , β = 0.7; b) – β = 0.8, β = 0.9.

The maximal mechanical torque for pole pairs numbers 6 and 7 are almost identic. Only in a closer view can see, that at shorter PMs' width (β = 0.6 , β = 0.7) for p = 6 torque is abit higher, but at wider PMs (β = 0.8, β = 0.9) torque is abit higher for p = 7. Generally for these two cases (pole pairs number is 6 and 7) the mechanical torque can assume as identic.

IV. CONCLUSIONS

The PMs width (angle α_{PM}), expressed with proportionality coefficient β, proves that there is an influence on the mechanical torque of MC. As wider are PMs, as higher is mechanical torque of MCs.

It is researched that at wider PMs – higher β – lead the mechanical torque to assume more trapeze form. As smaller there is the pole pair number as more emphatic is the tendency of mechanical torque to assume trapeze form.

Special case is when pole pair number p is one (Fig. 8). Wider PM has longer zone of interaction forces between the PMs on both half couplings and thus the mechanical torque has longer (at more turning angles θ) it's maximal value. Magnetic field has a physical quality – magnetic field is more robust at corners. When the magnets are relatively tight, at meeting of both half couplings' PMs corners, there is a strong attraction which makes the peak value.

The influence of PMs' width (coefficient β) is nonlinear and has its optimum at value β = 0.9 (Fig. 10).

The influence of pole pair number p also is nonlinear (Fig. 9). The calculations give an optimum, which is at two values: p = 6 and p = 7. The mechanical torque for these values can be taken identical. So the best maximal mechanical torque is for MC's construction with β = 0.9 and p = 6 or p = 7 – M_{max}=22.6 (Nm).

REFERENCES

[1] П. С. Сергеев, Н. В. Виноградов и Ф. А. Горяинов, Проектирование электрических машин. Москва: Энергия, 1969.г., 632 с.
[2] QuickField User' Guide version 5.8. Available: http://www.quickfield.com [Accessed: Feb. 10, 2011].
[3] A. Ya. Krasil'nikov and A. A. Krasil'nikov, „Calculation of the torque of a cylindrical magnetic clutch," Khimicheskoe I Neftegazovoe Machinostroenie, No. 3, pp. 8-10, 2009.
[4] L. Jing-fang, H. Choi and M. Walmer, Design of Permanent Magnet Systems Using Finite Element Analysis. Proceeding of 19th International Workshop on Rare Earth Permanent Magnets & Their Applications. Journal of Iron and Steel Research, International, Vol. 13, Sup. 1, I-IV (1-499), pp. 221-230, 2006.

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