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

Baiba Ose, Riga Technical University, Vladislav Pugachov, Institute of Physical Energetics

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 rare earth alloys as neodymium-iron-boron (Nd-Fe-B) or samarium-cobalt (Sm-Co).

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 rare earth alloy Nd-Fe-B (Fig. 2).

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 \( \beta \). The coefficient \( \beta \) is obtained from (1):

\[
\beta = \frac{\alpha_{PM}}{\alpha_{PM} + \alpha_{\delta}},
\]

where \( \alpha_{PM} \) is the PM’s angle with which understand the PM’s width and \( \alpha_{\delta} \) is the angle of airgap between two PMs next to each other (Fig. 3).

The coefficient \( \beta \) is changed from 0.6 to 0.9 with a step equal 0.1.

The dimensions of MC are given in Fig. 4.
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:

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

In (2) $p$ is the pole pair number, $B_{\text{PM}}$ is the residual induction of PM equal 1.28 (T) and $B_{\text{steel}}$ 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].

The influence of pole pairs number $p$ is shown in Fig. 5. As lower is the number $p$, as higher is yoke’s height $h_{\text{yoke}}$. 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 $\beta$ is 0.8 in Fig. 5.

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

![Fig. 4. Dimensions of MC.](image)

**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 $\mu_r = 1.184$.

The airgap is defined as air and its relative permeability is $\mu_{\text{air}}=1$. 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 $R_3$, 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 $\beta$ (0.6, 0.7, 0.8 and 0.9).](image)

![Fig. 7. Curves of mechanical torque for $p = 4$ by $\beta$ (0.6, 0.7, 0.8 and 0.9).](image)
Special case is when pole pair number is 1 (Fig. 8).

In this case the curve for $\beta = 0.9$ is very close to the trapeze form. But for $\beta = 0.6$ 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 $\theta$) it’s maximal value. Also in contraire situation ($\beta = 0.6$) – 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 $M_{\text{max}}$ and the pole pair number $p$ by different coefficients $\beta$.

The highest maximal mechanical torques are when the coefficient $\beta$ 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).
The maximal mechanical torque for pole pairs numbers 6 and 7 are almost identical. Only in a closer view can see, that at shorter PMs’ width ($\beta = 0.6$, $\beta = 0.7$) for $p = 6$ torque is abit higher, but at wider PMs ($\beta = 0.8$, $\beta = 0.9$) 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 $\alpha_{PM}$), expressed with proportionality coefficient $\beta$, 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 $\beta$ – 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 $\theta$) 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 $\beta$) is nonlinear and has its optimum at value $\beta = 0.9$ (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 $\beta = 0.9$ and $p = 6$ or $p = 7$ – $M_{\text{max}} = 22.6$ (Nm).

REFERENCES


B. Ose is a scientific assistant in Institute of Physical Energetics, in Riga. Born 1987. Defended mag.sc.eng. in 2010, in Riga Technical University, Department of Power and Electrical Engineering. Worked in LATVENERGO, BELSS. Now working in Institute of Physical Energetics. Fields of scientific interests: machines with permanent magnets, other permanent magnets’ applications for electro techniques, electrical machines, wind turbines. Aizkraukles street 21, Riga, LV-1006, Latvia. Phone: +371 29177492, e-mail: baiba.ose@gmail.com.

V. Pugachov is Head of Laboratory in Institute of Physical Energetics, dr.habil.sc.eng. Born 1940. Works in Institute of Physical Energetics, Riga. Fields of interests: brushless electrical machines and drives, machines with permanent magnets, permanent magnets for electro technical appliance and medical devices, plastic bonded magnets technology and making. He is author and co-author for more than 200 publications, including 4 scientific books and 50 patents and inventors certificates. Aizkraukles street 21, Riga, LV-1006, Latvia. Phone: +371 7558684, fax: +371 07550839. e-mail: magneton@edi.lv.