Control Load Motors as Electro-Magnetic Indicators

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ABSTRACT: *We have designed a new brake system that use the electromagnetic fields. We have used the control and drives available at a particular lab. For electric motors the created brake is highly adjustable and flexible. We have described the procedures and construction methods. We have identified important electromechanical indicators. We have demonstrated the system and use it for control load motors that record high energy saving.*

Keywords: Electromagnetic Brake, Design, Construction, Calibration

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1. Introduction

This paper presents the procedure of design, construction and calibration of new type of electromagnetic brake. The brake is made as controlled load for electrical motors up to 7.5kW.

2. Design and Construction

The brake has ferromagnetic disc with 8 ferromagnetic poles. Each pole has 690 winds of Cu wire (diameter of 0.95 mm). All conductors are in serial connection. Coils are powered with direct current. The direction of current should provide N-S poles cyclic. Brakes frame has two bearings, and they carry the shaft drive with disc. Between disc and poles is 0,8mm air gap. On the other side, the disc is attached to the motor shaft with footer.

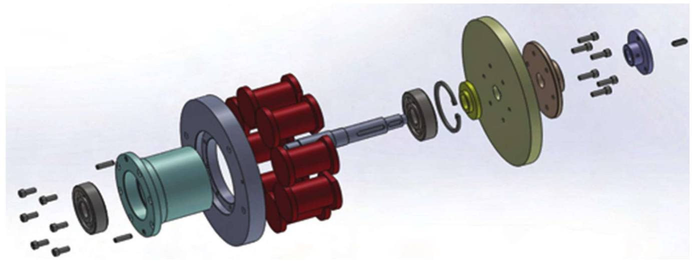

Figure 1. Parts of electromagnetic brake

Work principle: motor rotates disc. Disc is a part of magnetic circuit, also disc moves in a magnetic field. In the disc is induced emf and the current witch creates a braking torque.

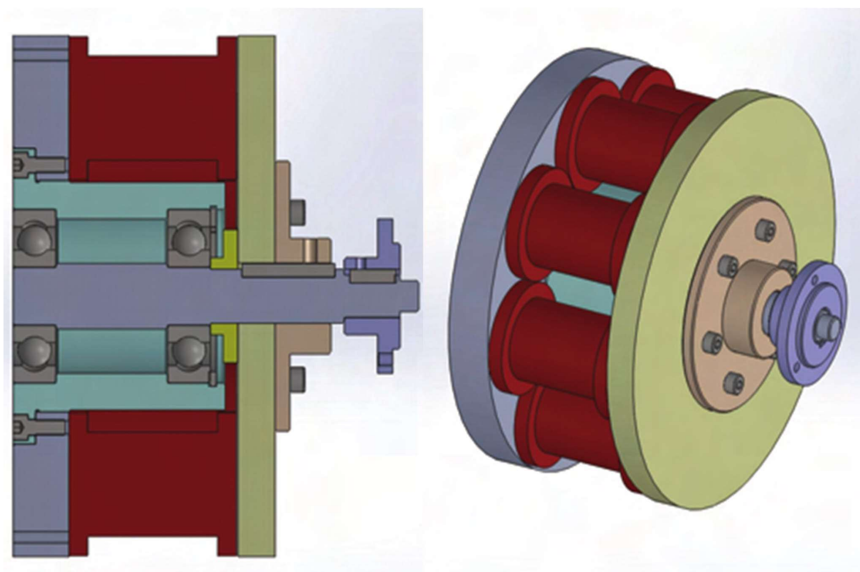

Figure 2. Cross section and complete electromagnetic brake

During design, special attention was paid to the calculation of the axial electromagnetic force. This brakes construction is different from the standard brakes and it creates an unwanted axial force with which poles attract rotating disc [1]. The construction does not contain poles on both sides, and does not have two rotating discs, so the axial forces are not mutually canceled.

For checking of construction parameters, FEM simulation was also performed. Figure 3. shows the approximate distribution of the magnetic field in described magnetic system. For values of excitation current of 0.7 A (maximum current in calibration procedure) the axial force of 8•2.1=16.8kN was achieved.

3. Calibration

Induction motor 2.2 kW, with voltage of 380V was first connected to the brake. Modified equipment and software to determine the energy efficiency class of three-phase induction motors [2] was used. The motor was first in regime no load. Braking current was gradually increased for different values of the terminal voltage up to 7 A. In doing so, important parameters of electric motor are measured, and from them are directly calculated electromagnetic power and torque. Motors load is gradually increased until it stops.

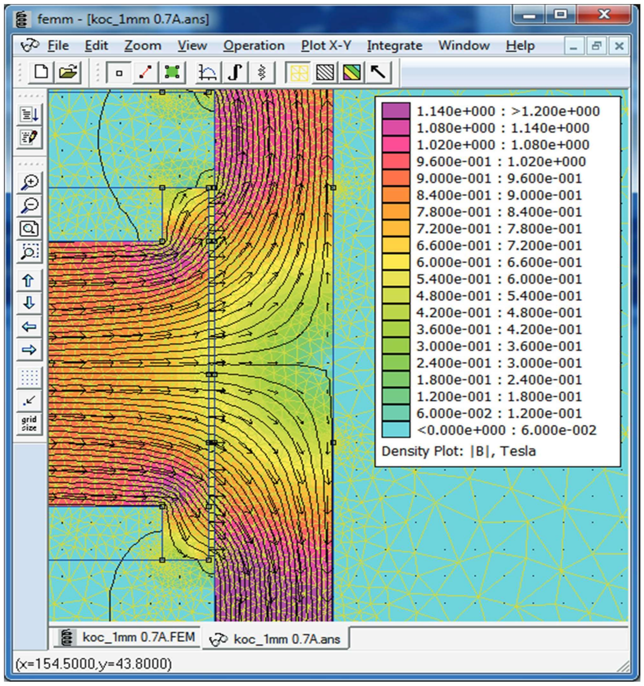

Figure 3. Result of FEM simulation

Figures 4 and 5 show the results of measurements. From the figure can be observed, that the value of the breakdown torque achieved with brake was more than 70 Nm. A maximum power witch is motor achieved is over 6 kW.

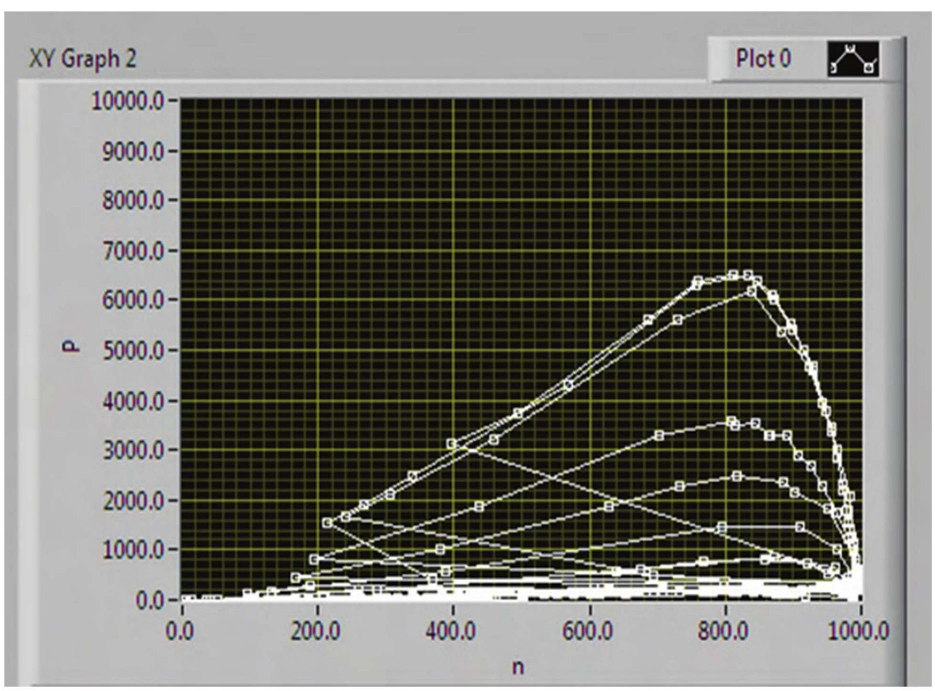

Figure 4. $P = f(n)$, $I_k = 0\text{-}7\mathrm{A}$

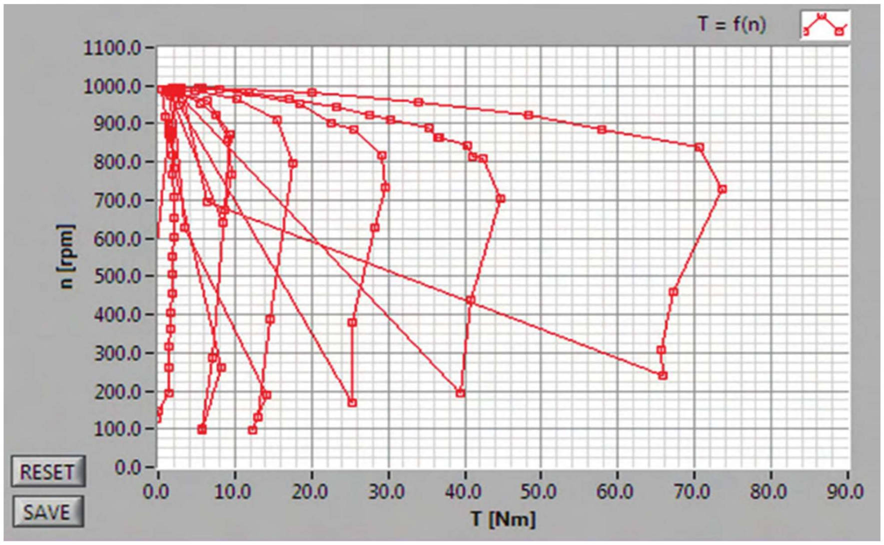

Figure 5. $n = f(T)$, $U = 50\text{-}400$ V, $I_k = 0\text{-}7$A

However, for the calibration of brake DC motor was used.

It has possibility of easier adjustment of mechanical characteristics: with voltage changing and decreasing the excitation current. Two DC motors were selected with powers 1.5 kW and 4.4 kW.

Several measurements were performed with different values of excitation current (up to a maximum nominal value), supply voltage (20V to 120V) and brakes current value from 0.2 A to 0.7 A. The results of the measurement are shown in the graph in Figure 8.

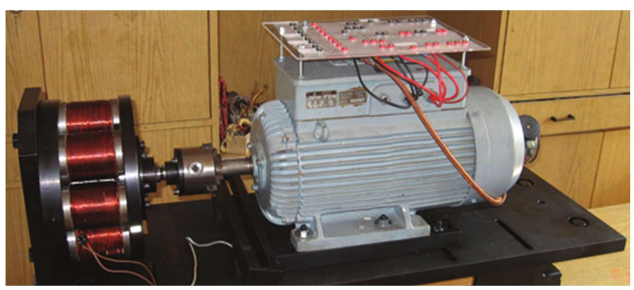

Figure 6. *DC* motor1 $P = 1500$ kW

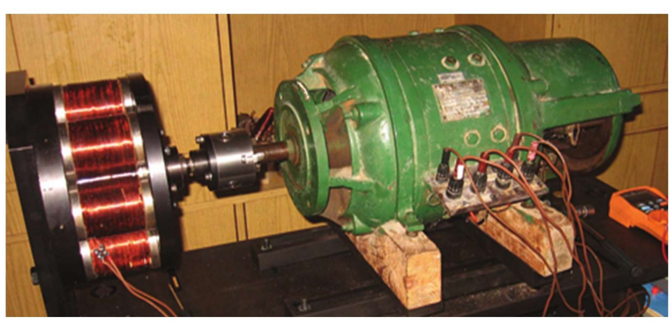

Figure 7. DC motor2 $P = 4400$ kW

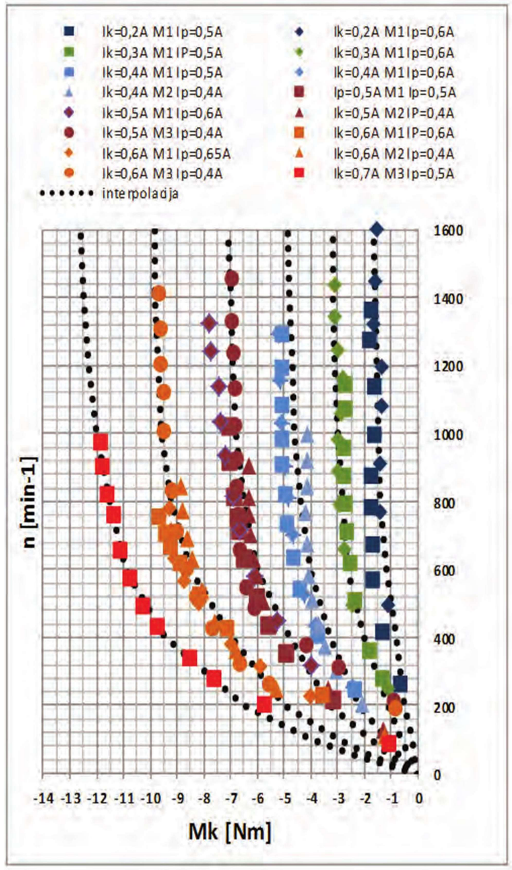

Figure 8. Results of calibration with two DC motors

Motor 2 was adjusted two times for brake testing. That was the reason why these results are specifically separated: mot2 i mot3.

Presented values are with accordance with expected values. Between the measured values the curve was drown and its discrete numerical values are shown in the Table 1.

	M_k [Nm] for I_p=0,2-0,7A					
***n* [min^{-1}]**	**0,2**	**0,3**	**0,4**	**0,5**	**0,6**	**0,7**
0	0	0	0	0	0	0
50	0,12	0,35	0,71	1,06	1,76	2,35
100	0,2	0,6	1,2	1,8	3	4
200	0,5	1,1	2,2	3,3	5	6,5
400	0,8	2	3,3	4,8	7	9,45
600	1,2	2,6	4	6	8,5	10,9
800	1,4	2,8	4,4	6,5	9,2	11,5
1000	1,5	3	4,6	6,8	9,6	12
1200	1,55	3,1	4,7	6,9	9,7	12,3
1400	1,6	3,15	4,8	7	9,8	12,5
1600	1,65	3,2	4,85	7,1	9,8	12,6

Table 1. Braking Torque Values

Shown values, hereafter, will be used to determine the analytical expression of the braking electromagnetic torque as function of braking current and speed.

4. Determination of the Analytical Expression of the Braking Torque

Here was used the MATLAB program and its application **cftool** with interpolation function (1).

$$M_{\mathrm{k}}\left(n\right) = A \cdot \mathrm{e}^{(B \cdot n)} + C \cdot \mathrm{e}^{(\mathrm{D} \cdot n)} \tag{1}$$

With this interpolation function dependence $M(I_k) = f(n)$ can be presented efficiently and with few variables.

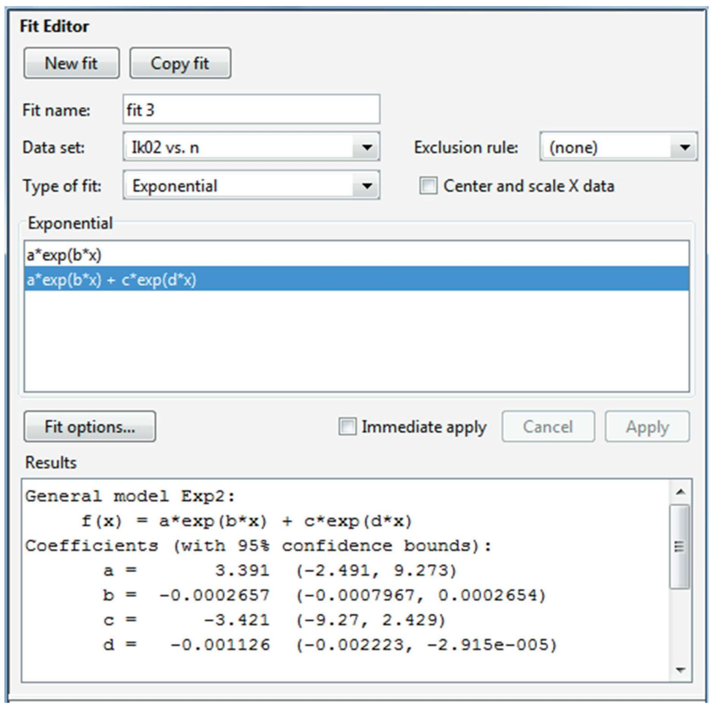

Figure 9. Calculated coefficients A, B, C and D to obtain the interpolation function $M = f(n)$ for $I_k = 0, 2$ A

Figure 9 shows an example of calculated parameters for braking current $I_k = 0, 2$ A.

Coefficients A, B, C and D were obtained for six values of braking current (0, 2; 0, 3; 0, 4; 0, 5 i 0, 6 A).

Thereafter was made a new interpolation of interpolating coefficients with cubic polynomial (2):

$$\mathrm{y} = p_1 \cdot I_{\mathrm{k}}^3 + p_2 \cdot I_{\mathrm{k}}^2 + p_3 \cdot I_{\mathrm{k}} + p_4 \tag{2}$$

All results are presented in matrix form, suitable for programming:

$$\begin{bmatrix} A_1 & B_1 & C_1 & D_1 \\ A_2 & B_2 & C_2 & D_2 \\ A_3 & B_3 & C_3 & D_3 \\ A_4 & B_4 & C_4 & D_4 \end{bmatrix} = \begin{bmatrix} 91,57 & 0,0093 & 86,41 & 0,0452 \\ 148,40 & -0,1440 & -141,20 & 0,0672 \\ -55,52 & 0,0074 & 52,78 & -0,0358 \\ 9,36 & -0,0012 & -9,09 & 0,0037 \end{bmatrix} \tag{3}$$

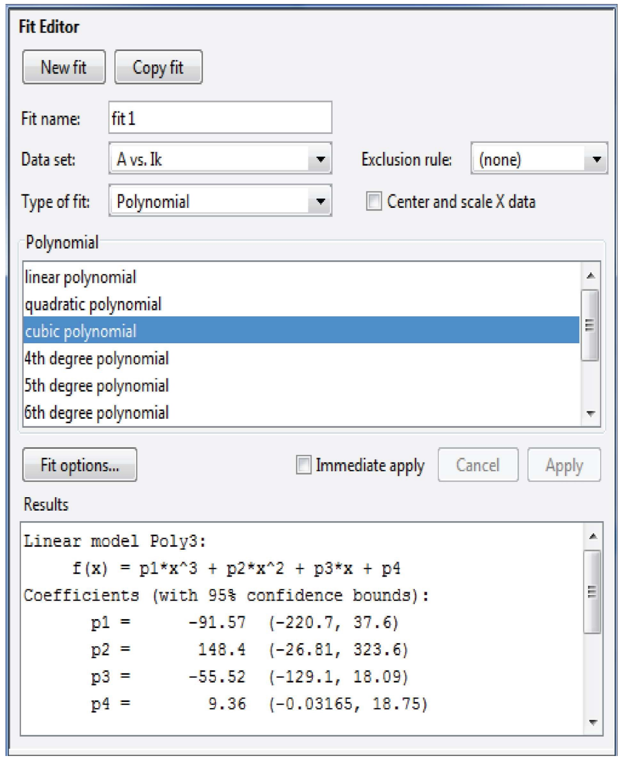

Figure 10. Calculated coefficients of interpolation polynomial for determination of coefficient A

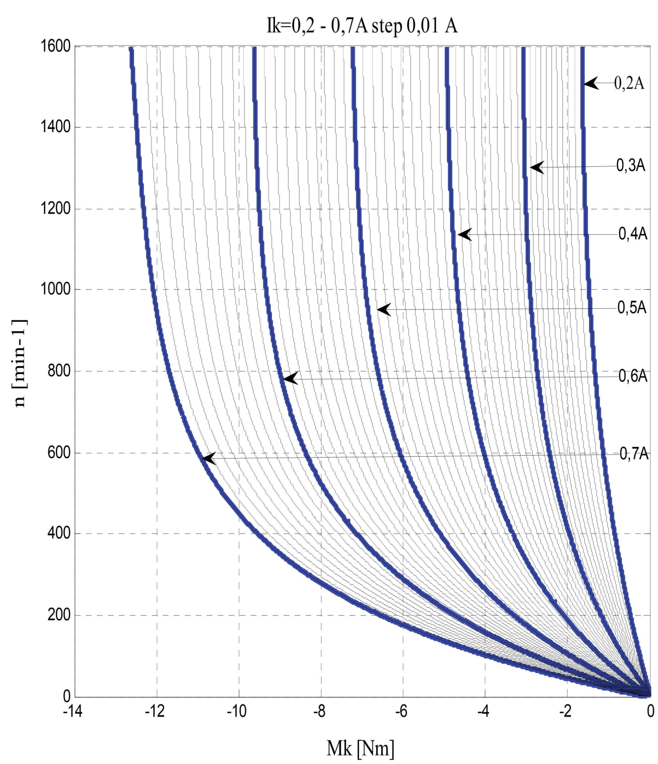

Figure 11. Set of analytical functions that describes electromagnetic torque for speed range of 0-1600 min-1 and braking currents from 0.2 A to 0.7A

$$A = A_1 \cdot I_k^3 + A_2 \cdot I_k^2 + A_3 \cdot I_k + A_4 \quad (4)$$

$$B = B_1 \cdot I_k^3 + B_2 \cdot I_k^2 + B_3 \cdot I_k + B_4 \quad (5)$$

$$C = C_1 \cdot I_k^3 + C_2 \cdot I_k^2 + C_3 \cdot I_k + C_4 \quad (6)$$

$$D = D_1 \cdot I_k^3 + D_2 \cdot I_k^2 + D_3 \cdot I_k + D_4 \quad (7)$$

The obtained results are shown in Figure 11. The figure shows set of analytical functions of electromagnetic braking torque as function of speed n and braking current I_k. Speed and braking current at some point define the braking electromagnetic torque at that point.

5. Future Steps

With described procedure it is possible to calculate the braking torque using the derived analytical expressions.

This means that the motor load (torque) can be determined, at any moment, if current values of only two parameters are known: speed of rotation and braking current.

The aim of further research can be introduced in this way: First, predefine motor load type: gravitational (constant load), fan or some other (variable load). Then, using feedback and new derived expression of required torque, braking current will be calculated considering the speed. By applying this current to the brake, motor will get the appropriate load.

6. Conclusion

This paper describes the process of design, construction and calibration of electromagnetic brake. The analytical expression of braking torque was derived, considering speed of rotation and braking current.

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