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RADIAL LOADS IN BEARINGS OF THE OPTIMISED ELECROMOTOR

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ABSTRACT
The paper analyses radial loads in bearings of the standard T80 asynchronous electromotor depending on the rotor assembling position and on the variation of temperature.
The mathematic model of the motor is elaborated in detail, taking into consideration the influence of mechanical, electric, magnetic and thermal quantities.
The adopted model is analysed for existing dimensions and for the dimensions after optimization of the rotor and stator.
The results for the electromotor model are encouraging and present a good base for modification in the design of the electromotor and bearing design as well.
Key words: Electromotor, Stator, Rotor, Rotating Shaft, Deflection, Stress, Critical Number of Rotations, Radial Loads in Bearings

1. INTRODUCTION
The electric drivers have many advantages and are more often used comparing to other prime movers as diesel engines, petrol engines, steam turbines and engines, gas turbines and hydraulic motors.
The electromotor is a part of a machine which converts electrical energy to mechanical energy and always presents a "challenge" for an engineer - constructor during analysis and its design process.
The paper analyses radial loads in bearings of the standards T80 three-phases-asynchronous electromotor depending on the rotor assembling position and on the variation of cooling temperature.
The radial loads in both bearings at A and B are calculated taking into consideration weight of rotor's package, driving and rotating force, eccentricity, cooling temperature and as well as influence of magnetic force [1,2,3,4,5].
The rotating shaft deflection, eccentricity and critical number of rotations as very important quantities of the electromotor were also calculated [1,2,3,4,5].
The analyses for adopted model were carried on taking into consideration the dimensions before and after optimization of the electromotor. Comparison of the results is satisfactory and presents a good starting point for modification in the design of the electromotor and its bearings..

2. MECHANICAL AND MATHEMATICAL MODEL
The electromotor has two main components: the stator and the rotor. The stator is static part of the motor containing a set of windings that establish a rotating magnetic field in the gap between the stator and the rotor, which presents the rotating part inside the stator.
The electromotor as an engineering system or machine is described by set of quantities some of which are usually fixed and called parameters. All the other quantities are treated as variables in the design

process. Its mathematical model formulates relations between the specified quantities - parameters and diameters of stator and rotor adopted as variables. Based on the stator/rotor dimensions an optimization model to find optimal diameters for minimal value of the lamina's surface of stator and rotor as subject to certain equality and inequality constraints has been elaborated in [4,6,7,8].
The rotor's shaft is subjected to bending, tension, torsion, temperature influence and magnetic forces acting in combination with one another. When they are combined, both static and fatigue strength are to be important design considerations, since shaft may be subjected to static stresses, completely reversed stresses and repeated stresses, all acting at the same time. Either the lateral or the torsion deflection of the rotor's shaft must be held to close limits, it should be made stiff enough so that the overall deflection is less than 10% of air gap between stator and rotor to enable a proper rotating magnetic field. Also, critical number of rotations needs to be at least 30% greater than rotation number and maximum stresses must be less than 70% of the allowed.
The adopted mechanical model for the rotating shaft with rotor package on it is given in Figure 1. where the position of the rotors package is changeable within limits allowed by length L_3.

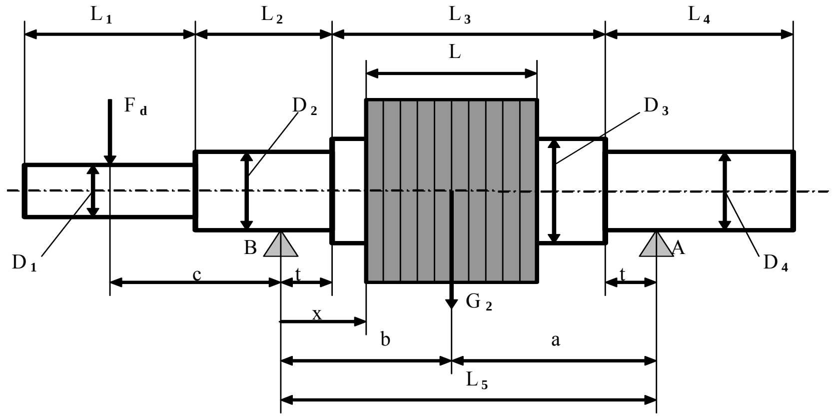

Figure 1. Model of the rotating shaft with rotor package

Position of the rotor package assembling on the rotating shaft is given by variable ***x*** representing a distance from the left bearing B to the to rotors package, Figure 1. Based on the geometrical and constructive constraints the variable

$$\boldsymbol{x} \in [t, (L_5 - L - t)] \qquad b = x + \frac{L}{2};\ a = L_5 - b; \tag{1}$$

Overall deflection of the rotor's shaft at a point in distance x from point B is calculated:

$$f = f_w + f_d + f_m [mm] \tag{2}$$

Deflection subjected to the weight of rotor package, to the driving force and magnetic force are in details elaborated at [1,2,3,4]. Eccentricity, critical number of rotations and stresses are calculated by:

$$e_o = k\delta + f_w + f_d,\ n_{cr} = 950 \cdot \sqrt{\frac{e_o - f_o}{e_o \cdot (f_w + f_b)}} [rot/\min]; \sigma = \frac{\sqrt{M_b^2 + M_t^2}}{W} \cdot 10^9 [Pa]; \tag{3}$$

Radial forces in bearings A and B are calculated [4,5]:

$$R_A = (G_2 + T_O) \cdot \frac{b}{L} + F_d \cdot \frac{c}{L} [N];\ R_A = (G_2 + T_O) \cdot \frac{a}{L} + F_d \cdot \frac{L + c}{L} [N] \tag{4}$$

The normal temperature of the cooling air, so called environment temperature is 40^o C. Increasing the temperature brings to decrease of the working power of the electromotor. If temperature increases for 10^o C, rising at 50^o C then power of will be 90% of nominal one. The average temperature of the air inside the electromotor is calculated [5]:

$$\theta_v = \frac{\sum P^{'}}{S_m} \tag{5}$$

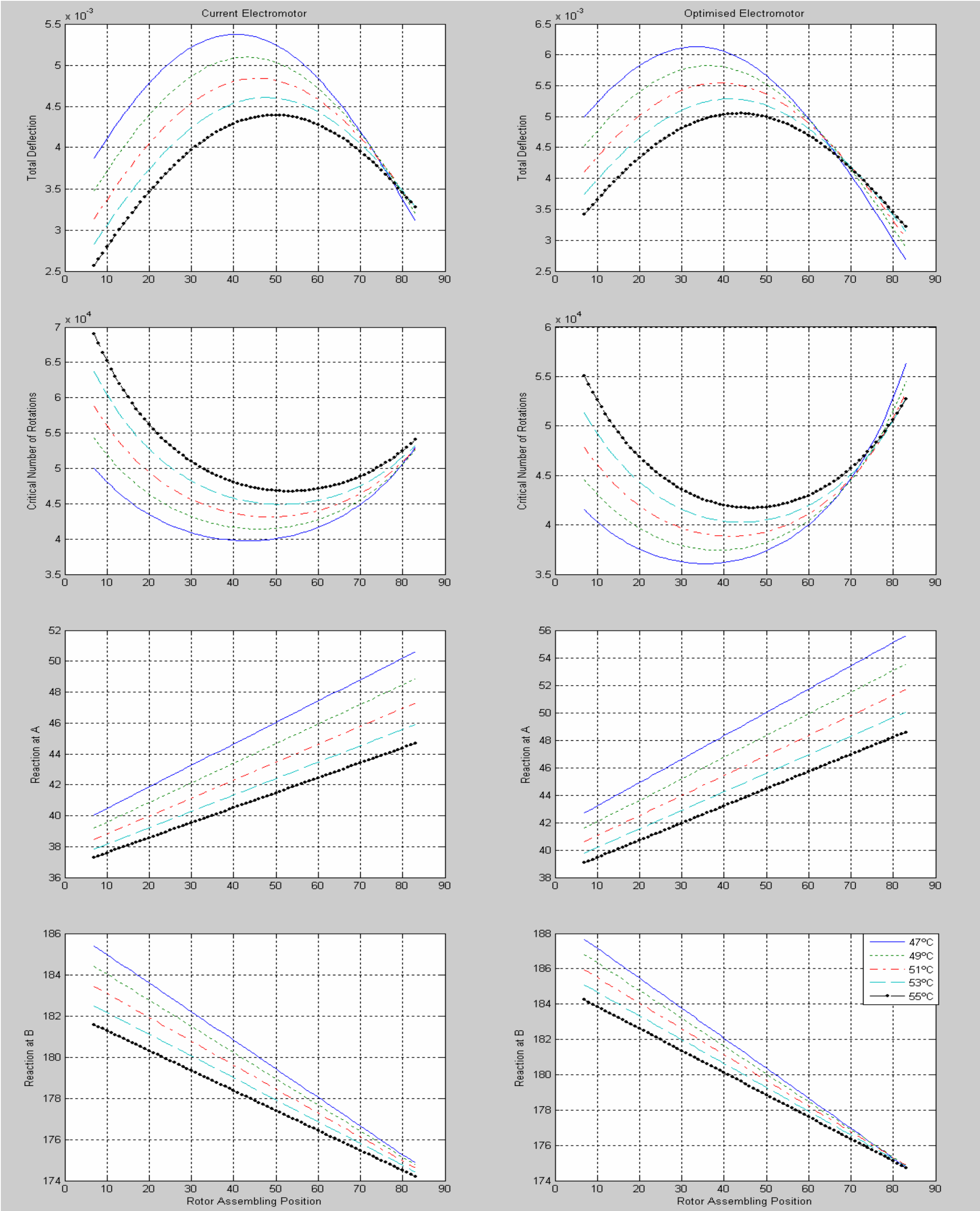

Figure 2. Results for the current and for the optimized electromotor

Where, $\Sigma P'$ [W] is overall power under normal temperature and S_m [mm^2] expresses conditions for cooling the motor and both are functions of geometrical, electric and mechanic parameters, calculated or to be read in tables or graphics. Calculated temperatures for current and optimal motor are given in *Table 1*.

From technical documentation for the adopted motor following values for specified quantities are read: power, P=0.55kW; rotation number, n=1400rot/min; exploitation coefficient, η=0.72; power factor, cosφ=0.73; modulus of elasticity E=200GPa; δ=0.25mm;… [1,2,3,4].

The deflections, critical number of rotations, eccentricity and stresses are calculated for both current diameters and optimal ones, *Table 1*. The results are graphically presented in *Figure 2*.

Table 1. Deflections, critical number of rotations and temperature

	D21	D3=D22	fw	fd	fm	f	ncr	θ
	mm	mm	mm	mm	mm	mm	Rot/min	°C
Current	70	25	4.41E-04	0.0022	0.0025	0.0052	4.08E+04	47.6
Optimal	66.64	24.23	4.46E-04	0.0025	0.0027	0.0057	4.02E+04	54
						<	>	
						0.1*0.25	1.3*1400	
						0.025	1820	

3. CONCLUSIONS

- Deflections, critical number of rotations and stresses are within limits, proving that optimal solution is acceptable and satisfactory;
- Cooling temperature in motor is higher for optimal solution because conditions for cooling are smaller, indicating that it is needed to add laminas in order to keep the same technology;
- Deflection and eccentricity (*Table 1, Figure 2*) have greater values at optimal electromotor and smaller values for critical number of rotations, but still within allowed limits;
- Higher cooling temperature decreases nominal power of the electromotor;
- Radial loads in bearings (RA and RB) increase for smaller cooling temperature, and their values are higher for optimized electromotor at the same temperature (*Figure 2*)

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