MAGNETIC CIRCUIT ADJUSTMENT OF DC MOTOR

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Abstract: This paper describes magnetic circuit adjustment of direct current motor by finite element method (FEM). The main purpose of this work is to design a new rotor packet which enables machine-making winding. This adjustment is necessary to improve series manufacture thus decrease economic cost of its production.

Keywords: FEM, DC motor, rotor slots

1. INTRODUCTION

Serial production of the certain type DC motor is not very economically efficient due to hand making rotor winding. Company´s new production technology enables machine-made winding. Unfortunately, this technology is not possible to apply on this type of rotor. This absence leads us to submission of this work. Company´s requirement is design of a new rotor which can by use for machine-made winding.

The best way to meet this requirement is expanding rotor slots from originally twelve to sixteen.

Original twelve-slots motor has been constructed for its specific applications. Therefore, the new sixteen slots motor has to have same proportions as the original one. In this way, the whole submission of this project is design of a new sixteen slots motor with same proportions and approximately same working characteristics as the original twelve-slots.

According to submission of the project, a new magnetic circuit of the machine is needed to design. Hence the FEM is used as a tool for magnetic solutions.

This paper was made in cooperation with Atas Elektromotry Náchod Company as a part of the project: "Analysis and modeling of low voltage motor".

Power	200W	**Direction**	both
Voltage	24V	**Duty**	S1
Current	10,5A	**Design**	IP 54
Rpm	3000 min^{-1}	**Weight**	3,3 kg

Table 1: Nominal values of the original machine

Figure 1: Direct current motor made by Atas

2. PARAMETRES OF THE ORIGINAL MACHINE

The original machine is direct current motor with ferrite permanent magnets on stator. Nominal values are shown in table 1.

2.1. WINDING PARAMETERS

This motor has two magnetic poles. The stator winding is loop type inserted in two layers. Each layer contains two coil sides and every coil has five ampere-turns. Total number of wires in one slot is twenty with its stacking factor 0.35. Commutator has twenty-four lamellas. Winding diagram is showed on figure 4.

2.2. MECHANICAL CHARACTERISTICS OF THE MACHINE

The new sixteen slots machine has to have approximately same characteristic (±5%) as the original one. Therefore, an accurate working characteristic measuring of the original machine was made (figure 2).These characteristic will be consequently compared with characteristic of the new machine as the final result.

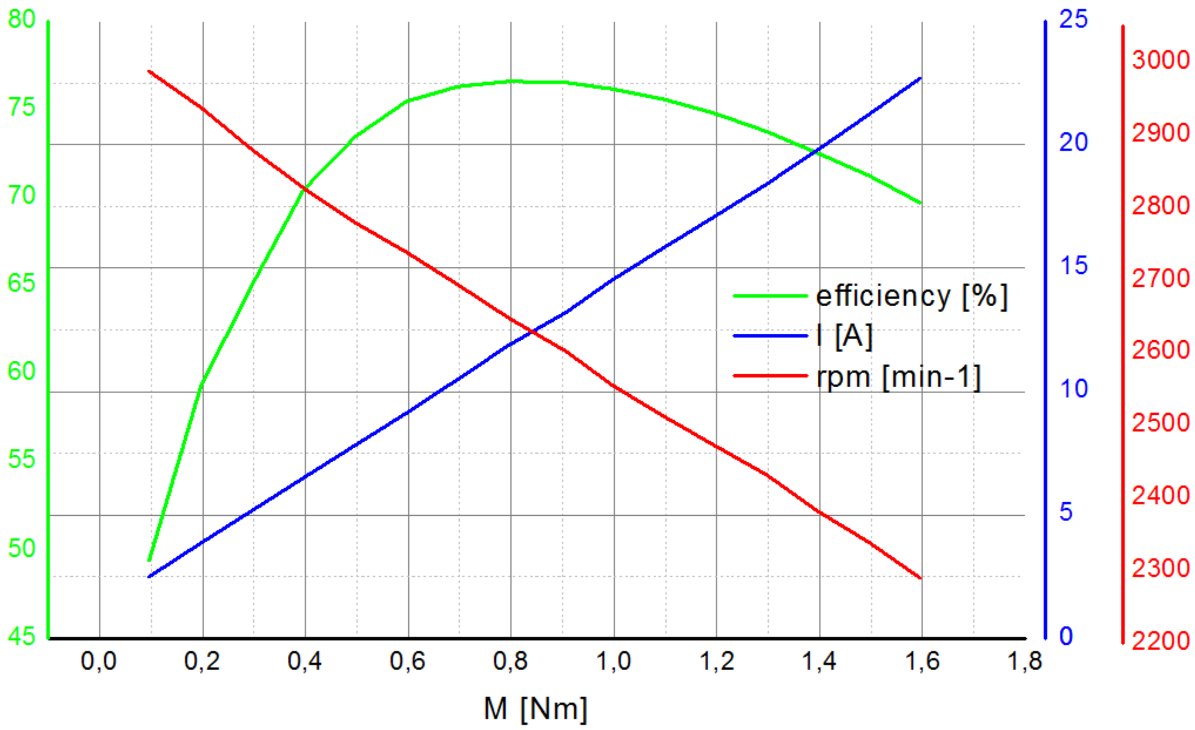

Figure 2: Load characteristic of original motor

3. MAGNETIC FIELD SIMULATION

As mentioned, the new magnetic circuit was designed by FEM. Simulations were made on 2D model cross section. According to low demands of the 2D model, FEMM 4.2 was used as a sufficient program for these magnetic FEM simulations.

Conformably to Atas design documentation, the 2D model of the original twelve-slot motor was drawn. This model was converted to a dwg.* format and imported to FEMM. According to all FEM simulation requirements, the initial conditions and materials property had to be modified.

Each material property was added to appropriate part of the machine model (including of ambient air). For fulfillment of the initial conditions, the magnitude of armature current with appropriate direction in each coil wire had to be set up. Hence it was necessary to know winding connection and commutation properties (figure 4). The armature current magnitude was chosen for its nominal value (I_n=10,5A).

For starting the solution was necessary to generate mesh of the model. Due to solution accuracy demands, the mesh was generated with the biggest possible element number.

After completing these conditions, it was possible to start the solution process. The results of this simulation are magnetic density and electric field intensity. Obtained results of magnetic density distribution of the twelve-slots machine are shown in figure 7.

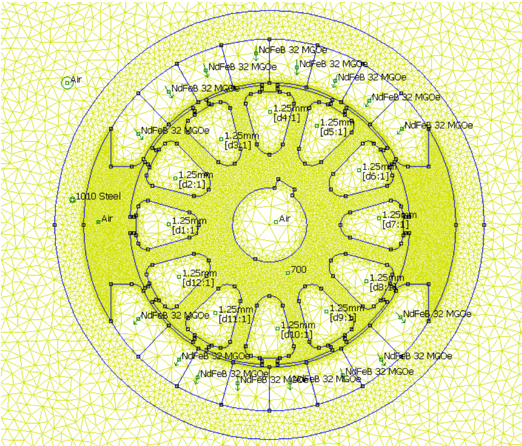

Figure 3: Final model of the machine imported in FEMM.

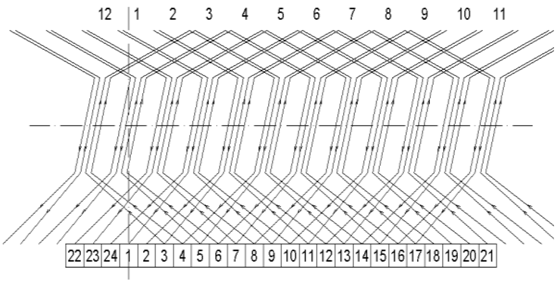

Figure 4: Winding conection

On the basis of these simulated values, the inner torque, magnetic flux and consequently inducted voltage characteristics were computed. For the computing of these characteristic, programmer's script Lua was used. This script is possible to implement in FEMM.

Results of the sixteen-slot machine were obtained on the basis of the twelve-slot machine. As mentioned earlier, the new sixteen-slots machine has to have approximately same parameters as the original. Therefore, the new slot shape was designed by the experimental method, where every new designed shape was compared with the original. During this design had to be considered magnetic saturation in slot teeth.

The final rotor shape design with its magnetic density is displayed on figure 7.

4. COMPARITON OF SIMULATED RESULDS.

The magnetic fluxes characteristic were obtained by FEMM simulation while using Lua programmer´s scrip. Inducted voltage behaviors were consequently calculated by the simple equation (1).

$$U_i = \frac{d\phi}{dt} \tag{1}$$

Where U_i - inducted voltage in one ampere turn [V]; Φ – magnetic flux [Wb]; t – time [s]

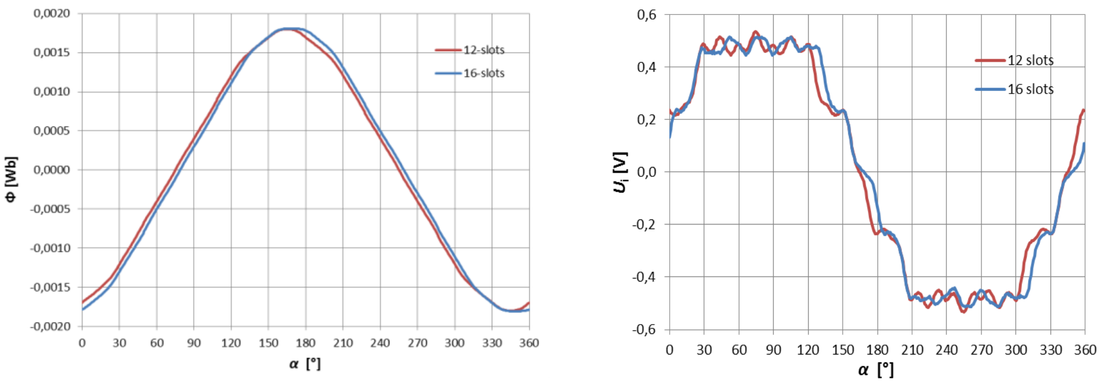

Figure 5: Comparison of the magnetic fluxes and inducted voltage in one ampere turn of the both motors

4.1. MAGNETIC DENSITY SIMULATION

Obtained results of the magnetic flux density of the both motors have approximately same magnitude. The maximum rotor flux density of the new 16-slots motor is 1.52 T (figure 7). This value is still below the magnetic saturation of the used material.

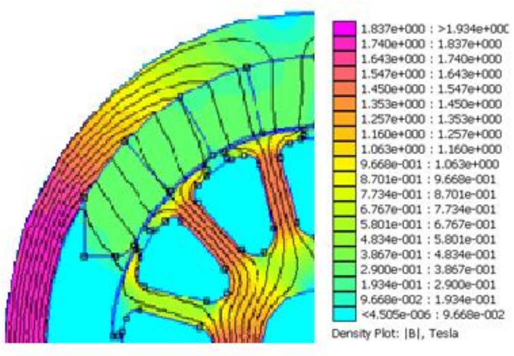

Figure 6: Magnetic flux density of 12-slots motor

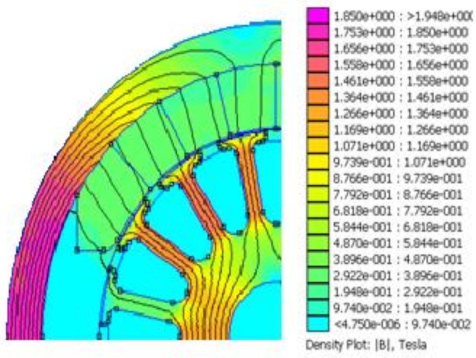

Figure 7: Magnetic flux density of 12-slots motor

4.2. SIMULATION OF INNER TORQUE BY FEMM:

Inner toque was simulated at its nominal value (In=10,5A) for both machines. Resulted value of 12-slots motor is Mv_{12}= 0,731 N.m. This value is coresponding with mechanical characteristic displayed in figure 2. Inner torque simulation result of the new machine is Mv_{16}= 0,744 N.m, thus it is only 1,8% difference between these torques.

4.3. COMPARISON OF SLOTS AND WINDING PROPERTIES

By the change of the slots number, the winding properties were also changed. Parameter´s differences of this adjustment are showed in table 2. The new 16-slots motor has bigger losses due to bigger length of winding wires. Difference (2,75W) is still suitable for company´s requirements.

	Original 12-slots	New 16-slots
Slot area	78,1 mm^2	56,7 mm^2
Number of conductors	20	16
Wire gauge	1,25 mm^2	1,25 mm^2
Stacking factor	0,32	0,35
Copper losses (I=10,5 A)	11,03 W	13,78 W
Winding resistance	0,4 Ω	0,5 Ω
No. of comutator lamelas	24	32

Table 2: Slots properties

5. CONCLUSION

According to submission of this project, the new sixteen-slots magnetic circuit was designed. The simulated characteristics of the magnetic flux and inducted voltage are almost the same as the original (figure 5.). For obtaining these results, the new winding and comutator were also proposed. Their properties are showed in table 2. As is displayed on the figures 6, the magnetic density distributions have approximately same magnitudes in the each parts of the model. The maximum flux density in the new rotor is 1.52 T. Therefore the new magnetic circuit is below saturation area. Thus the new motor can be made by the same material as the original (M700-50A).

On the basis of these results, the accurate drawing of the rotor packet was made. This drawing was send back to Atas Company to make a fist motor sample. Unfortunately, this sample has not been made yet, therefore we cannot show mechanical characteristic as the final result. If these final results be successful, we would like to continue in the innovation of this motor by improving efficiency by replacing ferrite magnets with a rare earth magnet.

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