FEM ANALYSIS ON A METHOD FOR POSITIONING OF THE BRUSHES ON NEUTRAL LINE AT D.C. MACHINES

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Abstract: *A new method for positioning of the brushes on the geometric neutral axis was elaborated for the motors used in electric traction. It involves the sole feeding of the armature and auxiliary pole windings with D.C. current. The justification of this new method using FEM analysis represents the main goal of this paper. The study starts from a real machine with known parameters then, by using a software package based on finite element method (Flux 2D), the electromagnetic torque corresponding to different situations is calculated. The proper position of the brushes corresponds to neutral line and coincides with a zero value of the developed electromagnetic torque.*

1. INTRODUCTION

In [1] is analytically justified the fact that the sole D.C. feeding of the armature and auxiliary pole windings gives a zero value electromagnetic torque only if the brushes are placed on the neutral line. On the basis of these results a new practical method for positioning of the brush rocker was elaborated. After the feeding of the two windings, which are series connected, the brush rocker has to be rotated until the rotor stands still. As a matter of fact, it operates the following rule: if the rotor rotates, for example, "forward" then the brush rocker has to be rotated "backward" until the rotor becomes motionless. This situation is obtained when the developed electromagnetic torque is null, that is when the brushes are positioned in the neutral axis. During this test, an important current (close to its rated value) flow through the two windings, this fact having a beneficent effect on the precision of the method [2-4].

This method has been used successfully at RATP Iaşi.

As follows, a study of this method with a software package based on finite element method will be presented [5].

2. THE PARAMETERS OF THE D.C. MACHINE, THE GEOMETRY, ELECTROMAGNETIC FIELD ANALYSIS

The rated values of the machine are: $P_N = 1.4kW$; $U_N = 220V$; $I_N = 7.5A$; $U_{eN} = 190V$; $I_{eN} = 0.5A$; $n_N = 1500$ rot/min. The armature has wave winding with $Z_e = K = 81$ (elementary slots and commutator segments respectively); $u = 3$ ($Z_c = 27$ – physical slot number); $a = 1$; $2p = 4$; $y = (K-1)/p = 40$; $y_1 = 20$; $y_2 = -20$. A detail of the armature winding is presented in Fig. 1.

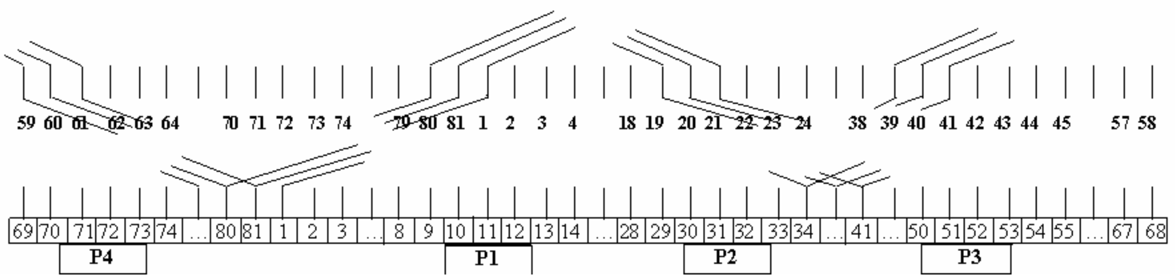
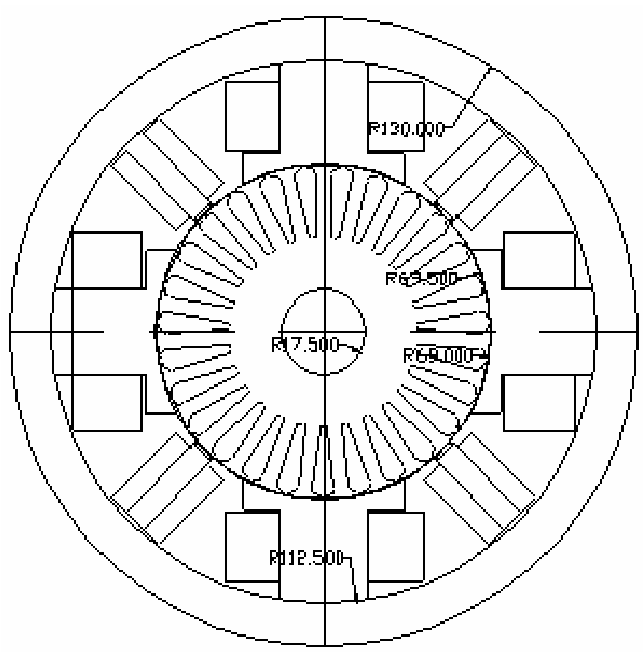
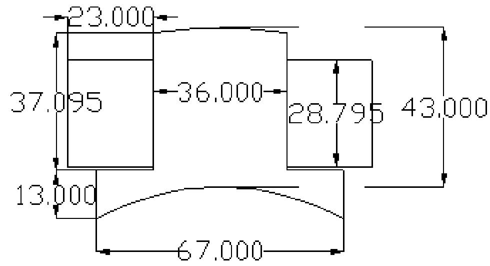


Fig. 1 – Armature winding

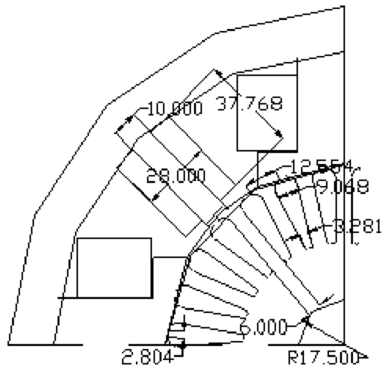
The geometrical parameters that describe the motor model are presented in Fig. 2.



a. General view



b. Main pole detail

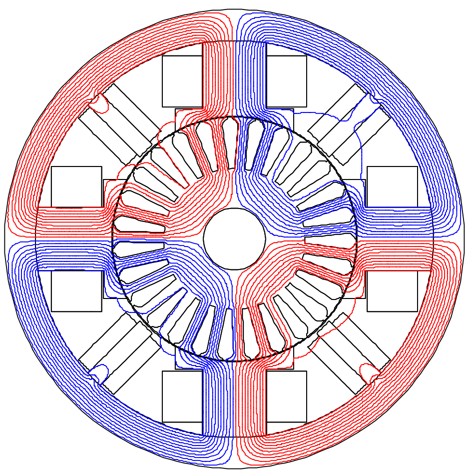


c. Auxiliary pole and rotor details

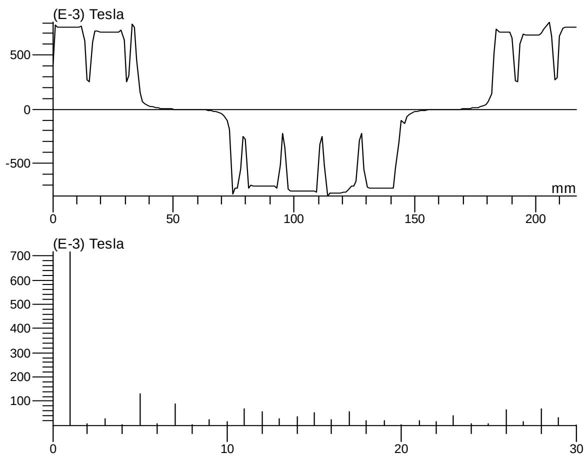
Fig. 2 – Geometrical parameters

The FEM analysis involved a magnetostatic solving process for different feeding situations. We were interested mostly in flux lines distribution, flux density curves including a Fourier analysis with the content in high order harmonics and the torque value that acts upon the rotor.

Fig. 3 presents the results obtained for a sole feeding of the excitation winding with rated current (excitation current density of 0.75 A/mm^2).



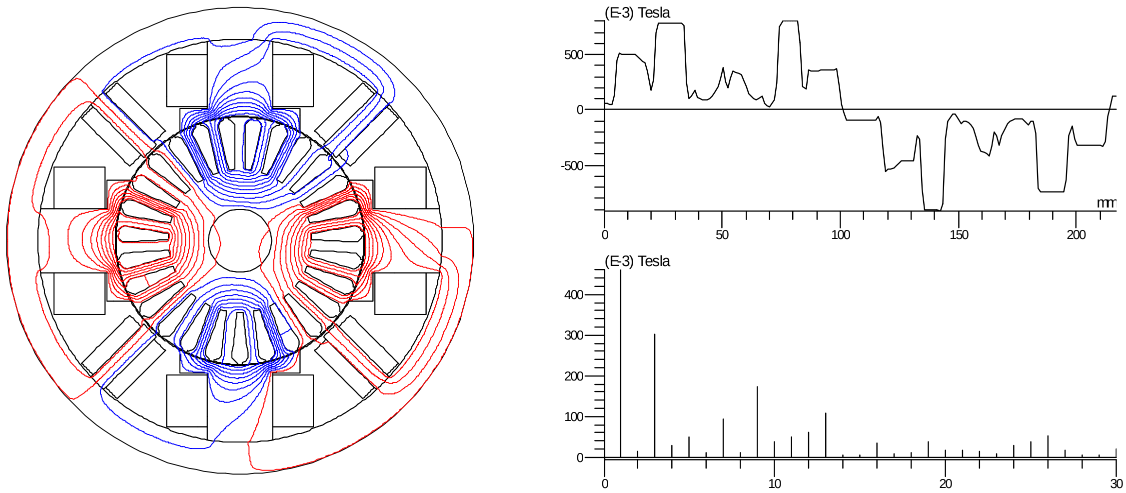
a. Flux lines distribution



b. Air-gap flux density

Fig. 3 – Feeding of the excitation winding

In Fig. 4 the results correspond to the situation when the current flows only through armature winding. Practically it is the armature reaction.

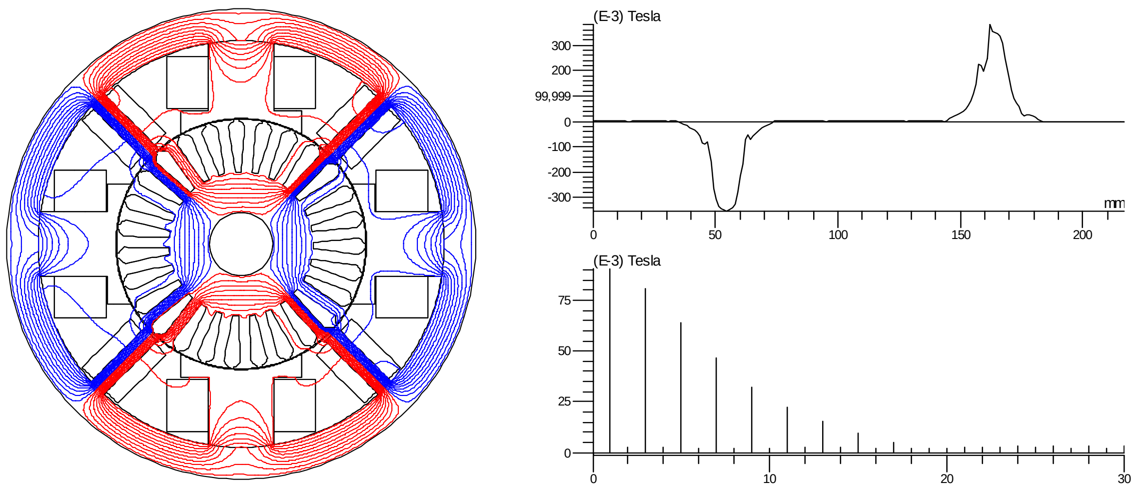


a. Flux lines distribution b. Air-gap flux density

Fig. 4 – Feeding of the armature winding

If we compare the results obtained for the two presented cases we notice that the fundamental created by the excitation winding has amplitude of 0.7 T (Fig. 3b) and the armature reaction "develop" a fundamental of only 0.46 T. Has also to be specified that all the analyses take into consideration an armature current density of 1 A/mm^2 (which corresponds to rated current of 7.5 A) and an auxiliary pole current density of 1.5 A/mm^2.

Fig. 5 shows the flux lines distribution and the air-gap corresponding to the case when the current flows only through auxiliary pole winding. The value of the flux density on the neutral line is of 0.35 T and the curve has an important content in high order harmonics.

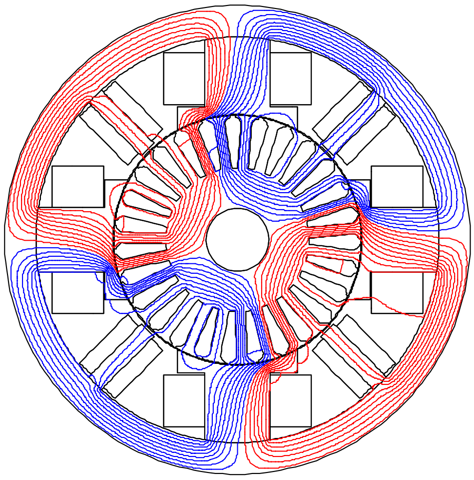


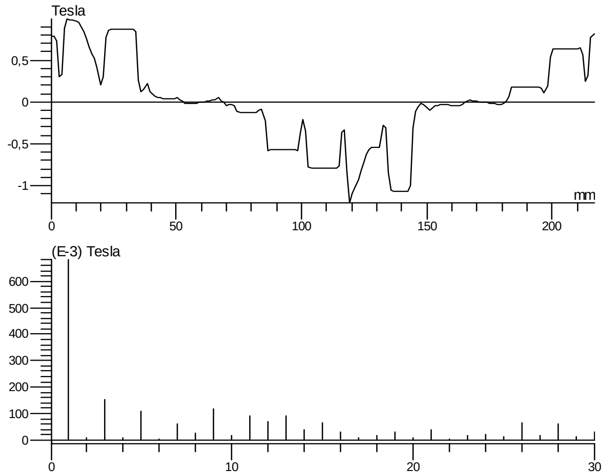
a. Flux lines distribution b. Air-gap flux density

Fig. 5 – Current in auxiliary winding

Fig. 6 presents the flux lines distribution for the case when the currents flow both through excitation and armature windings (auxiliary pole winding is free of current). A significant distortion of the magnetic field mainly under the excitation poles is noticeable. Also, it can be seen the important magnetic field located on "neutral" position, which has a negative effect upon commutation.

In Fig. 7 is finally presented the case of complete "load" of all the D.C. machine windings. Has to be pointed out the compensation effect played by the auxiliary poles. As result, the flux density value decreases close to zero on the neutral axis. As regards the fundamental





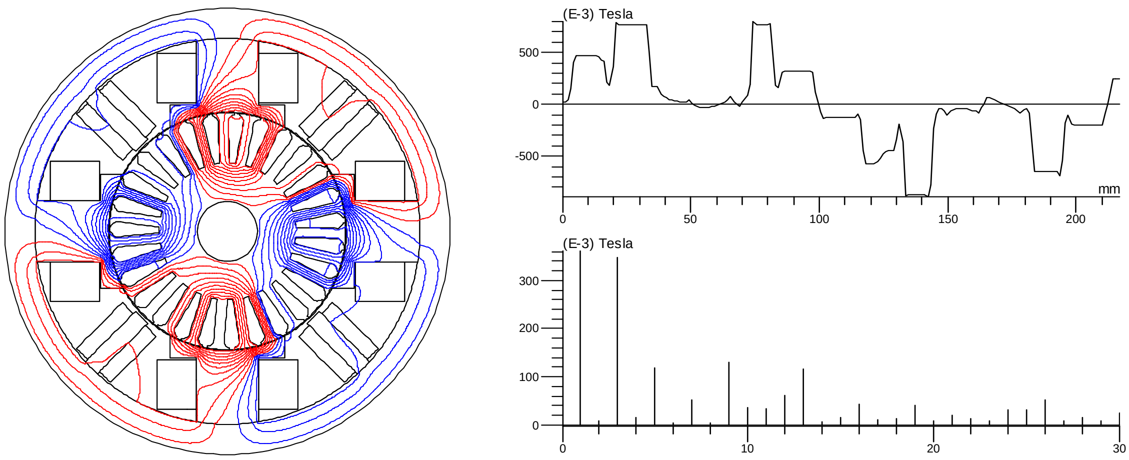
value of the air-gap flux density, there is a very small decrease (0.7 T to 0.68 T).

Fig. 6 – Current in excitation and armature windings

Fig. 7 – Current in excitation, armature and auxiliary pole windings

The following results present a magnetic field analysis when only the armature and auxiliary pole windings are energized (there is no excitation current). The goal is to justify the proposed method for positioning the brushes on neutral axis.

Fig. 8 to Fig 13 present six consecutive sequences in feeding the armature winding. They represent a total angle which corresponds to rotor tooth pitch. The difference between each sequence is equivalent to a rotation of the brushes with 2.22°.

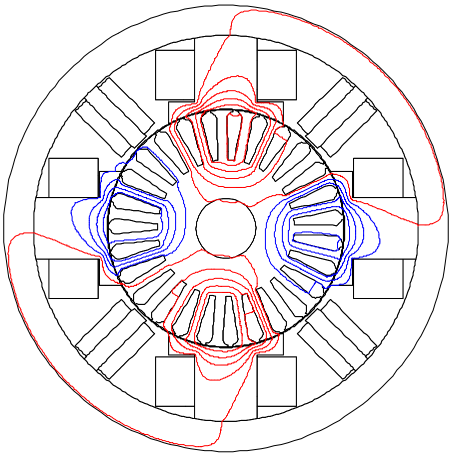


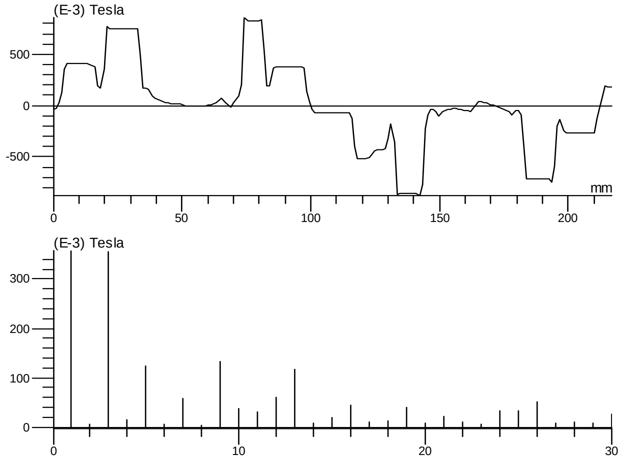
a. Flux lines distribution

b. Air-gap flux density

Fig. 8 – Reference angle α = -5.26°

The results prove a reduced alteration of the magnetic field and developed electromagnetic torques that vary proportionally with the rotation angle of the brushes. This fact allows the possibility to establish with high accuracy the position of the brushes that correspond to a zero value of the torque.

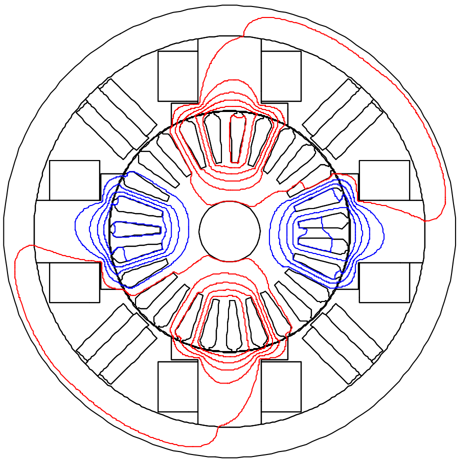


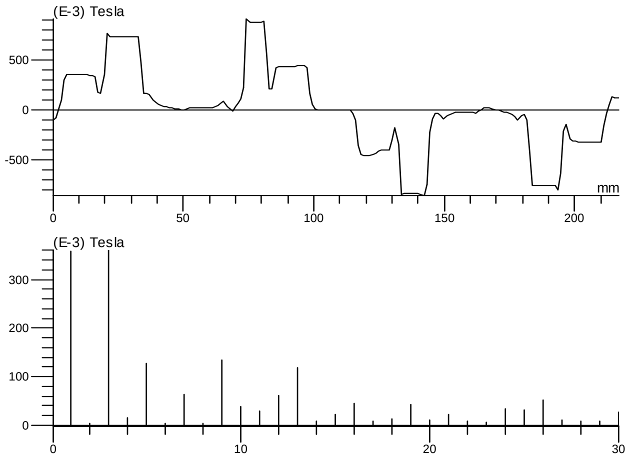


a. Flux lines distribution

b. Air-gap flux density

Fig. 9 – Reference angle α = -3.04°

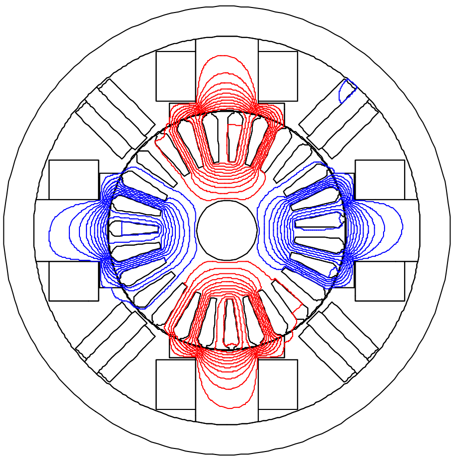




a. Flux lines distribution

b. Air-gap flux density

Fig. 10 – Reference angle α = -0.82°



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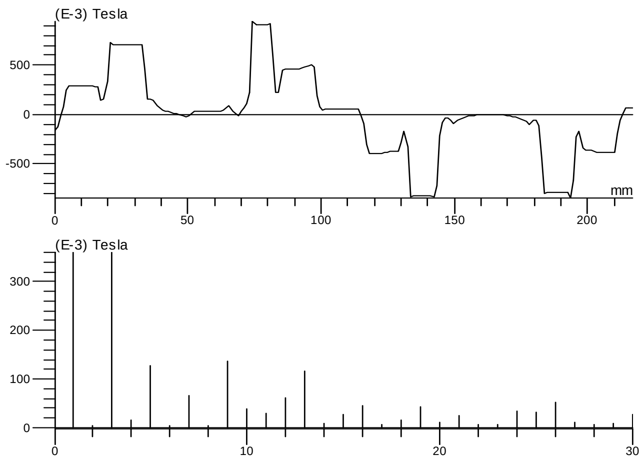

a. Flux lines distribution

b. Air-gap flux density

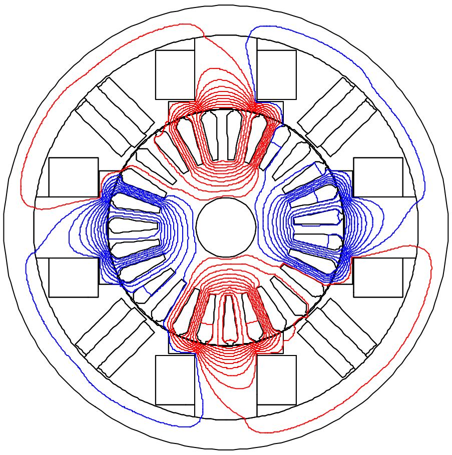

Fig. 12 – Reference angle α = +3.62°

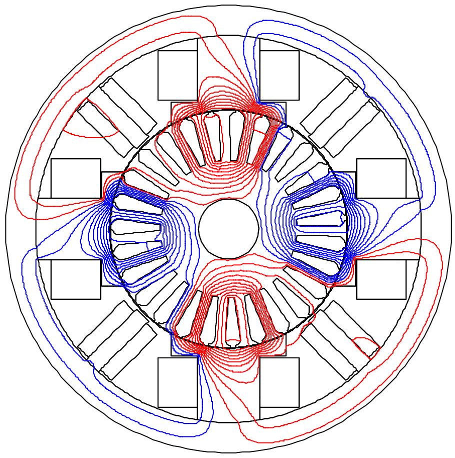

Fig. 13 – Reference angle α = +5.84°

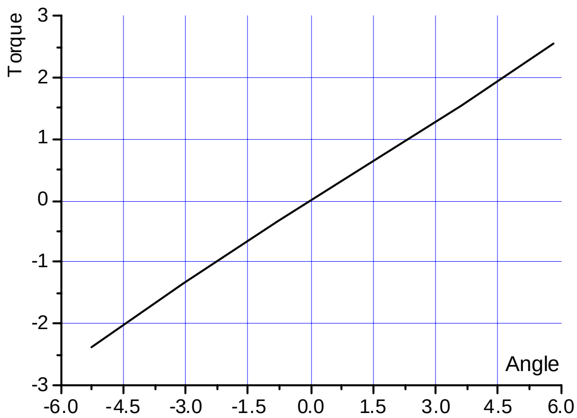

Fig. 14

In Fig. 14 the variation of the developed electromagnetic torque with the position of the brushes is presented. It proves one more time the efficiency of the proposed method. Since for positive angles the developed electromagnetic torque is also positive (the rotor rotates "forward") then the positioning of the brushes on the neutral line require a "backward" rotation of the brush rocker.

3. CONCLUSIONS

- In this paper a simulation of the operation of a D.C. machine was presented. The machine has been manufactured by a Romanian company and its rated values have been found in the catalogue;
- The FEM analysis offered the air-gap flux density values corresponding to main and auxiliary pole axes and pointed out the influence of the auxiliary poles.
- The six sequences of rotation of the brushes in the range – 5.26° to +5.84° showed the situation when the developed electromagnetic torque becomes zero. This fact justifies the proposed method for positioning the brushes on neutral axis.
- The method has been used successfully at RATP Iasi and in electrical machines laboratory.

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