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Effect of direct current motor parameters in the development of magnetic

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Abstract. Parameters affecting dc motor performance including number of poles, magnet gap at the middle of polar shoe and magnet gap in angels of polar shoe should be selected and improved so that motor performance and efficiency is increased significantly. In this article one dc motor was designed in different conditions and by the numerical analysis and then was analyzed electromagnetically in the transit state by the maxwell software. Obtained results characterized that by determining improved amount of affective parameters in dc motor performance, energy losses are decreased and the highest power and electromagnetic moment is utilized. Efficiency of motor is increased and also motor reaches to the stable state in the less time period.

Keywords: direct current motor, the number of poles, air gap, efficiency

1. INTRODUCTION

Dc motors are composed of two following main parts: a) The static part named inducer (stator) at creates the magnetic flux that are placed on this static part of the main poles and auxiliary poles. b) The rotating part named armature with that changes the electric energy to the mechanical energy in motors. There is aerial space between the static and rotating part. Dc motors always have had suitable and good position in the industry due to control of the exact speed and with the extensive range and also having high moment [1]. So these motors are very used in marine and military industries. Of these motors' advantages are: superiority of electromagnetic moment of dc motors to compare with ac motors with the variable frequency, control the exact and variable speed. Also benefiting dynamic power supply like battery has affected validity of Dc motors in many industrial and military industries [2]. Important applications of these motors re in sea subsurfaces, floating boats, military tanks, and other applications that need exact control of moment or speed. In this article three DC motor with different characteristics were designed in different conditions and then electromagnetically analyzed by the Maxwell software.

2. CALCULATION OF DC MOTOR BY THE USUAL METHOD

Some main equations for designing DC motor by direct stimulation have been presented by the 1-16 relations [3] until [14].

$$D^2 L = \frac{Pe}{\pi^2 \times B \times \frac{N}{60} \times Be \times A} \tag{1}$$

$$I = \frac{Pout}{V.\eta} \tag{2}$$

$$0.5 \le \frac{D}{P.L} \le 0.7 \tag{3}$$

$$\tau = \frac{\pi \cdot D}{2P} \tag{4}$$

We have in the 1-4 relations:

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D: is the external diameter of rotor, L: rotor length, Pe: electromagnetic power of motor and B: is the motor flux density that based on the motor function has different range. N: is Revolutions per Minute. Be: induction at air distance, A: electric loading of motor according to ampere-conductor /cm, i: nominal current, pout: nominal power, V: nominal voltage, η: efficiency that is about 90%, P: number of pole couple, τ : size of polar step curve.

$$Vmo = 2p\frac{V}{Ns} \tag{5}$$

$$YA = \frac{Ne \pm 1}{4} \tag{6}$$

$$Ra = \frac{P\theta.Nc.Lsp}{2.Scu.(2a)^2} \tag{7}$$

$$Dc = \frac{Nk.tc}{\pi} \tag{8}$$

We have in the 5-7 relations:

Vmo: Voltage between the collector blades, Ns: The number of coils series in parallelway each, YA: average step size slots, Ne: Number of rotor slots, Ra: wiring resistance of the armature, Nc: number of rotor conductors, Lsp: During a ring armature wiring in meters, Scu: pure copper cross-section of the groove, 2a: Number of parallel annular current, and the wiring is equal to 2. Dc: Diameter collector, Nk: Number of Blades Collector, tc: Total width of a blade collector and insulated, π : Is equal to 3.1415. Figure 1 shows a simple wave paths current the wiring.

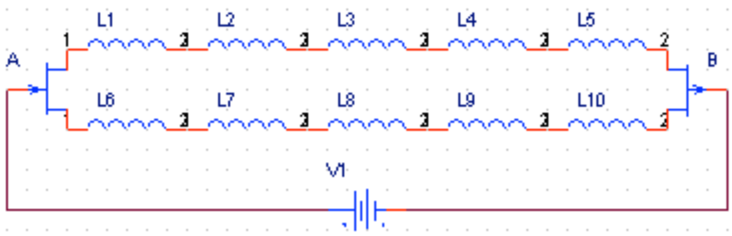

Figure 1. Current paths for wiring simple wave

$$S = 3.ea[et - (2 \times i)] \tag{9}$$

$$Zc = td + be + (et - tc)\left(\frac{D}{Dc}\right) \tag{10}$$

$$Fa = \tau.In \tag{11}$$

$$Spa = \frac{A}{Jpa} \tag{12}$$

The relations (9) to (12) we have:

S: useful contact brushes each category three, ea: Length of brushes, et: width brushes, Zc: the width of auxiliary pole, Td: the indentation step, be: track width, Fa: magnetic driving force, in: motor rated current, Spa: cross-section of the wire used for winding excitation, Jpa : The current density at the pole auxiliary winding.

$$S = Ea = k.\varphi.w \tag{13}$$

$$T = K.\varphi.Ia \tag{14}$$

$$airgap = \varepsilon \geq (0.6 - 1.5)B\frac{A}{Be} \tag{15}$$

$$Kc = \frac{td}{td - \frac{be^2}{5\varepsilon + be}} \tag{16}$$

In equation (13) to (16) we have:

Ea: force induced by the two ends of the armature, k: constant machine, T: Induction motor torque, Kc: Carter's coefficient. The equivalent circuit of a direct current motor in Figure 2 is given.

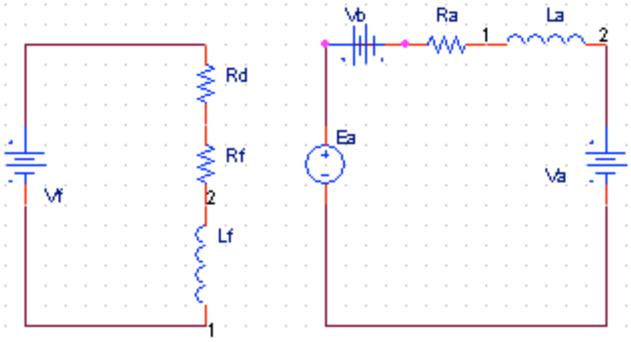

Figure 2. Equivalent circuit of a direct current motor with independent excitation

Armature orbit includes a voltage source and a resistor Ra is the ideal Ea. The equivalent circuit with an external resistor Rd and right with an internal resistance Rf is equivalent inductance Lf.

2.1. Determine Requirements

Dc motors used in the industry usually should satisfy the below requirements: high efficiency, noise decrease, extensive speed range, high reliability, high starting torque and rapid acceleration. Dc motor due to having many of above features, have well development and position in the industry.

2.2. FEM analysis

4- the intended model is a dc motor that has nominal power of 127kw and nominal speed of 222 cycle-minutes. In designing dc motor, most important parameters affecting high efficiency with maximum effectiveness are size of polar number, magnetic gap size and magnetic gap size in corners of main poles shoe. These parameters should be designed to impose motor under the best function condition. To increase efficiency, effectiveness and decrease saturation points, parameters affecting dc motor function are simulated in different amount for this motor by the Finite Element Method. Maxol software has ability to solve electromagnetic equations and dynamic- mechanical equations. So this software has been used to design and analyze noise and disturbances of intended motor in the transit state. Due to symmetry in dc motor, software draw motor as one fourth in order to decrease repeated calculations.

3. SIMULATION MODEL AND RESULTS

Parameters affecting the performance of the direct current motor, the number of poles, the air gap and the gap in the shoe is on electromagnetic analysis and parameter values used in the simulation are shown in Table (1) to (3).

Table 1. Main parameters of the direct current motor.

GENERAL DATA	
Machine Type	Motor
Rated Output Power (kW)	127
Rated Voltage (V)	520
Number of Poles	4
Given Rated Speed (rpm)	222
Type of Load	fan load
Operating Temperature (C)	75

Table 2. Parameters of the direct current motor rotor

ROTOR DATA	
Outer Diameter of Rotor (mm)	522.3
Inner Diameter of Rotor (mm)	177
Number of Rotor Slots	94
Slat Top Height- hs0 (mm)	2
Slat Median Height -hs1 (mm)	3
Slat Height-hs2 (mm)	44
Slat Top Width-bs1 (mm)	13
Slat Width-bs2 (mm)	11
Top Tooth Width (mm)	6.45491
Bottom Tooth Width (mm)	3.18025
Length of Rotor Core (mm)	450
Stacking Factor of Rotor Core	0.95
Type of Steel	M19_24G
Vent Type	Axial Hole
Number of Holes per Row	16
Inner Hole Diameter (mm)	35
Outer Hole Diameter (mm)	35
Inner Hole Location (mm)	240
Outer Hole Location (mm)	340

Table 3. Parameters of the direct current motor stator.

STATOR POLE	
Frame Outer Diameter (mm)	1100
Frame Overall Width (mm)	1100
Frame Thickness (mm)	60
Frame Material	steel_1008
Pole Length (mm)	440
Pole Stacking Factor	0.95
Pole Material	steel_1008
Pole Type	2
Bending angle of the pole shoe-Rp0 (mm)	22
Bending angle of the pole shoe-Rp1 (mm)	22
Height pole (mm)	49
Total Net Weight (Kg)	4232.23

3.1. Effect of pole

First state: DC motor has been simulated with two pole and air gap distance size of 2.2mm. Obtained results are shown in the figures 3 to 5.

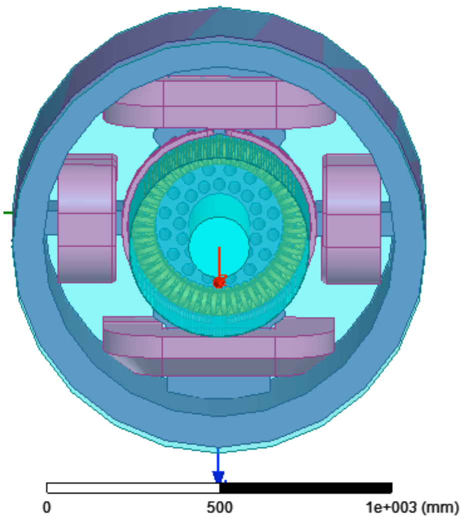

Figure 3. Three-dimensional view of a two-pole direct current motor.

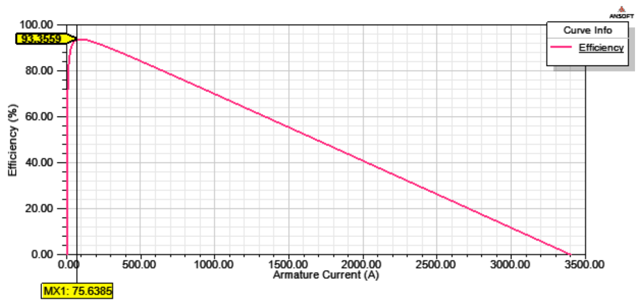

Figure 4. Graph Randman- direct current motor armature current polarization.

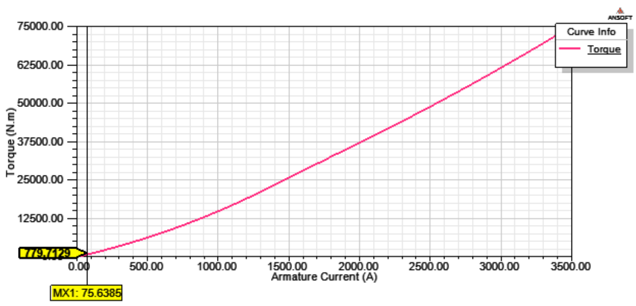

Figure 5. Diagram of torque DC motor armature current polarization.

Sate 2: DC motor has been simulated with 4 poles and air distance size of 2.2mm. Obtained results are shown in the figures 6 and 8.

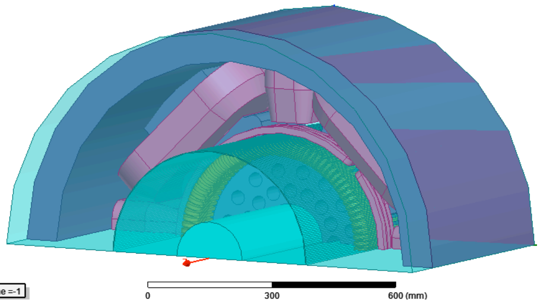

Figure 6. Three-dimensional view of a four-pole direct current motor.

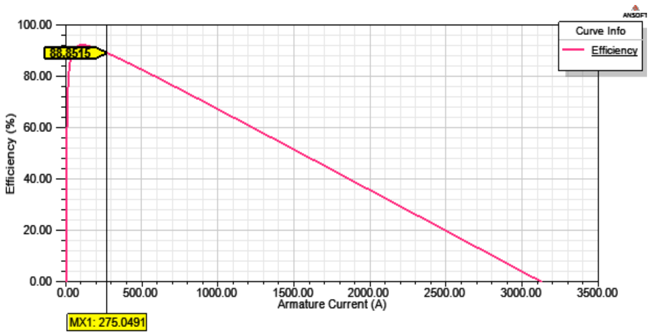

Figure 7. Graph Randman- direct current motor armature current four-pole.

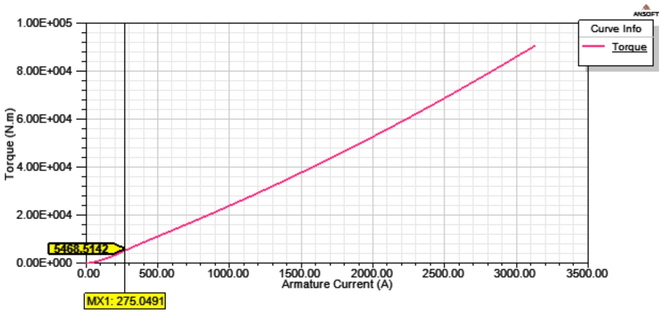

Figure 8. Diagram of torque DC motor armature current four-pole.

State 3: DC motor no.3 has been simulated with 6 poles and air distance sizes of 2.2mm. Obtained results are shown in the figures 9 and 11.

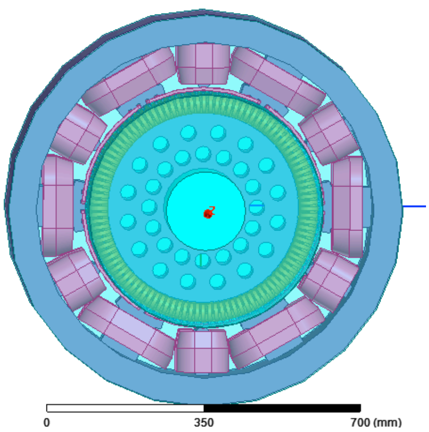

Figure 9. Three-dimensional view of a six-pole direct current motor.

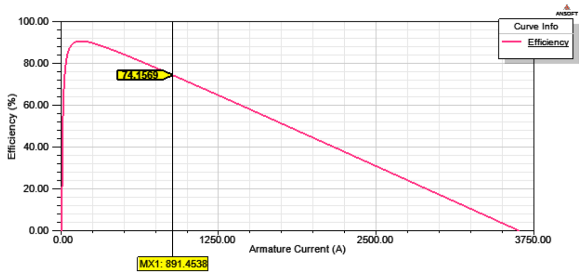

Figure 10. Graph Randman- direct current motor armature current six-pole.

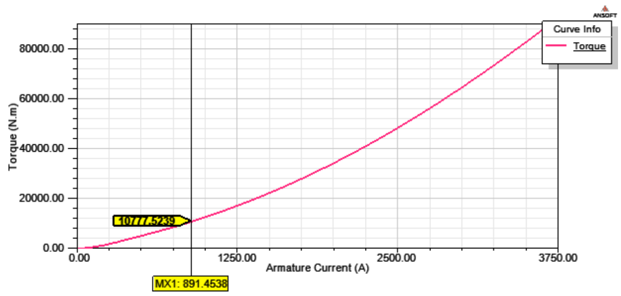

Figure 11. Diagram of torque DC motor armature current six-pole.

It is obvious from figures 3-11 that when number of poles is decreased the motor efficiency is increased and also iron losses is decreased but motor power and Turaqe is decreased. On the other hand by increase in number of poles, motor power and Turaqe is increased but in turn the efficiency is decreased. So, number of poles in DC motor is determined so that efficiency and Turaqe are in appropriate situation.

3.2. Effect of air gap

Direct current motor for three different modes of electromagnetic analysis and parameter values used in the simulation are shown in Table (1) to (3).

First state: DC motor has been simulated in the transient state with 4 poles and air gap distance size of 0/73 mm. Obtained results is shown in the figure 12 to 14.

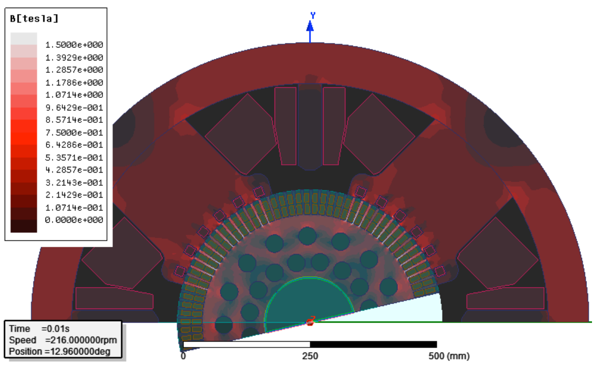

Figure 12. Distribution schema direct current motor with air gap flux density of 0.73 mm.

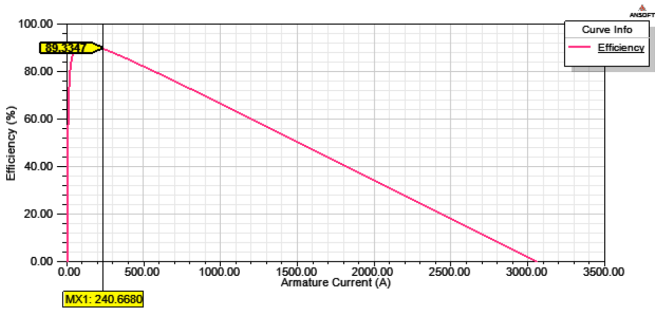

Figure 13. Graph Randman- direct current motor armature current 0.73 mm air gap.

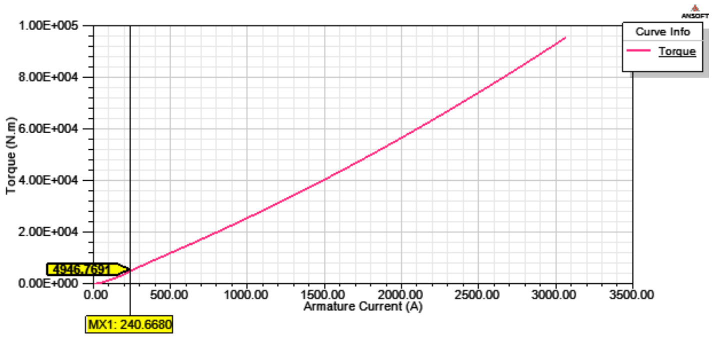

Figure 14. Diagram of torque current direct current motor armature with an air gap of 0.73 mm.

Second state: DC motor has been simulated in the transient state with 4 poles and air gap distance size of 2/2 mm. Obtained results is shown in the figure 15 to 17.

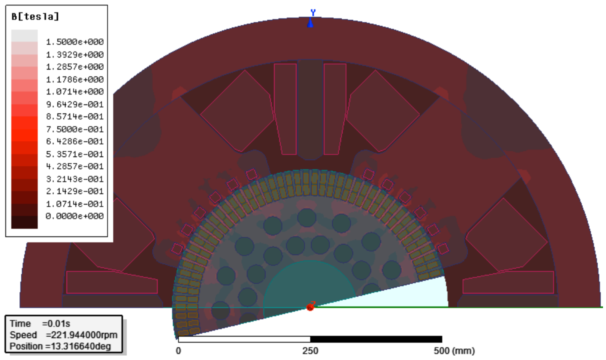

Figure 15. View of a direct current motor with air gap flux density distribution of 2.2 mm.

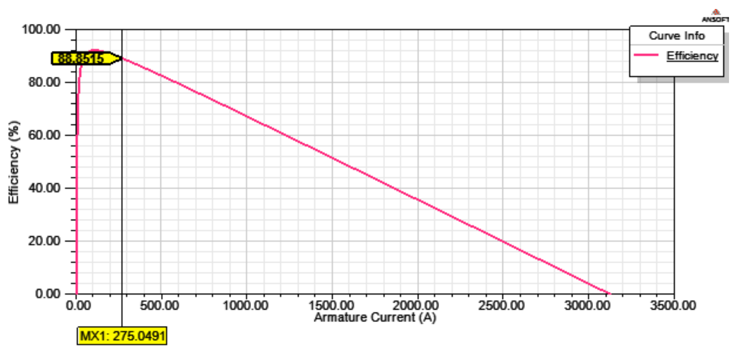

Figure 16. Graph Randman- direct current motor armature current air gap of 2.2 mm.

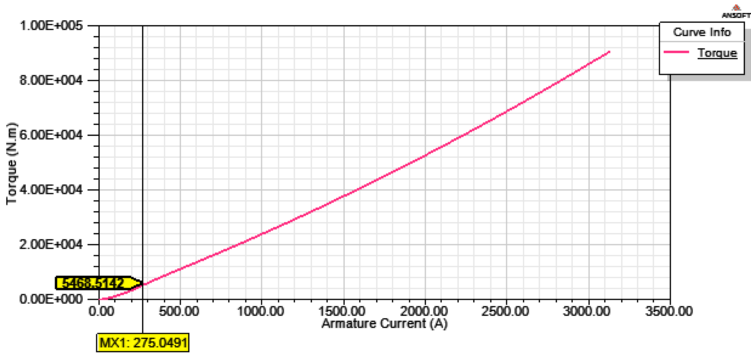

Figure 17. Diagram of torque current direct current motor armature with an air gap of 2.2 mm.

Third state: DC motor has been simulated in the transient state with 4 poles and air gap distance size of 0/73 mm. Obtained results is shown in the figure 18 to 20.

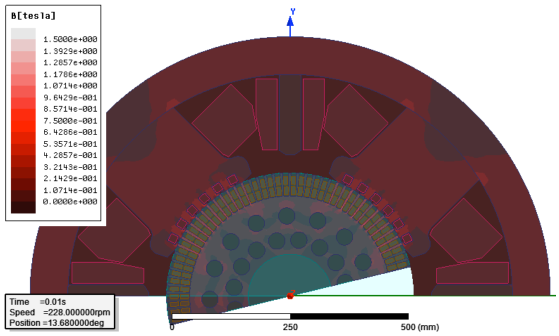

Figure 18. Direct current motor with air gap flux density distribution scheme 6.6 mm.

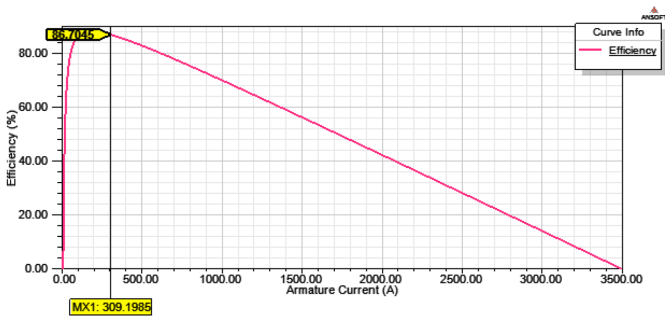

Figure 19. Graph Randman- direct current motor armature current air gap of 6.6 mm.

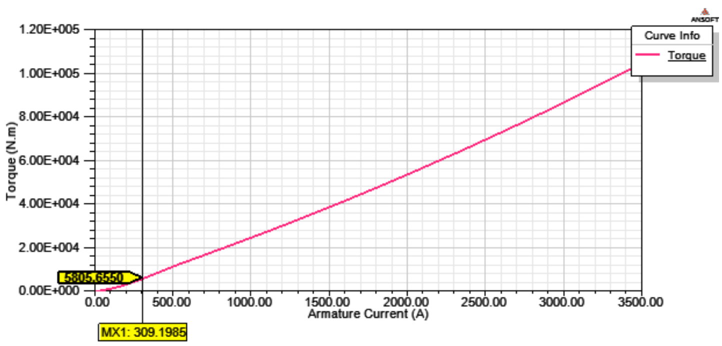

Figure 20. Diagram of torque current direct current motor armature with an air gap of 6.6 mm.

There is not magnetization reactance In DC motors due to lack of alternating current of armature wiring. So DC motors have large air distance gap than alternating current motors. As it is clear in figures 22-36, decrease of air distance gap increases efficiency and also but decreases motor power and also speed and Turaqe. Increase of air distance has advantages and disadvantages. By increase in air distance power efficiency is decreased but power, Turaqe and speed are increased. Larger air distance has advantages like improvement of Eruption form, decrease in noise and softer performance, simplicity in performing mechanic, increase of stability and decreases the decrease resulted by beats that are produced by armature slot in polar pieces but instead, as was stated, decreases the efficiency and increases ampere wiring turns.

3.3. Effect of air gap at the corners of the pole shoes

Direct current motor is the for three different cases of transient electromagnetic analysis and Parameter values used in the simulation shown in Table (1) to (3).

First state: one dc motor with 4 poles and magnetic gap of 2/2 mm has been simulated in the middle of main pole and with constant magnetic gap in the shoe surface. Obtained results are shown in the figure 21.

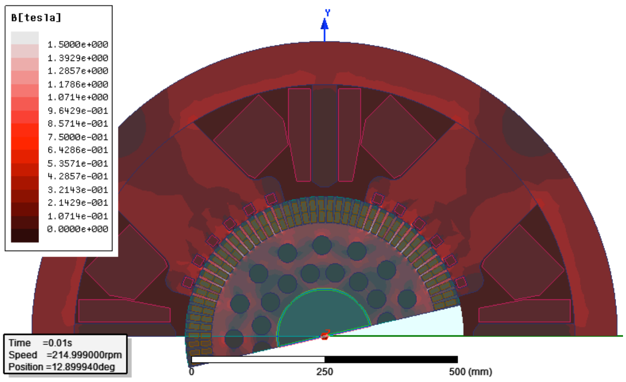

Figure 21. View of the flux density distribution of the direct current motor With uniform air gap in the shoe

Second state: one dc motor with 4 poles and magnetic gap of 2/2mm has been simulated in the middle of main pole and with unsteady magnetic gap that this gap in corners of polar shoe is 1/5 time more that magnetic gap in the middle of shoe. In figure 22 obtained results have been shown and also in this state has been suggested in figure 23.

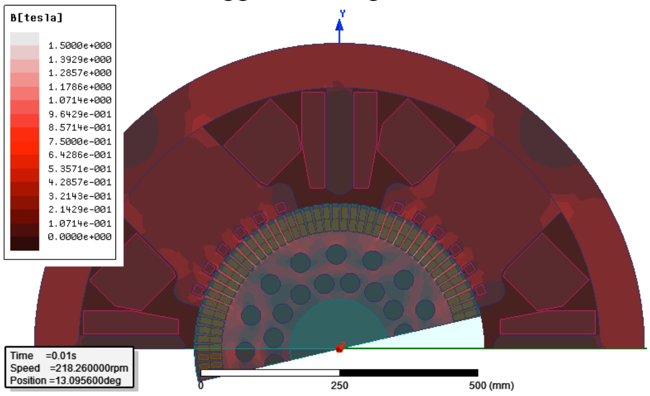

Figure 22. View of a direct current motor with air gap flux density distribution of non-uniform And 1.5-fold in the corners of the shoe.

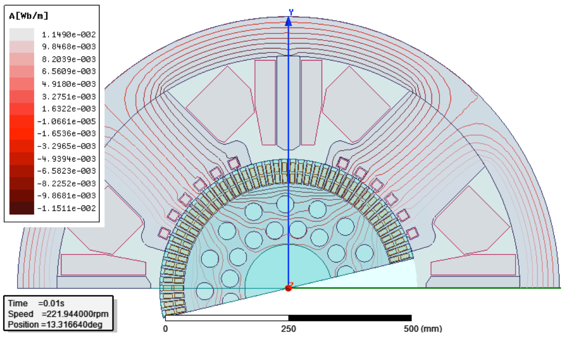

Figure 23. Two-dimensional view of the eruption of the direct current motor.

Third state: one dc motor , 4 poles and magnetic gap of 2/2mm has been simulated in the middle of main pole and with unsteady magnetic gap that this gap in corers of pole shoe is 2 times more than magnetic gap in the middle of shoe. Obtained results are shown at figure 23.

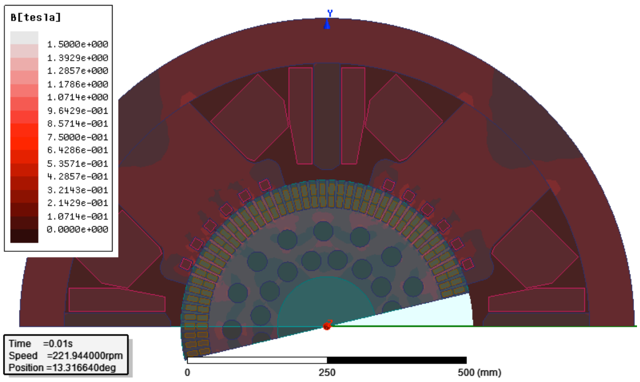

Figure 24. View of a direct current motor with air gap flux density distribution of non-uniform And 2 times around the shoe.

Length of magnetic gap should be selected in such a way that armature reaction field does not demagnetize one pole at the end completely. Well commutation is obtained when density of magnetic gap flux is decreased gradually from center of pole and when drops to zero when reaches to axel between two poles. Distribution curve of magnetic gap flux that suddenly drops from maximum to zero , causes problems in commutation and can improve magnetic noise and causes magnetic saturation points. In this article, magnetic gap length in the surface of main pole shoe has been studied and simulated for 3 ranges of magnetic gap. As observed in figures 21-24, size of magnetic gap in the surface of polar shoe was steady and same. In this state motor obtained magnetic saturation points. In the third stage, size of magnetic gap at corners of polar shoe was increased two times more than magnetic gap size at the middle of polar shoe that we had not saturation points in this stage. So density of field was decreased by closing to corners of poles shoe. Amount of field density decrease in region between poles became very more. To achieve favorable field form, polar shoe surface was determined so that magnetic gap was increased gradually in distance between pole center to pole edges.

4. CONCLUSION

In designing electric machines, electromagnetic, thermal and mechanical constraints should be considered. So achieving a acceptable design requires many computational repeats. Using new computers and software and also utilization of developed computational method make it possible to model machine behavior power exactly and assess new designs rapidly. effect of improved parameters was analyzed by maxwell software and then improved amount was determined for parameters affecting motor performance. When poles number was decreased, motor efficiency was increased and also iron losses decreased but motor moment and power decreased. On the other hand, increasing number of poles increased motor power and moment but instead efficiency decreased. So number of poles in dc motor was determined so that efficiency and moment was in suitable amount. Second parameter and affecting performance of dc motor was magnetic gap. Decrease in magnetic gap increased efficiency and eruption also but decreased motor power, speed and moment. Larger magnetic gap has advantages like improvement of eruption form, noise decrease and softener performance, mechanical ease, and stability increase. So magnetic gap in dc motor was determined to provide suitable amount for efficiency, moment, eruption form and motor mechanical performance. The third quantity affecting dc motor performance is magnetic gap size in the surface of polar shoe. Field density decreased by closing to corners of poles shoe and amount of decrease in field density was very higher in area between poles. Magnetic gap length was chosen in a way that armature reaction field does not demagnetize one pole at the end completely. So to achieve suitable field shape, polar shoe surface was determined in a way that to increase magnetic gap gradually at distance between pole center to pole edges.

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