ELECTROMAGNETIC FIELDS CALCULATION AT SINGLE PHASE SHADED POLE MOTOR

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Abstract: Finite Element Method (FEM) is used for calculation of electromagnetic field inside the single phase shaded pole motor, product of company Micron-Tech from Prilep under trade name AKO-16. Four different motor models for FEM application are developed. In first motor model magnetostatic approach for electromagnetic field calculation is implemented, meaning all electromagnetic quantities are evaluated at zero Herz frequency. Second model is developed using time-harmonic approach at fifty Herz frequency. Third and fourth motor model are developed by implementation of soft magnetic materials in stator notch and pole respectively and analyses is carried out in time harmonic domain. Obtained results are compared and conclusions are derived.

Keywords: Electromagnetic fields, FEM, Induction motor, Soft magnetic materials

INTRODUCTION

In spite of its simple construction single phase shaded pole motor (SPSPM) is very complex due to the existence of three magnetically coupled windings which produce an elliptic rotating magnetic filed in motor's air gap. Motor's rated data are: U_n=220 V, f_n=50 Hz, I_{1n}=0.125 A, P_{1n}=18 W, n_n=2520 rpm and 2p=2 (Fig.1)

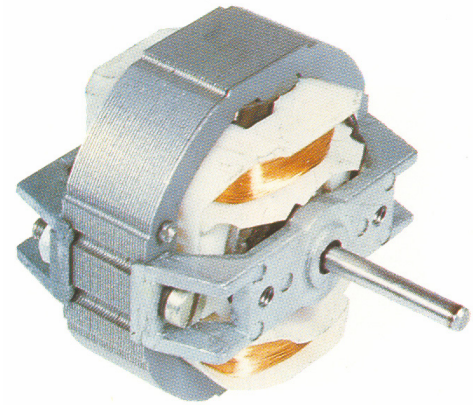

Fig.1 – *Prototype of motor AKO-16*

Extensive analysis of motor performance characteristic is implemented and they are calculated on the base of symmetrical components theory. Obtained characteristics are verified by experiment. Next step in motor research is to calculate electro-magnetic characteristics such as magnetic flux density inside the motor cross section. Over the past yearsFinitie Element Method has proved itself as valuable tool in motor design and analysis. In order to enable FEM calculation to be applicable, exact motor geometry with material characteristics is input in FEM pre-processing part. Very important issue is to define boundary conditions on outer motor geometry and in this case Dirichlet-boundary conditions are used. Another important subject in motor modelling is defining the mesh of finite elements. By dividing the motor's cross section into large number of regions i.e. elements with simple geometry (triangles) the true solution of magnetic vector potential is approximated by a very simple function. Two different approaches are used in magnetic field calculation: magnetostatic and time-harmonic. In magnetostatic approach all electromagnetic phenomena inside the motor are analysed in certain moment of time i.e. f=0 Hz. First, motor model is built , by inputting current density in main stator winding , than from the value of magnetic flux in short circuit coil current in the coil is calculated and input in the model. Finally having the both stator currents and from the value of magnetic flux in motor air gap, current in rotor squirrel cage winding is calculated. Having all three currents in the model the program is run at stator frequency f=0 Hz. In time-harmonic motor model only stator current is input and consequently currents in short circuit coil and rotor windings are freely induced. On that way analyse of electromagnetic phenomena inside the motors is closer to the real electromagnetic process inside the machine when it is supplied with voltage 220 V, 50 Hz. Both analyses are performed in 2D domain. Further improvement in motor design is achieved by implementation of soft magnetic powders in motor construction. On that way, rather high value of motor magnetic flux density in time-harmonic analysis is decreased which contributes towards decreased core saturation and iron losses.

FEM RESULTS

Results from magnetostatic analysis

After preparing all motor models program is executed and post-processing results such as magnetic field distribution in motor's cross section as well as spatial distribution of magnetic flux density in the middle of air gap line are obtained. All results are presented for magnetostatic and time-harmonic case. In Fig. 2 is presented magnetic flux density distribution at rated load in motor cross-section while in Fig.3 is presented spatial distribution of magnetic flux density in motor air gap. Further on, in Fig.4 is presented characteristic of air gap flux versus current in main stator winding $\Phi_\delta=f(I_1)$, when only stator windings are energized and there is not current in rotor winding, I_2=0, for rotor starting position 0°. This is adequate to ideal no-load operation and obtained characteristic represents the magnetization curve of prototype of AKO-16.

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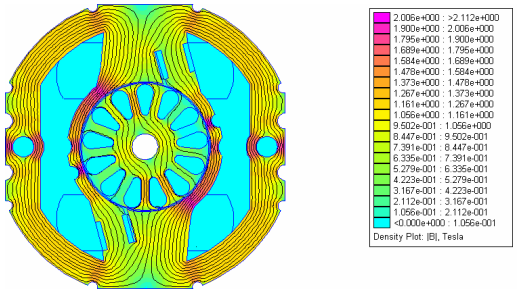


Fig.2 –Magneto-static *flux density distribution, rated load*

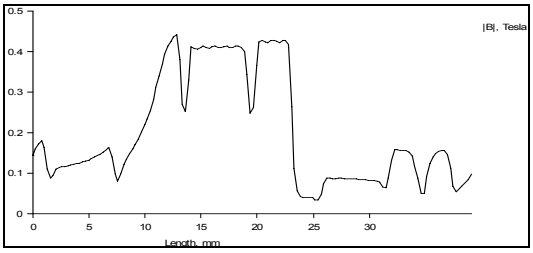


Fig.3 – *Flux density distribution in motor air gap*

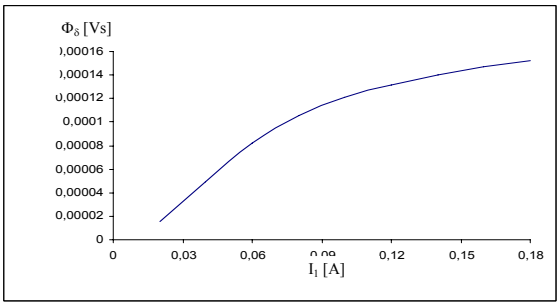


Fig.4 – *Air gap flux for I_1 and $I_3 \neq 0$, $I_2=0$*

Values of flux in motor air gap as well as electromagnetic torque when all three windings are energized for different rotor positions are presented in Figs. 5 and 6 respectively.

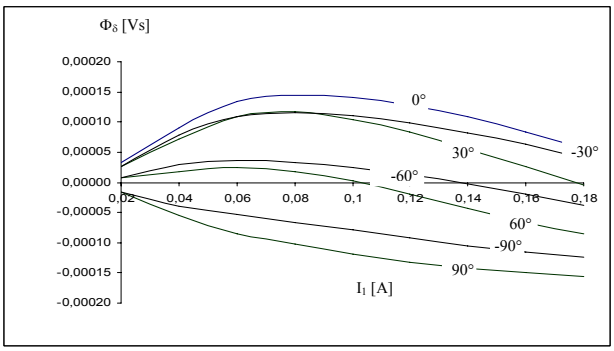


Fig.5 – *Air gap flux for I_1, I_2 and $I_3 \neq 0$, different rotor positions*

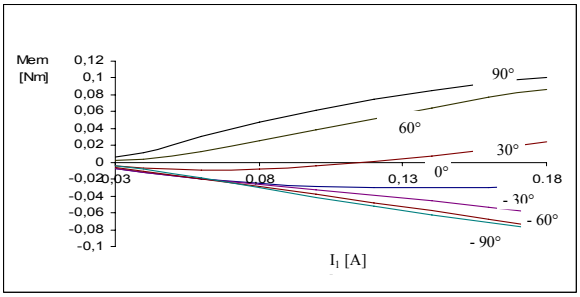
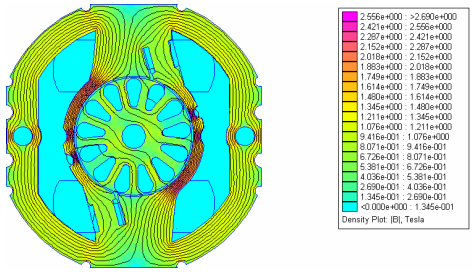


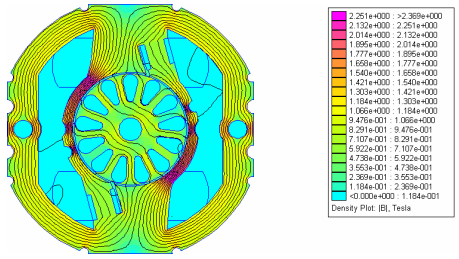
Fig.6 – *Electromagnetic torque for different rotor positions*

Results from time-harmonic analysis

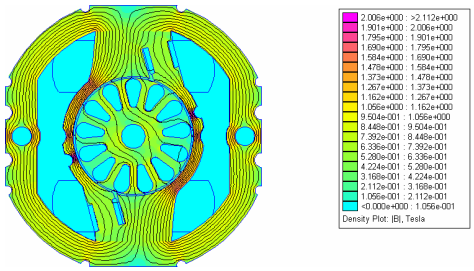
Time-harmonic analysis at f=50 Hz and for different operating regimes is carried out. In Fig. 7a is presented flux density distribution for rated load in motor prototype. From presented results it can be concluded that stator bridge in some critical points has increased value of flux density up to 2.6 T. Therefore soft magnetic material Somaly™500 is implemented in construction of stator notch (Fig. 7b) thus obtaining the experimental model E1 and further on, in construction of complete stator pole (Fig. 7c)-model E2.



(a)



(b)



(c)

Fig.7 – *Flux density in motor prototype and experimental models*

CONCLUSION

FEM is used for calculation of electromagnetic field inside SPSPM. Analysis is performed for magnetostatic case at frequency f=0 Hz and time-harmonic case at frequency f=50 Hz. Different electro-magnetic quantities are calculated such as air gap flux and electromagnetic torque. Angle of rotor skewing is also implemented in motor model and calculation of electromagnetic torque. Time-harmonic models are improved by usage of soft magnetic powders in motor construction which lowers the value of magnetic flux density in critical points where saturation occurs.

REFERENCES

[1] V.Sarac, "Different Approaches in Numerical Analysis of Electromagnetic Phenomena in Shaded Pole Motor with Application of Finite Elements Method,", In Proceeding(s) of the EMTS International Symposium of Electromagnetic Theory" , Berlin, 2010, pp. 97-100.