Modelling of Two-Dimensional Magnetic Fields and the Induction Motors

Nikolce Talevski, Mirka Popnikolova Radevska, Blagoja Arapinoski, Mile Spirovski
Faculty of Technical sciences at University of Bitola
Makedonska Falanga 33
Bitola, 7000, Macedonia

ABSTRACT: *We in this work have addressed the modelling of two-dimensional magnetic fields and analyse the three phase induction motors. During the calculation of the magnetic data, we look at the precision of the machines. We found that the magnetic field solution needs to be accurate for efficiency. We have used the set of programs for the generation of finite elements. The air gap flux distribution of flux is the main determinant of the execution of the motor windings during the distribution of electromagnetic field.*

Keywords: Three-Phase Induction Motor with Squirrel Cage, FEM 2D, Electromagnetic Analysis

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1. Introduction

The three-phase induction machines are widely used in everyday life. Asynchronous motors stand out as characteristic in both constructive and in terms of technical performance. Such type of electric motor or asynchronous motor with cage rotor is selected as the subject of research from which one part presented in this paper. It will be made on electromagnetic analysis of specific asynchronous motor. This analysis will be made software, which calculations will be made based on well-known method of finite elements. As a result of the analysis will be presented: The distribution of the magnetic field in all regions of the engine, the magnetic induction in the air clearance category of the machine, and calculating the moment of the electromagnetic motor at nominal load. Software which has been applied to obtain the distribution of the electromagnetic field in 2D motor domain uses the famous and powerful finite element method (FEM). The three-phase induction motor with cage has the following rated data: P_n = 400kW, U_n = 6000V, f_n = 50Hz, $2p$ = 6, $cos\, f$ = 0.86 , η = 0.84% n_n = 987min^{-1} and delta winding connection.

From the main linkage flux results, the motor inductance and the electromagnetic torque are determined numerically, and their characteristics for various load and rotor angular positions are presented.

2. Geometry of the Considered Problem

The subject of the research is three phase asynchronous motor with cage. As compared to the construction of the stator coil, the coil is identical to the standard three-phase asynchronous motors, in this case magnetic circuit of the stator is laminated and has 72 slots, they set a two-layered three-phase distributed coil with winding shortened step y = 11/12. The rotor has set a squirrel cage made of aluminium which has 90 channels. Complete geometry of three-phase induction motor with cage in 2D domain is presented on Figure 1.

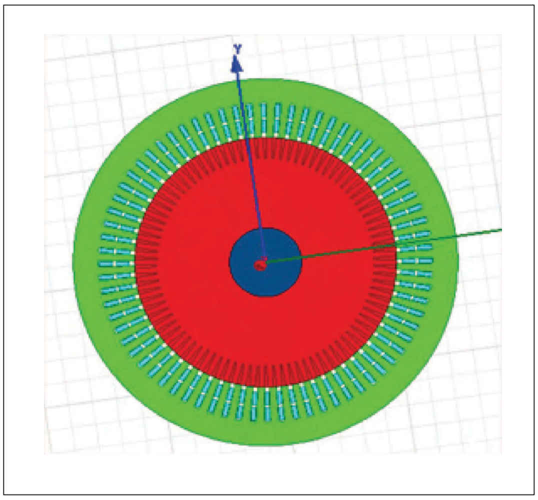

Figure 1. Geometry of model in 2D domain

3. Mathematical Model

The mathematical model is basically a program consisting of a system of Maxwell's equations well known in this analysis. Whit the settings of excitement of stator and rotor circuit process partially completes. It is necessary to make additional sections or places where they will present the socket burdens. By Figure 2 is represented excitement and terminals.

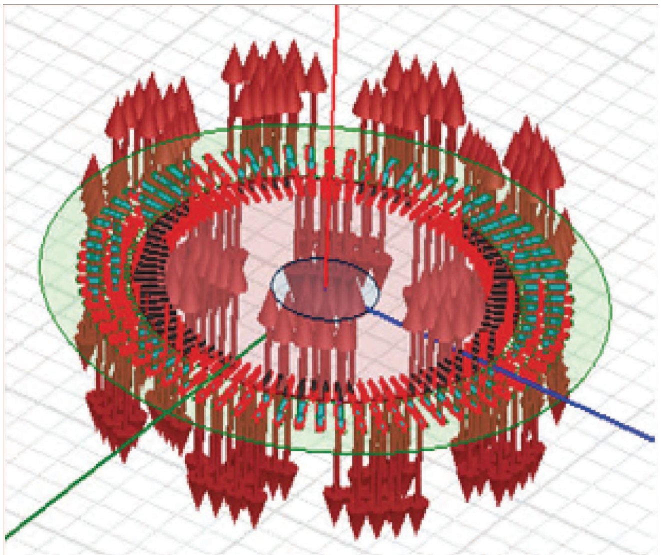

Figure 2. Excitements and terminals on asynchronous motor whit cage

The mathematical model provides an opportunity to solve equations for calculating the induction motor whit cage rotor. In such analysis is obtained from finite element network to test engine, and it can see that it is densest on-air gap between stator and rotor. By increasing the density of the network of finite element increases the accuracy of calculation. Generated mash for this type of asynchronous motor whit cage rotor in 2D analysis down to the final number of 31538 items. This is represented in Figure 3.

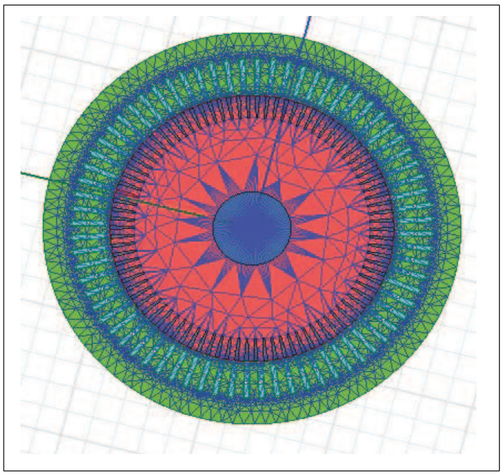

Figure 3. Finite element mash on asynchronous motor whit cage rotor complete geometry in 2D

4. Finite Element Method in 2D For Calculation of the Magnetic Field

For performing the analysis a two dimensional numerical calculation of the magnetic vector potential and flux density in a two dimensional domain of the three-phase induction motor with cage is required. For that purpose the above mentioned computer program based on 2D Finite Element Method has been used. The numerical calculation is based on the Poisons' equation for magnetic field distribution in three-dimensional domain:

$$rot(v(B)\,.\,rot(A)) = J\,(x, y, z) \qquad (1)$$

To realize a numerical solution of the equation (1) it is necessary to carry out a proper mathematical modelling of the machine. Then magnetic flux distribution can be plotted and this is presented on Figure 4 for excitation winding are energized with rated currents.

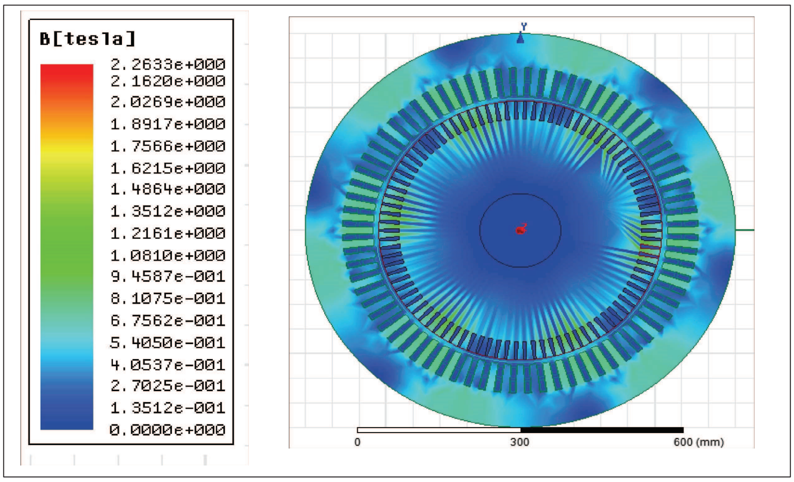

Figure 4. Magnetic field distribution in 2D motor domain

By using the procedure for numerical differentiation, the distribution of the magnetic flux density at the middle line of the air-gap in three-phase induction motor with cage rotor is determinate[1]. The characteristics of the magnetic flux density in dependence of the rotor position at different armature currents are presented in Figure 5.

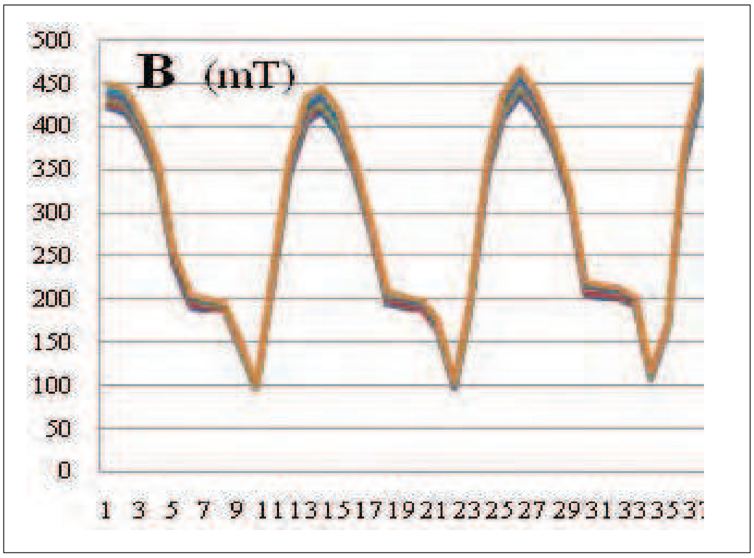

Figure 5. Characteristic of the magnetic flux density

Determination of the equivalent inductance between stator – rotor circuit can determine if there is value for the total energy for the magnetic field. The equivalent resistance is in direct relation to the magnetic flux, and determining the size necessary to know the load currents of the motor and the position of the rotor relative to the stator. Distribution of the magnetic field through the three – phase asynchronous motor whit cage rotor is represented in Figure 5.

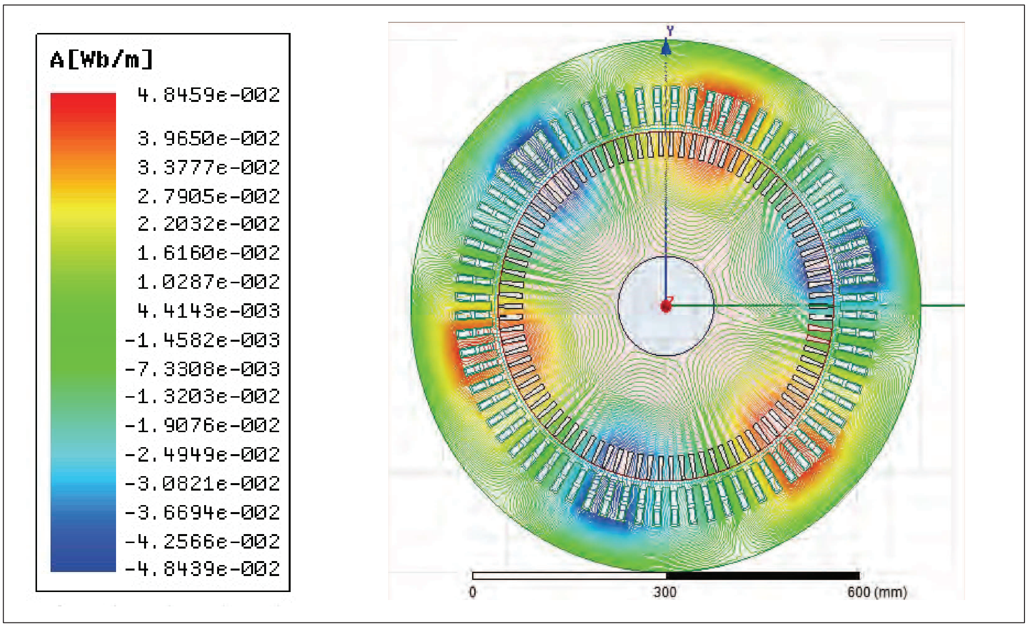

Figure 6. Magnetic field in asynchronous motor whit cage rotor

The characteristics of the magnetic field density in dependence of the rotor position at different armature currents are presented in Figure 6.

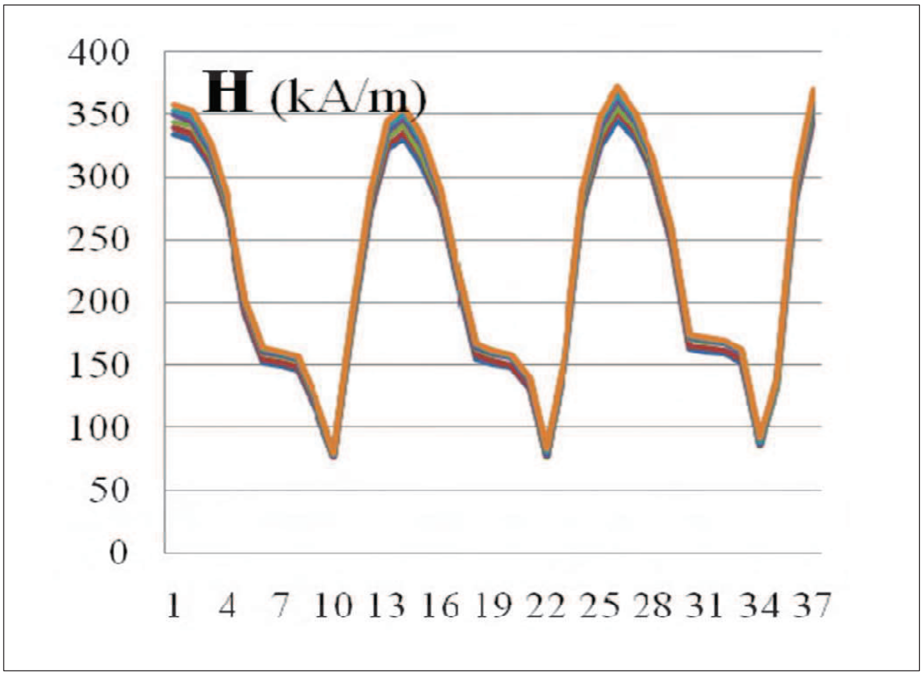

Figure 7. Magnetic field

Having the distribution of the magnetic vector potential in the whole investigate domain of the three-phase asynchronous motor with cage rotor, the main flux in the air gap is determinate as well as leakage flux in the stator and rotor windings, and is going to be determined starting from the equation:

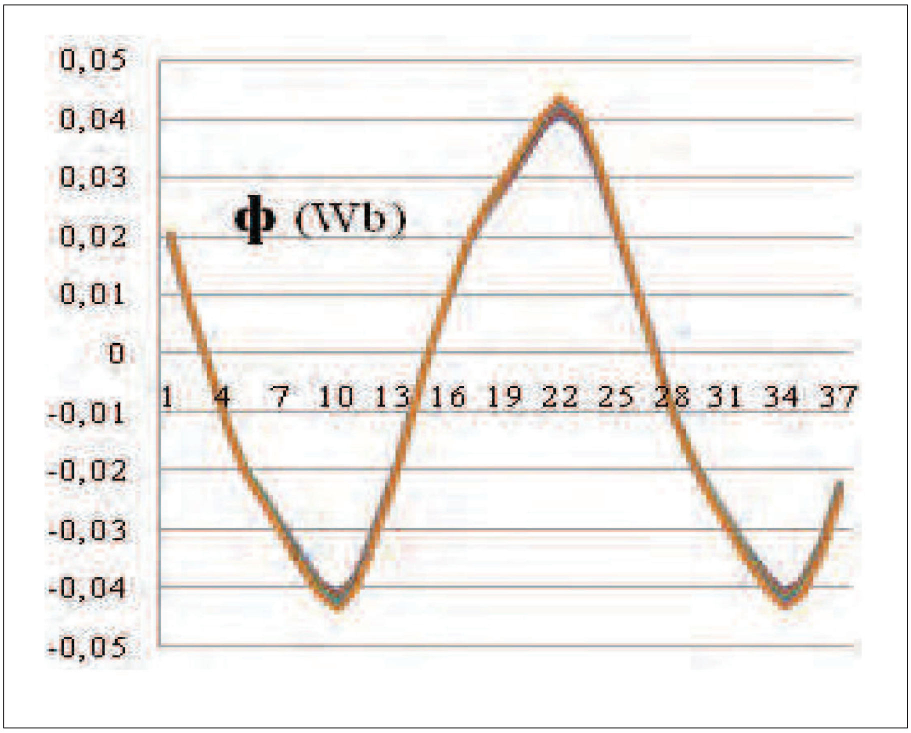

Figure 8. Air-gap flux linkage characteristics

$$\Phi_{\delta} = \int_{\Sigma} rot\mathrm{A}\, ds = \oint_{C} \mathrm{A}\, dr = \int_{\Sigma} \mathrm{B}\, ds = \iint_{S} (\mathrm{B} \cdot \mathrm{n})\, ds \tag{2}$$

Then result is:

$$\Psi_{\delta} = w\iint_{S} (\mathrm{B} \cdot \mathrm{n})\, ds = w\iint_{S} \left(\frac{\partial \mathrm{A}_{z}}{\partial \mathrm{x}} - \frac{\partial \mathrm{A}_{x}}{\partial \mathrm{z}} \right) dzdx \tag{3}$$

In the differentials replaced with differences and integrals with sums, for determining Ψ_{δ} , the relation is as follows:

$$\Psi_{\delta} = w \cdot L \sum_{i=1}^{N_x} \Delta \mathrm{A}_{\mathrm{Z}i} = w \cdot L\left(\mathrm{A}_{\mathrm{ZNx}} - A_{Z1}\right) \tag{4}$$

The air-gap flux linkage Ψ_{δ} for different constant rotor angular positions is presented on Figure 7.

The results of this crucial and addressing relevant matrices can afford to get the flux that occurs in the stator and rotor, for a period, and receive appropriate addictions. Flux can afford to be distinguished as a flux which is distributed stator coil, stator part of the circuit, and flux which is distributed through rotor coil, rotor part of the circuit. Distribution of flux throughout stator and rotor circuit of asynchronous motor whit cage rotor is represented in Figure 8 and Figure 9.

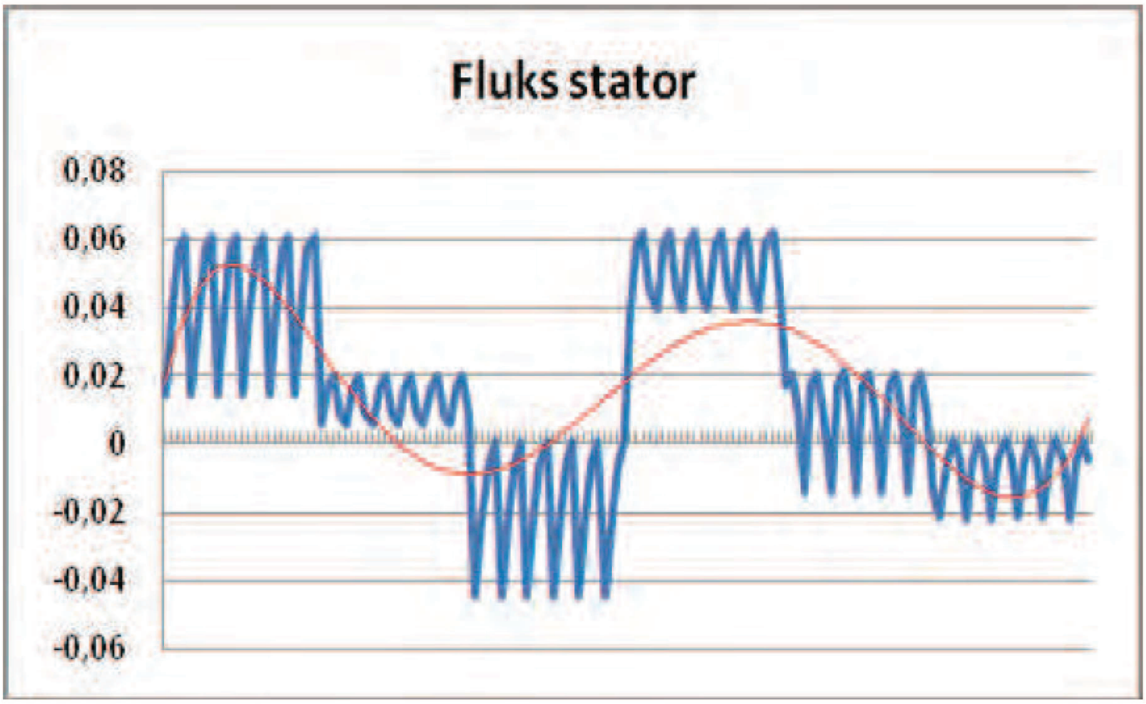

Figure 9. Distribution of flux – stator circuit

5. Calculation of Electromechanical Characteristics

The knowledge of electromagnetic torque characteristics is very important matter for analysis and performance of electrical

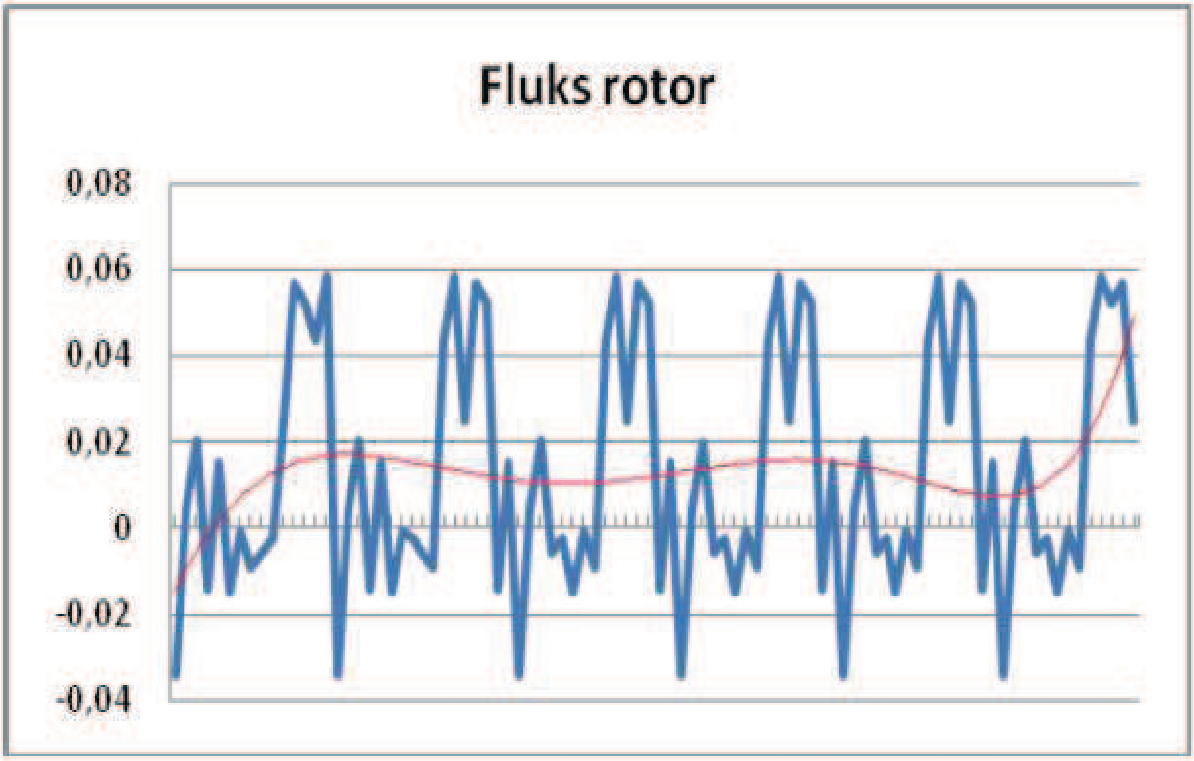

Figure 10. Distribution of flux – rotor circuit

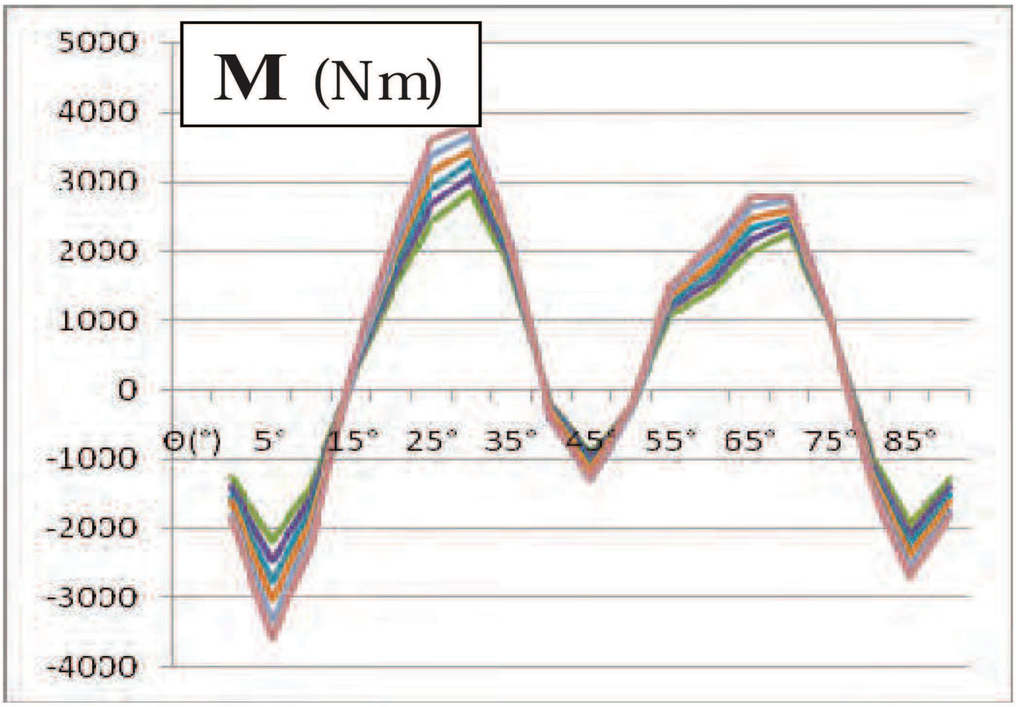

Figure 11. Torque characteristic of the three-phase asynchronous motor with cage rotor

motors. In this paper the energy concept for numerical calculation of electromagnetic torque is applied and for three phase asynchronous cage motor will be calculated by the change of the magnetic system co-energy at virtual angular displacement of rotor for different currents in the stator and rotor.

The torque characteristic of the three phase asynchronous motor with cage as a function of angular position of the rotor at rated load is given on the Figure 11.

The reliability of the calculated value of torque in this simulation analysis is confirmed, it is shown by the fact that the calculated value and the characteristic shape is identical to that obtained in experimental research done in real terms as an engine for the propulsion of a rubber band.

6. Conclusion

In this paper are presented some of the results obtained in extensive research that aims to contribute to improving the performance of three-phase asynchronous motor with cage rotor. Applied software which made simulation analysis is based on the finite element method implemented in two-dimensional domain. This contemporary method enables exact magnetic quantities such as air gap flux or flux density distribution to be evaluated in any part of the motor. The results of the field computations after they are used for calculations of electromechanical characteristics, as the static and dynamic torque.

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