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AN IMPROVED MODEL OF SINGLE PHASE SHADED POLE MOTOR BY METHOD OF GENETIC ALGORITHMS

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Abstract. Single phase shaded pole motor will be analyzed in this paper. First motor electro-mechanical characteristics are calculated by analytical method of symmetrical components. Then new improved model of the motor is developed by optimization methods. In this specific case is used method of genetic algorithms. Goal function which is improved (increased) by the method of genetic algorithms is electromagnetic torque. Gained results by both methods are compared.

Keywords: electromechanical characteristics, electromagnetic torque, genetic algorithm, symmetrical components, shaded pole motor

INTRODUCTION

Single phase shaded pole motor is well known for its simple construction as well as for its complexity regarding electromagnetic processes which occur inside it. Compared with other types of motors complexity of electromagnetic processes come from existence of three electromagnetic coupled windings and occurrence of elliptical electromagnetic field inside the motor. In this paper is analyzed single phase shaded pole motor AKO-16, product of MIKORON – Prilep.

Cross section of the motor with rated data $2p = 2$; $24W$; $2200\,\text{min}^{-1}$ is given on fig.1 where (1) denotes main excitation stator winding, (2) rotor squirrel cage winding and (3) is a shading coil ring placed on stator pole.

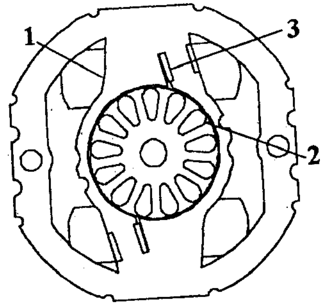

Fig. 1. Cross section of single phase shaded pole motor

METHOD OF SYMMETRICAL COMPONENTS

At single phase shaded pole motor exist two separate stator windings which are space shifted by an angle $\alpha \neq 90^\circ$ and consequently currents which flows through both stator windings (main and short circuit coil) are time shifted by an angle $\beta \neq 90^\circ$. On that way magnetic flux vector describes ellipse. One approach for analyzing electromagnetic field inside the motor is with method of symmetrical components.

Stator currents using symmetrical components can be calculated from:

(1) $$I_1 = -j\left(\frac{I_1^- e^{j\alpha}}{\sin\alpha} - \frac{I_1^+ e^{-j\alpha}}{\sin\alpha}\right)$$

(2) $$I_3 = j\left(\frac{I_1^-}{\sin\alpha} - \frac{I_1^+}{\sin\alpha}\right)$$

Symmetrical components of stator currents can be found from following equations:

(3) $$I_1^- = \frac{I_1^+\left(jZ_{1b} - e^{-j\alpha}Z^+\sin\alpha - je^{-j\alpha}Z_{ab} + jZ_{ab}\right)}{jZ_{1b} + e^{j\alpha}Z^-\sin\alpha - je^{j\alpha}Z_{ab} + jZ_{ab}}$$

(4) $$I_1^+ = \frac{V_1\sin\alpha\left(jZ_{1b} + e^{j\alpha}Z^-\sin\alpha - je^{j\alpha}Z_{ab} + jZ_{ab}\right)}{(A\cdot B)+(C\cdot D)}$$

(5) $$A = jZ_{1b} - e^{-j\alpha}Z^+\sin\alpha - je^{-j\alpha}Z_{ab} + jZ_{ab}$$

(6) $$B = je^{j\alpha}Z_{1a} - Z^-\sin\alpha + je^{j\alpha}Z_{ab} - jZ_{ab}$$

(7) $$C = jZ_{ab} - Z^+\sin\alpha - je^{-j\alpha}Z_{ab} - je^{-j\alpha}Z_{1a}$$

(8) $$D = jZ_{1b} + e^{j\alpha}Z^-\sin\alpha - je^{j\alpha}Z_{ab} + jZ_{ab}$$

For impedances Z^+ and Z^- following equations are valid:

(8) $$Z^+ = \frac{Z_0 Z_2^{'+}}{Z_2^{'+} + Z_0}$$

(9) $$Z^- = \frac{Z_0 Z_2^{'-}}{Z_2^{'-} + Z_0}$$

(10) $$Z_2^{'+} = \frac{R_2'}{s} + jX_2'$$

(11) $$Z_2^{'-} = \frac{R_2'}{2-s} + jX_2'$$

(12) $$Z_0 = R_0 + jX_0$$

Z_{1a} and Z_{1b} are consequently impedances of main stator winding and short circuit coil. Z_{ab} is mutual impedance between main stator winding and short circuit coil. Z_0 is the impedance between main stator winding and rotor winding, while R_2' and X_2' are rotor parameters.

α is a space angle between axises of symmetry of main stator winding and short circuit coil.

For rotor currents symmetric components can be found from:

$$I_2^+ = I_1^+\frac{Z_0}{Z_0 + Z_2^+}$$

$$I_2^- = I_1^-\frac{Z_0}{Z_0 + Z_2^-}$$

Electromagnetic torque can be calculated from symmetrical components of rotor currents:

(15) $$M_{em}^{\ +} = \frac{9{,}55}{n_s}\frac{2\left|I_2^+\right|^2 R_2'}{s}$$

(16) $$M_{em}^{\ -} = \frac{9{,}55}{n_s}\frac{2\left|I_2^-\right|^2 R_2'}{2-s}$$

(17) $$M_{em} = M_{em}^{+} - M_{em}^{-}$$

Results gained from this analytic calculation performed in FORTRAN are compared to motor experimental data at rated load condition.

Table 1

Comaration of analytic calculation and experimental data

Analytic calculation	Experiment
$U_n = 220V$	$U_n = 220V$
$I_1 = 0{,}125A$	$I_1 = 0{,}125918$
$P_1 = 18{,}11404W$	$I_1 = 18W$
$\cos\varphi = 0{,}653888$	$\cos\varphi = 0{,}654$
$n = 2520\min^{-1}$	$n = 2000\min^{-1}$

Electromechanical characteristics obtained from method of symmetrical components are presented on figure 2 and 3.

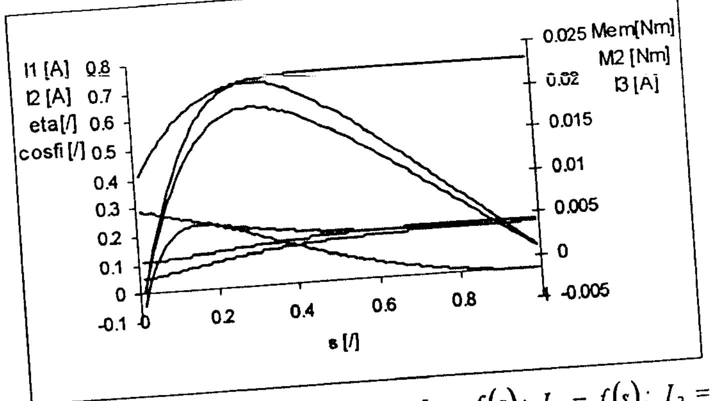

Fig. 2. Electromechanical characteristics $I_1 = f(s)$; $I_2 = f(s)$; $I_3 = f(s)$ $M_{em} = f(s)$; $M_2 = f(s)$; $\eta = f(s)$ *and* $\cos\varphi = f(s)$

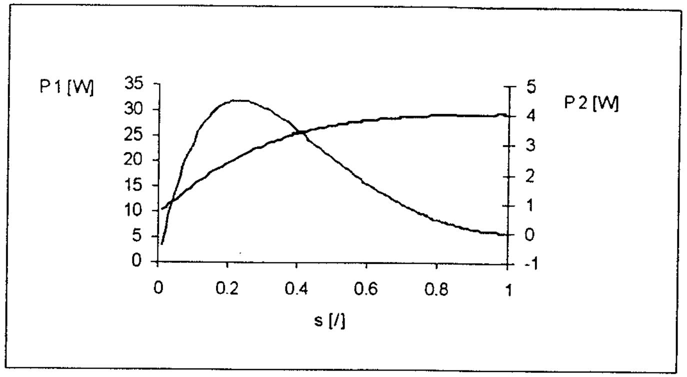

Fig. 3. Electromechanical characteristics $P_1 = f(s)$ *and* $P_2 = f(s)$

METHOD OF GENETIC ALGORITHM

In engineering practice , concept of optimization means creating better and more economical solution using existing resources. Is especially important in design of electrical machines. One powerful tool which enables creating optimal solution of designed electrical machine is numerical optimization which means optimization of certain machine parameters.

In this paper is used method of genetic algorithms and optimized parameters are current density in main stator winding Δ $\left[A/m^2\right]$, specific magnetic induction B $[T]$ and angle of rotor skew α_{sk} [°] in order larger electromagnetic torque to be achieved.

Described mathematical model of symmetric components is input in program of genetic algorithm which operates under C++ programming language. Program is using one input file in which are defined ranges of variation of above mentioned three motor parameters :

1. Current density in stator winding D [5÷10] 10^6 $[A/m^2]$.
2. Specific magnetic induction B [0.35÷0.45] [T].
3. Angle of rotor skew α_{sk} [15÷20] [°].

Program creates 6000 generations of each varied parameter . Values of varied motor parameters as well as value of electromagnetic torque through different generations are presented in Table 2.

As output program give the most favorable set of varied parameters with which the largest electromagnetic torque can be obtained.

In this specific case set of most favorable parameters are:

1. Д=5001000,00 $[A/m^2]$
2. B=0.44991 [T]

3. α_{sk} =15.00500 [°]
Value of electromagnetic torque for this set of parameters is:
$M_{em} = 0.02577164080\ Nm$.

In table 3 is given comparation between motor parameters while in table 4 is presented comparation between motor characteristics at rated load condition calculated by both methods.

As can be seen from table 4 electromagnetic torque is increased. In the same time motor currents are increased as well as efficiency factor while power factor is decreased. Comparation of electromagnetic characteristic $M_{em} = f(s)$ for both motor models is given on figure 4.

T a b l e 2

Change of motor parameters through generations by method of genetic algorithms

Nr. of generation	Current density $[A/m^2]$	Specific magnetic induction [T]	Angle of rotor skew [°]	Electromagnetic torque [Nm]
1	6.231.500,00	0,4477400	18,23	0,02400199293
200	5.007.500,00	0.4499100	15.118	0.02574312430
500	5.007.500,00	0.4499100	15.033	0.02576055752
1000	5.007.500,00	0.4499100	15.0005	0.02576719648
1500	5.005.000,00	0.4499100	15.0005	0.02576890609
6000	5.001.000,00	0.4499100	15.0005	0.02577164080

T a b l e 3

Comparation of motor parameters calculated by both methods

Parameter	Motor model by symm components method	Motor model by genetic algorithm method
Stator current density [A/m²]	Δ=8·10⁶	Δ=5001000.00
Specific magnetic induction [T]	B=0.404	B=0.44991
Rotor skew [°]	α_{sk}=17	α_{sk}=15.0005
Diameter of main stator winding wire [m]	d=1.4·10⁻⁴	d=2·10⁻⁴
Nr. of turns of main stator winding	W=3488	W=3132
Main stator winding resistance [Ω]	$R_1 = 492{,}987$	$R_1 = 243{,}4428$
Main stator winding reactance [Ω]	$X_1 = 498{,}1717$	$X_1 = 411{,}1\ 54$
Rotor winding resistance [Ω]	$_2 = 457{,}044$	$_2 =\ 6\ {,}5851$
Rotor winding reactance [Ω]	$X_2 = 76{,}7101$	$X_2 = 61{,}85346$
Sh u l s s	$R_3 = 18474{,}29$	$R_3 = 14895{,}64$
	$_3 = 127{,}5\ 15$	$_3 = 102{,}8\ 22$
M b	$X_{13} = 175{,}9108$	$X_{13} = 141{,}8407$
Mut. react. between main stator wind. and rot. wind. [Ω]	$X_{12} = 2163{,}34$	$X_{12} = 1\ 44{,}361$

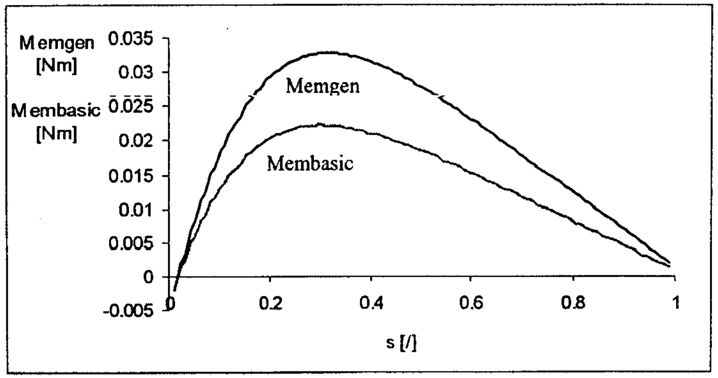

Fig. 4. Comparation of electromagnetic torques calculated by both methods

T a b l e 4

Comparation of motor characteristics calculated by both methods

Motor data	Motor model by symm. components method	Motor model by genetic algorithm method
Stator current [A]	$I_1 = 0{,}125918$	$I_1 = 0{,}167979$
Short circuit coil current	$I_3 = 0{,}006301$	$I_3 = 0{,}008270$
Rotor current	$I_2 = 0{,}087812$	$I_2 = 0{,}1175\ 4$
Power factor /	$\cos\varphi = 0{,}653888$	$\cos\varphi = 0{,}586278$
Input power [W]	$P_1 = 18{,}11404$	$P_1 = 21{,}\ \ 19$
Output power [W]	$P_2 = 4{,}149448$	$P_2 = 6{,}177527$
Efficiency factor [/]	$\eta = 0{,}229074$	$\eta = 0{,}285123$
Electromagnetic torque [Nm]	$M_{em} = 0{,}018075$	$M_{em} = 0{,}0257716408$

CONCLUSION

Main purpose of this paper is to present new model of shaded pole motor calculated by method of genetic algorithms which has increased electromagnetic torque compared to basic model of the motor , calculated by analytic method of symmetrical components.

Main goal of the calculation was achieved by increasing the electromagnetic torque from 0,018075 to 0,02576. The increasment of electromagnetic torque is followed by reasonable increasment of currents and output power while power factor is decreased. Motor model gained by method of genetic algorithm can be implemented in cases when buyer has more strict requirements regarding output power or torque. In the same time efficiency factor is significantly improved.

Method of genetic algorithms offers versatile opportunities for motor modeling by changing the number of motor variables which are varied or by changing the goal function which is optimized (for example efficiency factor instead of electromagnetic torque).

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EURODEEM – POSSIBILITIES AND CHALENGES

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Abstract. Because of the good electromechanical features and the higher reliability,the induction motors are widely spread in the world. Almost 50% of the power production is used for induction motors energy supply.That's the reazon the improvement of their energy indicators to be bound up with the improvement of industrial energy efficiency and reduction of power plants.

The European Commission and European Committee of the Manufacturers of Electrical Machines and Power Electronics (CEMEP) expect all induction motors manufactured in Europe to have the energy indicators that meet the requirements of EuroDEEM (The European Database of Efficient Electric Motors). The motors can be classified in three classes: Eff.1 – best indicators, Eff.2 – good indicators, Eff.3 – normal.

In this article is shown an application to use a software choosing three-phase induction motors for particular devices while having in mind the economic and technical criteria for the optimal choice. There are some recommendations about the application of the EU-RODEEM requirements towards the induction motor manufacturers in our country and the ways to improve the energy efficiency.

Key words: EuroDEEM, efficiency, data bases, manufacturers

The improvement of the performance of electric motor systems has been widely recognised to be one of the most important energy saving targets, because motive power accounts for about 400 TWh/ years in the European Union and about two-thirds of this amount could be saved through energy efficiency upgrading actions.

The European Commission is supporting a series of actions aimed at exploiting the large energy saving potential and namely:

- energy efficiency labeling of equipment,
- definition and implementation of efficiency standards,
- Research,Development and Demonstrations,
- Technical Tools (Calculation aids,databases)
- Voluntary agreements with Original Equipment Manufacturers (OEM) etc.