THE START OF ASYNCHRONOUS ENGINE WITHOUT PHASE SHIFT ELEMENT

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REZUMAT. Cuprinsul lucrării se referă procedeul de pornire a engineului monofazat fără înfăşurare auxiliară de pornire sau fără elemente de defazaj cunoscute şi folosite în practică. Sunt prezentate particularitățile constructive ale engineului. Fiind luate în consifderație procesele fizice corespunzătoare construcției deosebite, acestea au fost descrise matematic. Analiza matematică a permis de a determina tensiunile electromotoare induse în înfăşurări, forțele magnetizante şi cuplul electromagnetic aplicat la arbore la pornirea engineului monofazat.

Cuvinte cheie: engine asincron, elemente de defazaj, câmp magnetic, cuplu electromagnetic, axe magnetice.

ABSTRACT. The paper refers to the process of starting the single-phase engine without auxiliary starting winding or phase shift elements known and used in practice. Constructive particularities of the engine are presented in the work. Physical processes appropriate to the special construction had been considered and described mathematically. The mathematical analysis allowed determining the induced electromotive voltages in windings, the magnetizing forces and the electromagnetic torque applied to the shaft at single-phase engine start.

Keywords: asynchronous engine, phase shift elements, magnetic field, electromagnetic torque, magnetic axis.

1. INTRODUCTION

It is often necessary to transform the three-phase asynchronous engine into single-phase engine in practice, due to the lack of three-phase power supply network. A phase shift element is necessary in this case (capacity, resistance, inductance) to ensure the single-phase engine start [1].

The start can be achieved in such cases by using two phases of the stator connected to the single-phase network and one phase or two phases of the rotor.

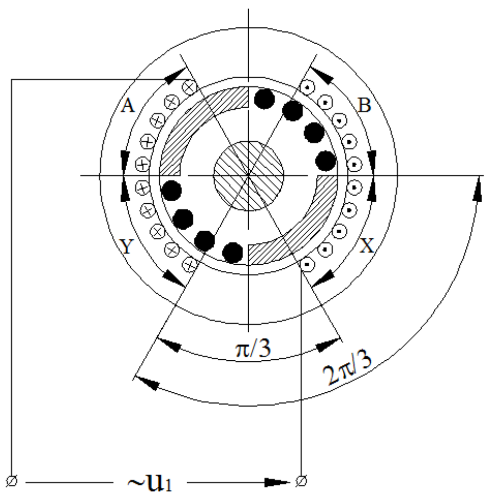

Fig. 1. The cross section of MASF with the asymmetric rotor

Half of the rotor bars are cut from the shortcutting rings if the rotor is shortcutted. Thus, three-phase engine start can be achieved being converted into single-phase engine without any phase shift element [2].

The winding of asynchronous engine without phase shift element has one phase on the stator, which occupies ⅔ of stator's package Z_1 notches (fig. 1). The rotor made of ferromagnetic solid material, or assembled from electrical steel laminations, contains cast aluminum winding, which occupies more than ½ of the rotor Z_2 notches.

Figure 2 shows the shortcutted rotor winding of the asynchronous engine with one phase on the stator.

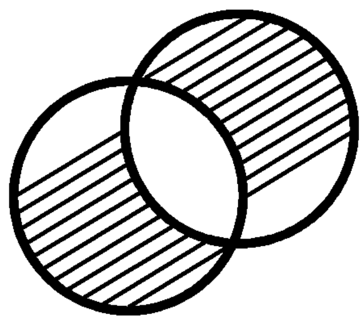

Fig. 2. The MASF rotor winding

2. MAGNETIZING FORCES AND ELECTROMOTIVE VOLTAGES

The proposed asynchronous engine has electromagnetic properties common with the repulsion engine proposed by Adkins and further revised by Arnold [3]. We assume that the magnetic axes of the stator and rotor windings coincide (fig. 3) and the rotor is in standby regime.

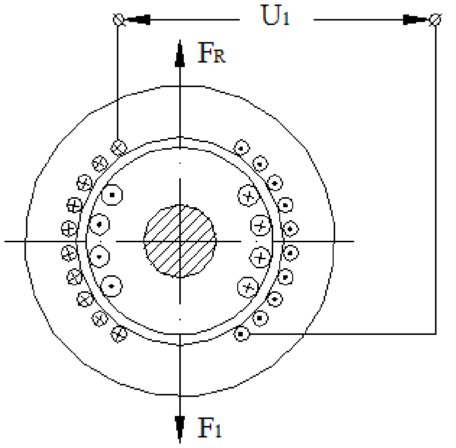

Fig. 3. The physical model of magnetizing forces representation in case if the magnetic axis of the windings coincide

At voltage supplying of stator winding the current I_1 is closing through it, which produces the magnetizing force

$$F_1 = \frac{\sqrt{2} \cdot W_1 \cdot k_{W1}}{\pi \cdot p} \cdot I_1 \quad (1)$$

oriented as it is shown in figure 3.

The magnetizing force F_1 produces the pulsed magnetic flux Φ_m, which induces the pulsed electromotive voltage in the stator winding

$$E_{1p} = \pi \cdot \sqrt{2} \cdot f_p \cdot \Phi_m \cdot W_1 \cdot k_{W1} \quad (2)$$

and in the rotor winding

$$E_{2p} = \pi \cdot \sqrt{2} \cdot f_p \cdot \Phi_m \cdot W_2 \cdot k_{W2}. \quad (3)$$

Taking into account the particularities of the rotor winding the electromotive voltage inside the bar is obtained:

$$E_{2p} = \pi \cdot \sqrt{2} \cdot f_p \cdot \Phi_m. \quad (4)$$

The magnetizing force is produced under the influence of closed rotor currents through bars and shortcut rings:

$$F_R = \frac{\sqrt{2} \cdot m_2 \cdot W_2 \cdot k_{W2}}{\pi \cdot p} \cdot I_2 \quad (5)$$

Because $m_2 = \frac{Z_2}{2}$, $W_2 = \frac{1}{2}$, and $k_{W2} = 1$ it follows that:

$$F_R = \frac{Z_2}{\sqrt{2} \cdot \pi \cdot p} \cdot I_2, \quad (6)$$

and is oriented in opposite direction of F_1 force on the same axis (fig. 3).

The magnetizing forces F_1 and F_R are operating in opposite directions, and it follows that:

$$F_1 - F_R = F_m \quad (7)$$

Taking into account the expressions (1), (6) and (7) we obtain

$$\begin{aligned} F_m &= \frac{\sqrt{2} \cdot W_1 \cdot k_{W1}}{\pi \cdot p} \cdot I_1 - \frac{Z_2}{\sqrt{2} \cdot \pi \cdot p} \cdot I_2 = \\ &= \frac{1}{\pi \cdot p}\left(\sqrt{2} \cdot W_1 \cdot k_{W1} \cdot I_1 - \frac{Z_2}{\sqrt{2}} \cdot I_2\right) \end{aligned}. \quad (8)$$

The resultant pulsating force F_m produces the respective succession fluxes being decomposed into direct and reverse successions. These fluxes create couples oriented in opposite directions by interacting with respective currents, thus the rotor remains still. This regime corresponds to shortcut regime [4].

The voltages' equations are as follows:

$$\left.\begin{aligned} \underline{U}_{sc} &= -\underline{E}_1 + \underline{I}_{1sc}(r_1 + jX_1) \\ 0 &= \underline{E}_2 - \underline{I}_{2sc}(r_2 + jX_2) \end{aligned}\right| \quad (9)$$

Further, we admit that the axes of stator and rotor windings form an angle equal to $\pi/2$ electrical degrees and the rotor is still (fig. 4).

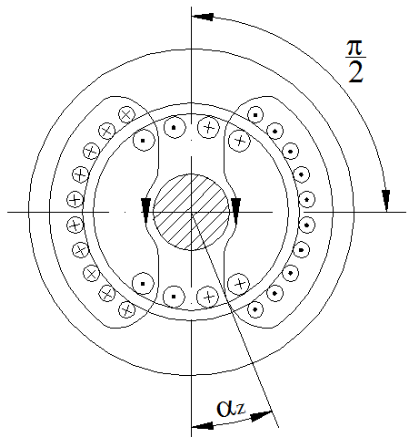

Fig. 4. The physical model of representation of phase shifted windings by π/2 angle

The magnetizing force F_1 produces the pulsed magnetic flux Φ_m, which induces electromotive voltages shifted by phase at α_z angle in the rotor winding bars

$$E_{2b} = \sqrt{2} \cdot \pi \cdot f_1 \cdot \Phi_m \cdot l_\delta \cdot \sin \alpha_{Z2} \qquad (10)$$

and

$$\alpha_{Z2} = \frac{2p \cdot \pi}{Z_2}. \qquad (11)$$

The I_2currents are closing under the influence of electromotive voltage E_{2b} through the rotor winding bars. The currents from the bars placed on both sides of the axis of stator winding produce the magnetizing forces oriented in opposite directions F_{R1} and F_{R2} (fig. 5), which can be written as

$$F_{R1} = \frac{Z_2}{\sqrt{2} \cdot \pi \cdot p} \cdot \frac{I_2}{2} \qquad (12)$$

and

$$F_{R2} = \frac{Z_2}{\sqrt{2} \cdot \pi \cdot p} \cdot \left(- \frac{I_2}{2} \right). \qquad (13)$$

As a result, these two couples applied to the rotor are likewise oriented in opposite directions and their sum is equal to zero. Thus, the rotor will remain still.

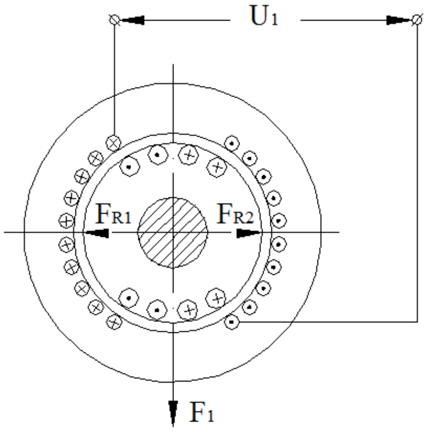

Fig. 5. Graphical representation of the magnetizing forces F_{R1} and F_{R2}

The equilibrium equations of voltages will be the same as those for the case when the stator and rotor windings axes coincide (9).

In the last case we admit that the magnetic axis of the stator and rotor winding are forming the γ angle. We, also, admit that the rotor rotates with an angular speed Ω in clockwise direction. It is evident that an electromotive voltage named of the displacement E_{2R} is induces in the rotor winding. The amplitude of the induced electromotive voltage does not dependent on the magnetic flux pulsation, but only on the angular speed of the rotor, as it is in the direct current machines

$$E_{2R} = K \cdot \Omega \cdot \frac{\Phi_m}{\sqrt{2}} \qquad (14)$$

where $K = \frac{p \cdot N}{2\pi \cdot a}$.

One can decompose the stator magnetizing force F_1 into two components (fig. 6) oriented by:
the magnetic axis of the rotor winding d_R

$$\underline{F_{s1}} = \underline{F_1} \cdot \cos \gamma \qquad (15)$$

the magnetic axis of the rotor winding q_R

$$\underline{F_{s2}} = \underline{F_1} \cdot \sin \gamma \ . \qquad (16)$$

The rotor magnetizing force F_R can, also, be decomposed into two components oriented by:
the magnetic axis of the stator winding α_s

$$\underline{F_{R1}} = \underline{F_R} \cdot \sin \gamma \qquad (17)$$

the magnetic axis of the stator winding β_s

$$\underline{F_{R2}} = \underline{F_R} \cdot \cos \gamma . \qquad (18)$$

The electromagnetic force proportionate to the

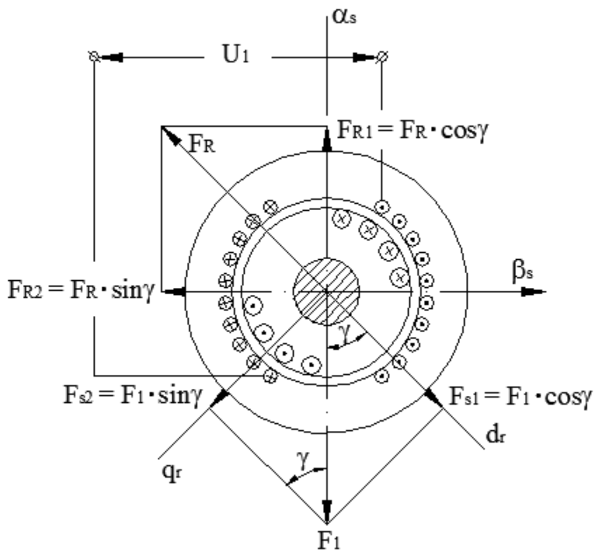

Fig. 6. Decomposition of stator F_1 and rotor F_R magnetizing forces

magnetic fluxes and stator and rotor currents produce electromagnetic couples acting on the rotor. The forces $\underline{F}_1$ and $\underline{F}_{R1}$ are partially compensated reciprocally. The same partial compensation exists between forces $\underline{F}_R$ and $\underline{F}_{s1}$.

Therefore, the electromagnetic force produced by the magnetic flux Φ_m and the rotor current I_2 closed through the rotor winding will act on the rotor. The I_2 curent increases due to the appearance of the displacement electromotive voltage E_{Rd}. Thus, the reciprocal position of the axes α_s, β_s and respectively d_R, q_R determined by the γ angle, assure the start of the single-phase asyncronous engine without phase shift element.

The current $I_2 = I_{2\max}$ for $\gamma = 0$, but $\Phi_m = 0$, then the electromagnetic torque is:

$$M = k \cdot \Phi_m \cdot I_2 \cos\varphi_2 = 0 \qquad (19)$$

If $\gamma = \pi/2$, then $I_2 = 0$ despite the fact that the flux $\Phi_m = \Phi_{max}$, $M = 0$.

The current $I_2 = I_{2\max}$ for $\gamma = \pi/4$, and the magnetic flux is produced by $\underline{F}_1$ - $\underline{F}_{R1}$ and assures the engine start.

3. THE CALCULATION OF ROTOR WINDING PARAMETERS

The resistances and reactances of stator windings are calculated using the known methods described in literature of specialty [5]. The parameters of shortcutted rotor winding, indicated din figure 2, has calculation particularities different from those of the symmetric rotor winding.

The resistance of rotor bars placed under one pole and those of the shortcut rings' segments between two neighbour bars is given by the expression:

$$r_t = \rho \frac{l_b}{q_b \cdot n} + \frac{2 \cdot \pi \cdot D}{n \cdot Z_2} \cdot \frac{\rho}{q_I} \qquad (20)$$

The total reactance of the rotor winding is:

$$x_t = 4 \cdot l_\delta \cdot f_1 \left(\lambda_c + \lambda_d + \lambda_f\right) \cdot 10^{-6} \qquad (21)$$

The reistance and dispersion reactance values reported to the dispersion winding are expressed as follows:

$$r'_2 = k \cdot r_2; \quad x'_2 = k \cdot x_2 , \qquad (22)$$

where $k = \dfrac{4 \cdot m_1 \cdot (W_1 \cdot k_{W1})^2}{Z_2}$.

4. CONCLUSIONS

- ✓ The possibility of using single-phase or three-phase engines supplied from the single-phase network without phase shift elements was found.
- ✓ The constructive elements of windings used in this case had been indicated. The equilibrium equations of voltages describe the processes present in the engine.
- ✓ The expressions for determining the perameters of the rotor winding and magnetizing forces had been shown.
- ✓ The rotor position in reference to the stator winding was determined for obtaining a maximum start torque.

REFERENCES

[1] **E. Lopuhina.** „Asinhronnîe ispolnitelnîe microdvigateli dlea sistem avtomatiki", Moskva, Vîsşaia Şcola, 1988, p. 327.

[2] **T. Ambros, A. Câmpeanu, C. Carabadjac** „Metode de compensare a succesiunii inverse în motoarele asincrone monofazate" Prima Conferința Internațională de sisteme electromecanice, Chişinău, 1997.

[3] **M. Burduniuc, P. Lungu, T. Ambros** „Motoare monofazate fără element de defazaj" Conferința Tehnico-Științifică a studenților şi doctoranzilor, Chişinău, 2012, p. 475-476.

[4] **T. Ambros, M. Burduniuc,** „Compensarea succesiunilor curenților rotorici la pornirea motorului cu o singură fază" Conferința Tehnico-Științifică a studenților şi doctoranzilor, Chişinău, 2011, p. 260-264.

[5] **T. Ambros** „Proiectarea maşinilor electrice" Universitatea Tehnică a Moldovei, Chişinău 2004, p.210.

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