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Contribution to the Improvement of the Technological Performances of Single Phase Induction Motor with Capacitor (MAC)

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Abstract: Questions of great interest deserve to be raised in the precise calculation of the single phase induction motor. They relate to the influence of the active losses in iron and of the higher harmonics on the technological performances. These problems were developed a little for the symmetrical machines. On the other hand, they were the subject often of negligence in the research tasks for the actuators of low power. Their consideration more complicates the mathematical models and consequently calculations of the technological performances. The consideration of these two non linearities made it possible to improve rigorously precision of the calculation of the mechanical characteristic and the energy indices of condenser micro motor. The results obtained as well theoretical as experimental confirm well the considerable impact of the losses iron and the higher harmonics on the characteristics. This constrained to hold account of it in any calculation of optimization of the asynchronous condenser micro motors.

Key words: Induction motor, performances, quality

INTRODUCTION

The electric micro motors integrated in the accessories of small power which assist us with the daily work are seldom treated in the scientific and technological literature. These generally discrete actuators and of great diffusion are everywhere (Multon, 2000). Theoretical and experimental research on the micro motors is complex. Although they function with the same physical principles as the machines of large and average powers, it is that the negligible technico- economical effects for these last are not it any more for them (Stolting and Beisse, 1991).

In front of the great diversity of these actuators, our research will be limited to the micro motors with induction single-phase current with cage very snuffed in the applications of great series. They are a priori robust, of simple and economic manufacture for a long lifespan. Our approach rests on the resumption of the calculation of their technological performances by taking account of some non linearities such as the higher losses iron and harmonics.

During the dimensioning of the three-phase and symmetrical electric machines of averages and great powers we suppose their effect is often supposed relatively negligible (Alikhanian, 1976).

Their taking into account is justified times by the introduction of coefficients calculated on the basis of empirical or semi formula empirical (Poloujadoff, 1964; Grellet, 1989). However, in the case of the asymmetrical engines supplied with single-phase current and to low power their impact is so significant on the technological dimensioning and performances which we cannot be unaware of them.

Influence higher losses iron and harmonics

Influence losses iron: The presence of the opposite component of the current in the asymmetrical engines contributes to the growth of the absorptive Power (P_S) covering all the losses related to the components direct and opposite and implies the weakening of the mechanical power.

Consequently all this led to the reduction in the output and the restriction of the use of the asynchronous motor single-phase current.

The losses iron appear in the asymmetrical asynchronous micro engine following the elliptic spinning field pattern (Hammond and Rogers, 1974). They can be defined as the sum of the losses due respectively to the fields direct and opposite (Ernst, 2001; Muljadi, 1993).

The possibility of considering the influence of these losses is to use the corrected primitive electric model (Fig.1).

$$r_{mA} = 2\, E^2_{A1}/\Delta\, P_{Fer\, S1} = 2\, E^2_{A2}/\Delta\, P_{Fer\, S2} \tag{1}$$

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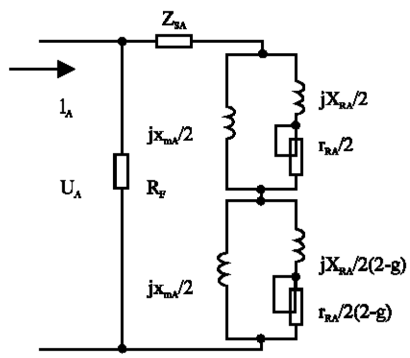

Fig. 1: Electric model with taking into account of the losses iron (Collkins, 1991)

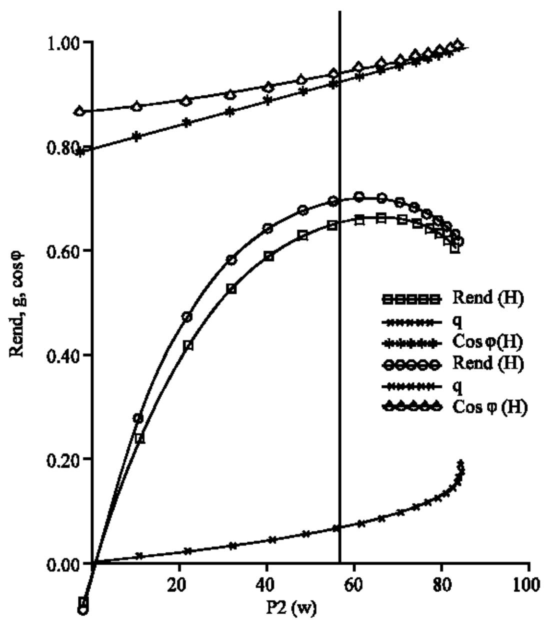

Fig. 2: Influence losses iron on the external indices of single phase induction motor with capacitor P = 60W; 2p = 2

with:

$$E_{A1} = I_{A1}(r_{rA1}+jx_{rA1});\quad E_{A2} = I_{A2}(r_{rA2}+jx_{rA2})$$

$$\Delta P_{Fer\,S2} = \Delta P_{Fer\,S1}(E^2_{A2}/E^2_{A1})$$

The precise calculation of the active losses in the iron of the rotor proves very delicate. It can be solved by the same method applied to the stator. But the electric and mathematical model becomes cumbersome and complicated. However as their values are really unimportant it without much error is allowed to neglect them.

The error on the calculation of the losses iron comes owing to the fact that the complementary currents are supposed in phase with the tension U and not with the fém E_{A1} and E_{A2}.

The correction of the electric model traditionel by the insertion of an active resistance in the magnetizing pocket and the evaluation progressively stator losses iron for each variation of the coefficient of saturation K_μ contributes to reduce this error amply.

The precision of the fem $E_{1(1)}$ of the fundamental harmonic during the calculation of the magnetic circuit (R_{my}, X_{my}) is obtained by an iterative calculation with: like first approximation

$E_{1(1)} = 0.9\ U_{nom.}$ for g = 0.005 (first point for the mode with vacuum) and like criterion of end of the iteration:

$$|\Delta E|<1$$

The mathematical model (2) adapted for the calculation of the forward currents and stator and rotor opposite by taking account of the influence of the losses iron has as a base the electric model corrected according to.the following :

The fascinating mathematical model in consideration the losses iron is as follows [Lapoukhina, 80].

$$\begin{vmatrix} U \\ U \\ \\ 0 \\ 0 \end{vmatrix} \begin{Vmatrix} Z_{SA}+Z_{OA} & Z_{SA}+Z_{OA} & Z_{OA} & Z_{OA} \\ (j/k)(Z_{SB}+ & -(j/k)(Z_{SB}+ & (j/k)(Z_{OB}) & -(j/k)(Z_{OB}) \\ Z_C+Z_{OB}) & Z_C+Z_{OB}) & & \\ Z_{OA} & 0 & Z_{OA}jx_{RA}+r_{RA}/g & 0 \\ 0 & Z_{OA} & 0 & Z_{OA}+jx_{RA} \\ & & & +r_{RA}/(2-g) \end{Vmatrix} \begin{vmatrix} I_{A1} \\ I_{A2} \\ \\ I_{RA1} \\ I_{RA2} \end{vmatrix} \qquad (2)$$

avec:

$$Z_{OA} = jx_{mA}\,r_{mA}/r_{mA}+jx_{mA};\quad Z_{SA} = r_{SA}+jx_{SA};$$
$$Z_{SB} = r_{SB}+jx_{SB};\quad Z_{OB} = k^2 Z_{OA}$$

The precise values of the stator currents make it possible to obtain a clear improvement in the evaluation of the electric losses in the stator and the condenser as well as the precision of the factor of power. The computation results are represented on Fig. 2.

Influence higher harmonics of space: Degree of importance of the impact of the higher harmonics of space on the external characteristics. The current asynchronous motors of low power have stator windings carried out for a number of notches per pole and by phase (q) relatively small C' is why the taking into account of the higher harmonics of space becomes very current and their role is accentuated even more when they are asynchronous micro engines single-phase currents because of the presence of the third harmonic.

The presence of the higher harmonics of space of the magnetic field is justified by non the sinusoïdality of the distribution of the whorls and the magnetomotive force through the boring of the stator.

Models electric and mathematical suggested for the catch in count higher harmonics: The electric model which takes into account the influence of the higher harmonics of space is represented in Fig. 3. The model mathematical (2) is intended for the study and asynchronous micro engine single-phase current with condenser (SPIM) analyzes

We can have an infinity of equation but we limit ourselves to consider only five higher harmonics. The computation results confirm that only the 3^{2nd}, 5^{2nd} and 7^{2nd} harmonics have a rather remarkable influence (Fig. 3) on the characteristics of the micro asynchronous motor single-phase current (Lapoukhina and Sementlchouhou, 1980) the mathematical model for the micro motor single-phase with cage rotor with the taking into account of the higher harmonics is presented as follows

$$\hat{U} = I_{A1}[r_{SA}+j(x_{SA}+\sum_{\nu} x_{vmA})] + I_{A2}[r_{SA}+j(x_{SA}+\sum_{\nu} x_{vmA})] + j\sum_{\nu} I_{vR1}\, x_{vmA} + j\sum_{\nu} I_{vR1}\, x_{vmA}$$

$$\hat{U}_k = jI_{A1}[r_{SB}+j(x_{SB}+k^2\sum_{\nu} x_{vmA} - x_C)] - j\,I_{A2}\,[r_{SB}+j(x_{SB}+k^2\sum_{\nu} x_{vmA} - x_C)] - k^2\sum_{\nu} I_{vR1}\, x_{vmA} + k^2\sum_{\nu} I_{vR2}\, x_{vmA}$$

$$0 = j\,I_{A1}\, x_{vmA} + I_{vR1}[\,r_{vRA}/\,g_{v1} + j\,(x_{vRA} + x_{vmA})]$$

$$0 = j\,I_{A2}\, x_{vmA} + I_{vR2}[\,r_{vRA}/\,g_{v2} + j\,(x_{vRA} + x_{vmA})]$$

The resolution of the model by computer allows calculation and analyzes characteristics of the condenser micro motor.

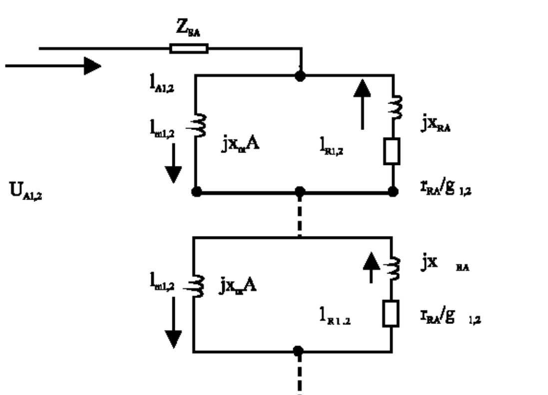

Fig. 3: Electric model for the micro motor single-phase current with element of starting and the influence of the higher harmonics

The couple resulting from the symmetrical components

$$C_{1,2} = 2\sum_{\nu=1} (\nu.\, I_{\nu R1,2}\, /\, \Omega_0\, G_{\nu 1,2})\, r_{\nu R} \quad (4)$$

where Ω_0 is the angular velocity of synchronism of the fundamental harmonic of the field. The resulting couple:

$$C = C_1 - C_2 \quad (5)$$

The coefficient of saturation K_μ is given on the basis of developed method of precise calculation of the magnetic circuit of the micro motor.

The iterative procedure converges quickly and requires to the maximum 3 to 5 approximations.

In the capacity as first approximation $E_{1(1)} = 0.9U_n$ for g = 0.005.

$$\Delta E_{(1)} = E_{1(2)} - E_{1(1)}$$

$$E_{1(i)} = E_{1(i-1)} + (E_{1(i-1)} - E_{1(i-2)})\, \Delta E_{(i-1)}/\Delta E_{1(i-2)} - \Delta E_{1(i-1)} \quad (6)$$

RESULTS AND DISCUSSION

The program (Fig. 4) was tested on asynchronous micro engines single-phase currents with condenser of various powers. Moreover calculation was carried out for the fundamental one and five harmonics of a higher nature: The fundamental one, the third, the fifth, the seventh and two principal harmonics of teeth

The computation results are compared with those raised in experiments (Fig. 5).

The Table 1 gathers the computation results and experimental obtained for two resistivities different from the bars rotoriquess $\rho = 0.0440\ \mu\Omega$ m and $\rho = 0.055\ \mu\Omega$ m. and at a temperature of service of 75°.

Analyze computation results and experimental of MAC: The inrush current I_D and the couple C_D calculated practically do not differ from those experimental L' variation of the computation results and tried out do not exceed the 10-15% (Table 1)

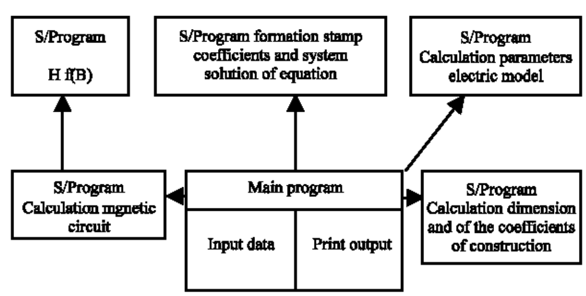

Fig. 4: Diagram of the calculation programme of the characteristics of MAC (Lapoukhina and Sementtchoukov, 1980)

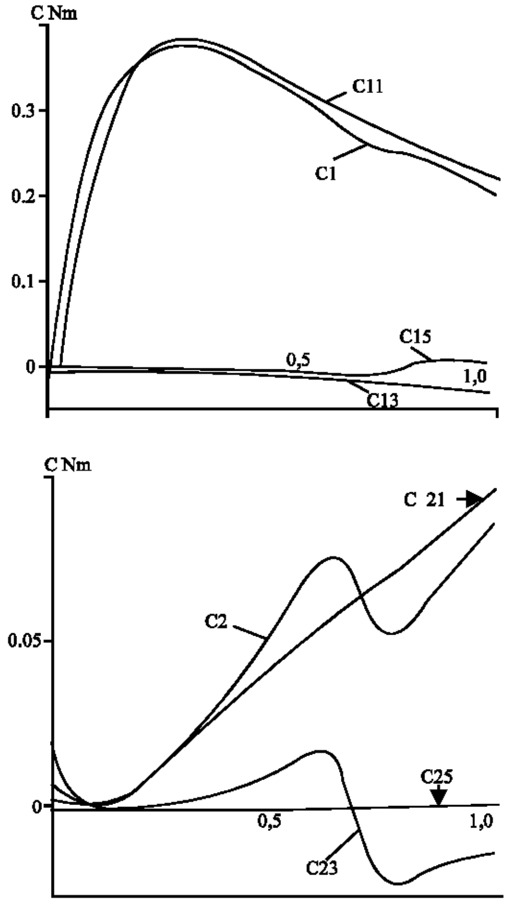

Fig. 5: Direct couples (A) and opposite (b) and respectively their higher harmonics of Mac-50 space: P = 50W; 2p = 2

Table 1: Comparison of the calculated results and Experimental P = 50W; 2p = 2

Sizes	Calculated ρ= 0.044 (μΩ,m)	Calculated ρ = 0.055 (μΩ,m)	Experimental
I_o	0.21	0.208	0.22
I_d	1.115	1.034	1.015
P_{S0}	41.7	43.4	43.8
P_{Sd}	246.1	231	217.4
C_d	0.118	0.13	0.109

The variation of the calculated no-load current I_0 is below 5% compared to the experimental one.

For the absorptive power with vacuum with the two various resistivities, the variation is 5%.

The cracks and the bumps on the mechanical characteristic are conditioned initially by the 3^{2nd} harmonic of the opposite field and in a degree the less couple of the 5^{2nd} harmonic of the direct field.

The calculations carried out on several micro engines single-phase currents reveal that the higher harmonics of space exert a significant influence on the mechanical characteristic Fig. 6.

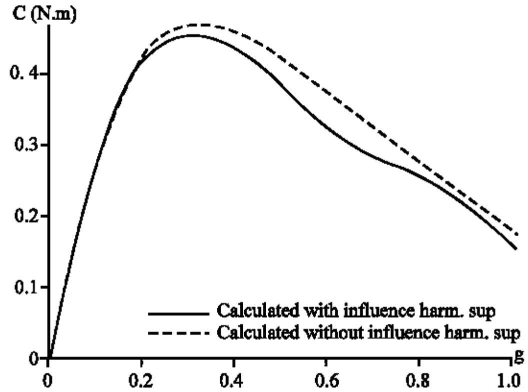

Fig. 6: Mechanical characteristics of Mac-60 and the impact higher harmonics of space P = 60W, 2p = 2 (Lapoukhina and Sementtchoukov, 1980; Muljadi, 1993)

This influence is concretized by a regression of 8 à12% of the computed values for the 1 and 3, starting torque to 5% for the maximum couple to 4% for the nominal couple.

The divergence of the results does not exceed the 10 à15%. The form of the electromechanical characteristics calculated by computer and experimental is the same one. For a lower operating temperature currents I_A, I and the power P_{SA}, P_S calculated increase with starting and are found in the field of the experimental data. The starting torque varies little.

CONCLUSION

The taking into account of the losses iron and the harmonics higher in the calculation of the technological performances of condenser the micro engine single-phase current contributes to the improvement of their precision at the time of their design. These results can be also exploited for the precision of the parameters of the condenser micro motors.

The technological performances obtained of the micro engines can be still better if the consideration of the irregularity of the air-gap, of the mutual influence of teeth and the currents between the rotor bars is taken into account. A method of precision of the calculation of the magnetic circuit and determination of the parameters of their equivalent electric circuits, plus a best alternative of the condenser will contribute enormously to qualitative calculation preliminary for the construction of the condenser micro motors in the various constant-speed drives or variable like to the establishment of their healthy mathematical model for the various techniques of detection of the failures.

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