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Geometry influence of stator and rotor armatures on energy efficiency of induction motors

Ion Voncilă, Elena Selim, Ion Paraschiv

Abstract. *This paper presents the geometry influence of stator and rotor armatures on induction motor energy efficiency. The entire work is analyzed using a Motor-CAD programming environment. In principle, in the first stage, the influence of each armature is distinctly visualized upon loss level, for given effective power and given cooling algorithm through geometry changes that concern aspects related to the dimensions of the ferromagnetic core and the notches practiced within it. Afterwards, in a second stage, a synergistic modification of the induction motor geometry is carried out by cumulating the changes (cooperative effect) at the level of the two armatures, aiming to find the topology that provides – for some given effective power, and cooling algorithm – the highest energy efficiency.*

Keywords*: induction motor, energy efficiency, geometrical optimization*

1. Introduction

Induction motors have a wide applicability in industry, being used in electric drive systems from low power (hundreds of W) to high power (tens of MW). In these circumstances, the visualization of the energy efficiency of this motor has a great importance for practice, because reducing the impact on the environment calls for an overall increase in efficiency. It is worth noting that the power of electric motors, according to the classic design algorithm, is proportional to their volume. Therefore, a structure of a certain volume, in the vision of some smooth armature/ without notches, allows the development of a particular global power; being a conservative system, each motor, at an effective power developed at the shaft, will also claim an amount of losses in the electromechanical conversion process. The real induction motor has notched armatures and contains, within its structure, both windings, placed in these notches, and ferromagnetic core (into which the notches are made). Thus, the issue of conversion becomes more complicated, the technical and energetic performances of the engine being strongly influenced by the geometrical particularities of the two armatures. The influence of the stator and rotor armature geometry on the technical performance of the squirrel cage rotor induction motor is highlighted in various specialized works [1], [2], [3]. The visualization of energy performances is presented, as an historical evolution for induction motors - in the paper [4], which also highlights the importance of armatures geometry and the materials embedded within the structures of electromechanical conversion, to ensure a high efficiency of these motors.

Of course, knowing these influences on the technical and energetical performances of the geometry of the stator and rotor armatures, in the case of induction motors, many works also deal with the ways in which these performances can be improved [5], [6], [7], [8]. Defining new classes of energy efficiency as well as finding new applications for induction motors is a continuous concern of both the academic world and industry specialists, highlighted in works [9], [10], [11]. This paper studies how the structural modifications of the two armatures of the induction motor (modification of the notches number, modification of the shape of the notches and, implicitly, the teeth) influence the losses quantity developed within it (ultimately influencing the efficiency /motor energy efficiency).

2. Determination of energy efficiency for the reference geometry of the induction motor

To view the total losses within the structure of an induction motor, related to reference geometry, the Motor-CAD programming environment was used. The defining sizes of the structure and the cross-section of the reference geometry of the induction motor chosen for the study are shown in Figure 1. Figure 2 shows a detailed view regarding the internal structure of the two armatures of the motor, with the stated purpose of visualizing the particularities of the notches (and teeth) on the stator and rotor armatures (which constitute the reference for the following analyzes within the work).

As can be seen from Figures 1 and 2, in the case of the reference geometry, the stator and rotor notches are trapezoidal in shape, while the teeth on the two armatures are rectangular. The number of notches on the two armatures, in the case of the reference geometry, has the following values (Fig. 1): Z1=18, Z2=26 respectively.

Next, in the case of reference geometry, the level and distribution of losses within the constituent elements of the induction motor were evaluated in two cases: a) for given cooling (natural convection at the limit value, from a temperate-continental climate, of the ambient temperature, respectively , $T_a = 40^0$ C) – without taking into account the variation of losses with temperature (Table 1); b) for given cooling (natural convection at the limit value, from a temperate-continental climate, of the ambient temperature, respectively, $T_a = 40^0$ C) - taking into account the variation of losses with temperature (Table 2).

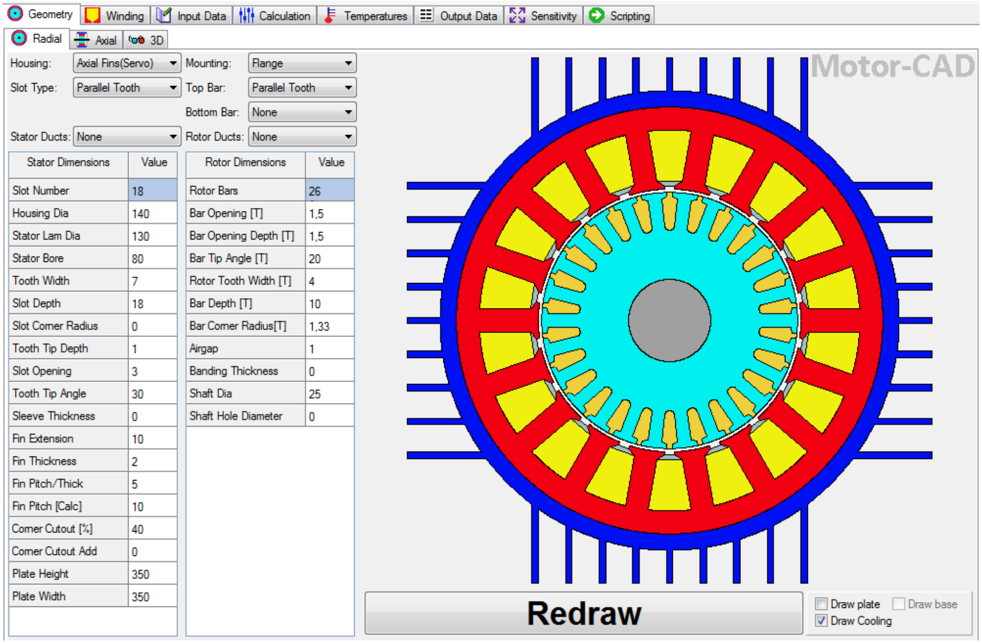

Figure 1. Reference geometry of analyzed induction motor

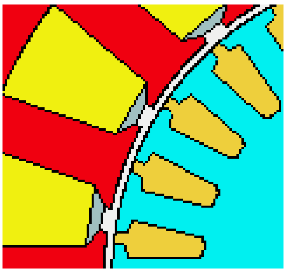

Figure 2. The shape of teeth and notches in the analyzed induction motor – reference geometry

In the case of considering the variation of losses with temperature, the following were used:

- The variation of the conductive material resistivity with temperature (copper for the stator winding, respectively aluminum for the rotor winding), in the form of:

$$\rho_T = \rho_{20}(1 + \alpha(T - 20)) \quad (1)$$

where: ρ_T - is the resistivity value of the material at a working temperature T.

ρ_{20} - is the value of the resistivity of the material at the reference temperature, indicated in the standards ($\rho_{20_{Copper}} = 1{,}72 \times 10^{-8} \lfloor \Omega m \rfloor$, $\rho_{20_{Al}}=$ 2,82$\times$ $10^{-8} \lfloor \Omega m \rfloor$);

a – is the coefficient of variation with temperature of the resistance of the conductive materials used for analysis ($\alpha_{Copper} = 4 \times 10^{-3} \left\lfloor {}^{1}/{}_{{}^\circ C} \right\rfloor$, $\alpha_{Al} =$ $4{,}3 \times 10^{-3} \left\lfloor {}^{1}/{}_{{}^\circ C} \right\rfloor$).

- Variation of shaft speed losses in the form of:

$$P_{speed} = P_{input} \times \left\lfloor \frac{Shaft\ speed}{Speed\lfloor REF \rfloor} \right\rfloor^{coef\lfloor A \rfloor} \tag{2}$$

where: $Speed\lfloor REF \rfloor = 3000\lfloor rpm \rfloor$; $coef\lfloor A \rfloor$ = 1,5, values valid for the variation of losses in the stator ferromagnetic core; $Speed\lfloor REF \rfloor = 3000\lfloor rpm \rfloor$; $coef\lfloor A \rfloor =$ 1 – for variation of bearing losses.

Table 1 shows both the distribution of losses developed within the structure of electromechanical conversion (without considering variation with temperature) and distribution of dissipated losses to the environment, to achieve thermal equilibrium with it, in the case of reference geometry, with the number of notches mentioned in Figure 1 and the shape of the notches and teeth, on the two armatures, highlighted in Figure 2.

Table 1. Distribution of losses within the induction motor structure, for reference geometry, without considering variation with temperature

Developed losses Z1=18; Z2=26		Dissipated losses in the environment Z1=18; Z2=26	
Variable	Value [W]	Variable	Value [W]
Loss [Stator Copper]	120	Main Winding (Copper Loss Multiplier)	1
Loss [Stray Load Stator Copper]	0	Stall Operation (Copper Loss Multiplier)	1
Loss [Stator Copper] (Active)	63,55	Fault Operation (Copper Loss Multiplier)	1
Loss [Stator Copper] (EWdg Front)	28,22	Loss[Stator Back Iron] Schematic Addition	0
Loss [Stator Copper] (EWdg Rear)	28,22	-----	
-----		Dissipation - Housing - Active [Con]	27,37
Loss [Stator Back Iron]	30	Dissipation - Housing - Active [Rad]	28,86
Loss [Stator Tooth]	40	Dissipation - Front Housing OH [Con]	14,53
-----		Dissipation - Front Housing OH [Rad]	15,44
Loss [Rotor Cage]	50	Dissipation - Rear Housing OH [Con]	16,13

Developed losses Z1=18; Z2=26		Dissipated losses in the environment Z1=18; Z2=26	
Variable	Value [W]	Variable	Value [W]
Loss [Rotor Cage] (Active)	42,36	Dissipation - Rear Housing OH [Rad]	17,03
Loss [Rotor Cage] (EndRing Front)	3,818	Dissipation - Front Endcap [Con]	1,009
Loss [Rotor Cage] (EndRing Rear)	3,821	Dissipation - Front Endcap [Rad]	1,409
-----		Dissipation - Rear Endcap [Con]	7,546
Loss [Stray Load Iron]	0	Dissipation - Rear Endcap [Rad]	9,612
Loss [Stray Load Stator Iron]	0	Dissipation - Plate [Con]	44,4
Loss [Stray Load Rotor Iron]	0	Dissipation - Plate [Rad]	69,42
Loss [Rotor Tooth]	20	Total Dissipation to model ambient node	260
Loss [Total]	260		

Table 2 underlines the same data, as shown in Table 1, but considers variation in relation to the temperature of the losses developed within the analyzed induction motor.

Table 2. Distribution of losses within the induction motor structure, for reference geometry, considering variation with temperature

Developed losses Z1=18; Z2=26		Dissipated losses in the environment Z1=18; Z2=26	
Variable	Value [W]	Variable	Value [W]
Loss [Stator Copper]	176,8	Main Winding (Copper Loss Multiplier)	1
Loss [Stray Load Stator Copper]	0	Stall Operation (Copper Loss Multiplier)	1
Loss [Stator Copper] (Active)	93,61	Fault Operation (Copper Loss Multiplier)	1
Loss [Stator Copper] (EWdg Front)	41,57	Loss [Stator Back Iron] Schematic Addition	0
Loss [Stator Copper] (EWdg Rear)	41,57	-----	
-----		Dissipation - Housing - Active [Con]	37,36
Loss [Stator Back Iron]	30	Dissipation - Housing - Active [Rad]	39,3
Loss [Stator Tooth]	40	Dissipation - Front Housing OH [Con]	19,79
-----		Dissipation - Front Housing OH [Rad]	20,78
Loss [Rotor Cage]	80,3	Dissipation - Rear Housing OH [Con]	22
Loss [Rotor Cage] (Active)	68,03	Dissipation - Rear Housing OH [Rad]	23,12
Loss [Rotor Cage] (EndRing Front)	6,13	Dissipation - Front Endcap [Con]	1,326
Loss [Rotor Cage] (EndRing Rear)	6,135	Dissipation - Front Endcap [Rad]	1,846

Developed losses Z1=18; Z2=26		Dissipated losses in the environment Z1=18; Z2=26	
Variable	Value [W]	Variable	Value [W]
-----		Dissipation - Rear Endcap [Con]	10,04
Loss [Stray Load Iron]	0	Dissipation - Rear Endcap [Rad]	13,04
Loss [Stray Load Stator Iron]	0	Dissipation - Plate [Con]	58,23
Loss [Stray Load Rotor Iron]	0	Dissipation - Plate [Rad]	90,65
Loss [Rotor Tooth]	20	Total Dissipation to model ambient node	347,054
Loss [Total]	347,054		

There is a strong variation with temperature of the losses of the two windings: stator and rotor, respectively. On the other hand, it is noted that the cooling process is sufficient to eliminate the developed losses, without being able to specify the thermal time constant to achieve the balance with the environment. The energy efficiency assessment will be made based on a comparative analysis, which is ultimately the case for given technical characteristics when balancing the losses developed within the structure.

3. Determination of energy efficiency for changes in the geometry of stator and rotor armatures of the induction motor

By means of Motor-CAD programming environment, were analyzed the effects generated at the level of the total losses in the motor, but also on the components of the losses developed in the constitutive subassemblies of the induction motor, by changing the geometry of each armature, but also by a synergistic change, cumulative, of the two basic armatures of such type of motor. First, the results are presented for the losses within the induction motor, losses based on which, for a given effective shaft power, the efficiency of this motor can be determined (the classic formulation of the concept of energy efficiency).

As stated above, the evaluation is done by effectively comparing the total losses within the conversion structure.

In the following, the obtained results are presented in an analytical manner, by quantifying the level of losses at the variation of the geometry of each armature of the motor (cases A and B), followed by the case of the synergistic, cumulative change of the global geometry of the induction motor (case C). It is worth mentioning that the geometry of the motor still retains cylindrical symmetry on a macroscopic level, the changes being aimed at the internal components of the induction motor structure (ferromagnetic core, geometry of the notches, etc.).

A. Stator armature geometry modification

a) Increasing the number of stator notches Z1 = 24

For this case, the distribution of the main losses within the structure of the induction motor is comparatively presented, in the case of considering the variation of losses with temperature, with the distribution of the same categories of losses for the reference geometry, in Table 3.

Table 3. Distribution of losses within the structure of the induction motor, modified stator geometry (notches number), considering variation with temperature

Developed losses for reference geometry Z1=18; Z2=26		Losses developed for modified stator geometry Z1=24; Z2=26	
Variable	Value [W]	Variable	Value [W]
Loss [Stator Copper]	176,8	Loss [Stator Copper]	175,5
Loss [Stator Copper] (Active)	93,61	Loss [Stator Copper] (Active)	81,12
Loss [Stator Copper] (EWdg Front)	41,57	Loss [Stator Copper] (EWdg Front)	47,18
Loss [Stator Copper] (EWdg Rear)	41,57	Loss [Stator Copper] (EWdg Rear)	47,18
Loss [Rotor Cage]	80,3	Loss [Rotor Cage]	80,09
Loss [Rotor Cage] (Active)	68,03	Loss [Rotor Cage] (Active)	67,85
Loss [Rotor Cage] (EndRing Front)	6,13	Loss [Rotor Cage] (EndRing Front)	6,114
Loss [Rotor Cage] (EndRing Rear)	6,135	Loss [Rotor Cage] (EndRing Rear)	6,119
Loss [Total]	347,054	Loss [Total]	345,563

b) Modification of stator notch shape, rectangular notches: Z1 = 18

The new shape of the stator notches is exemplified in the detail shown in Figure 3.

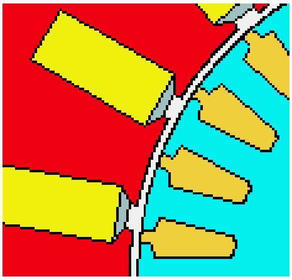

Figure 3. The shape of teeth and notches for the analyzed induction motor, modified stator geometry

Table 4 shows, also through comparative analysis regarding the reference geometry, the distribution of the main losses within the structure of the induction motor, considering the variation of these losses with temperature, for the case of changing the shape of the stator notches.

Table 4. Distribution of losses within the structure of the induction motor for modified stator geometry (notch shape), considering variation with temperature

Developed losses for reference geometry Z1=18; Z2=26		Losses developed for modified stator geometry (notch rectangular shape) Z1=18, Z2=26	
Variable	Value [W]	Variable	Value [W]
Loss [Stator Copper]	176,8	Loss [Stator Copper]	175,8
Loss [Stator Copper] (Active)	93,61	Loss [Stator Copper] (Active)	76,01
Loss [Stator Copper] (EWdg Front)	41,57	Loss [Stator Copper] (EWdg Front)	49,9
Loss [Stator Copper] (EWdg Rear)	41,57	Loss [Stator Copper] (EWdg Rear)	49,9
Loss [Rotor Cage]	80,3	Loss [Rotor Cage]	79,99
Loss [Rotor Cage] (Active)	68,03	Loss [Rotor Cage] (Active)	67,77
Loss [Rotor Cage] (EndRing Front)	6,13	Loss [Rotor Cage] (EndRing Front)	6,107
Loss [Rotor Cage] (EndRing Rear)	6,135	Loss [Rotor Cage] (EndRing Rear)	6,112
Loss [Total]	347,054	Loss [Total]	345,799

B. Modification of rotor armature geometry

a) Reducing the number of rotor notches: Z2 = 22

For this case, taking into account that for the same number of stator notches it is possible to choose of a number of rotor notches, within a relatively wide range, the choice consisted in a decrease of the of rotor notches number in relation to the reference geometry.

The new distribution of the main losses within the structure (the losses in the iron and those in the bearings being influenced, only, by the speed at the shaft; the regime analysis was done for the shaft speed equal to the synchronism speed, respectively, 3000 rpm). Table 5 presents the analysis comparison developed in case A for the new value of the number of rotor notches.

Table 5. Distribution of losses within the induction motor structure, for modified rotor geometry (lower number of rotor notches), considering the variation with temperature

Developed losses for reference geometry Z1=18; Z2=26		Losses developed for modified rotor geometry Z1=18, Z2=22	
Variable	Value [W]	Variable	Value [W]
Loss [Stator Copper]	176,8	Loss [Stator Copper]	174,7
Loss [Stator Copper] (Active)	93,61	Loss [Stator Copper] (Active)	92,51
Loss [Stator Copper] (EWdg Front)	41,57	Loss [Stator Copper] (EWdg Front)	41,08
Loss [Stator Copper] (EWdg Rear)	41,57	Loss [Stator Copper] (EWdg Rear)	41,08
Loss [Rotor Cage]	80,3	Loss [Rotor Cage]	80,06
Loss [Rotor Cage] (Active)	68,03	Loss [Rotor Cage] (Active)	66,5
Loss [Rotor Cage] (EndRing Front)	6,13	Loss [Rotor Cage] (EndRing Front)	6,777
Loss [Rotor Cage] (EndRing Rear)	6,135	Loss [Rotor Cage] (EndRing Rear)	6,782
Loss [Total]	347,054	Loss [Total]	344,734

b) Increasing the number of rotor notches: Z2 = 30

Increasing symmetrically the number of rotor notches in relation to the reference geometry, the situation highlighted in Table 6 was obtained for the distribution of the main losses developed within the structure.

Table 6. Distribution of losses within the structure of the induction motor, for modified rotor geometry (larger number of rotor notches)

Developed losses for reference geometry Z1=18; Z2=26		Losses developed for modified rotor geometry Z1=18, Z2=30	
Variable	Value [W]	Variable	Value [W]
Loss [Stator Copper]	176,8	Loss [Stator Copper]	176,8
Loss [Stator Copper] (Active)	93,61	Loss [Stator Copper] (Active)	93,61
Loss [Stator Copper] (EWdg Front)	41,57	Loss [Stator Copper] (EWdg Front)	41,57
Loss [Stator Copper] (EWdg Rear)	41,57	Loss [Stator Copper] (EWdg Rear)	41,57
Loss [Rotor Cage]	80,3	Loss [Rotor Cage]	80,29
Loss [Rotor Cage] (Active)	68,03	Loss [Rotor Cage] (Active)	69,4
Loss [Rotor Cage] (EndRing Front)	6,13	Loss [Rotor Cage] (EndRing Front)	5,438
Loss [Rotor Cage] (EndRing Rear)	6,135	Loss [Rotor Cage] (EndRing Rear)	5,443
Loss [Total]	347,054	Loss [Total]	347,043

c) Changing the shape of the rotor notch, round/circular notches: Z2 = 26

The new geometry of the rotor notches (for the same number of notches on the rotor armature, with the one in the reference geometry) is shown in Figure 4.

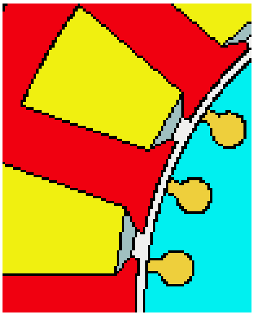

Figure 4. Shape of teeth and notches at the analyzed induction motor - modified rotor geometry

The distribution of losses developed, in the new configuration, is presented in Table 7.

Table 7. Distribution of losses within the induction motor, for modified rotor geometry (notch shape), considering variation with temperature

Losses developed for reference geometry Z1=18; Z2=26		Losses developed for modified rotor geometry (round/circular notches) Z1=18, Z2=26	
Variable	Value [W]	Variable	Value [W]
Loss [Stator Copper]	176,8	Loss [Stator Copper]	176,7
Loss [Stator Copper] (Active)	93,61	Loss [Stator Copper] (Active)	93,6
Loss [Stator Copper] (EWdg Front)	41,57	Loss [Stator Copper] (EWdg Front)	41,57
Loss [Stator Copper] (EWdg Rear)	41,57	Loss [Stator Copper] (EWdg Rear)	41,57
Loss [Rotor Cage]	80,3	Loss [Rotor Cage]	80,06
Loss [Rotor Cage] (Active)	68,03	Loss [Rotor Cage] (Active)	71,94
Loss [Rotor Cage] (EndRing Front)	6,13	Loss [Rotor Cage] (EndRing Front)	4,057
Loss [Rotor Cage] (EndRing Rear)	6,135	Loss [Rotor Cage] (EndRing Rear)	4,065
Loss [Total]	347,054	Loss [Total]	346,79

C. Synergistic modification of induction motor geometry

In this last analysis of the paper, radical structural changes were made, aiming at a synergistic change of the geometry (either a stator-rotor synergistic change that targets only the simultaneous modification of the notches number on the two armatures, or a synergistic change only at the level of the rotor armature, that aims both the changing the notches number at the level of this armature, in relation to the reference geometry as well as the change in the shape of the rotor notches).

a) Total modification of stator and rotor geometry (number of notches only)

Table 8 presents the results obtained regarding the distribution of the main losses within the induction motor structure, for stator-rotor synergistic modification (simultaneous modification of the notches number on the two armatures).

Table 8. Distribution of losses within the structure of the induction motor, for modified stator and rotor geometry, considering variation with temperature

Losses developed for reference geometry Z1=18; Z2=26		Losses developed for total modification of stator and rotor geometry Z1=24; Z2=22	
Variable	Value [W]	Variable	Value [W]
Loss [Stator Copper]	176,8	Loss [Stator Copper]	175,9
Loss [Stator Copper] (Active)	93,61	Loss [Stator Copper] (Active)	81,34
Loss [Stator Copper] (EWdg Front)	41,57	Loss [Stator Copper] (EWdg Front)	47,3
Loss [Stator Copper] (EWdg Rear)	41,57	Loss [Stator Copper] (EWdg Rear)	47,3
Loss [Rotor Cage]	80,3	Loss [Rotor Cage]	80,15
Loss [Rotor Cage] (Active)	68,03	Loss [Rotor Cage] (Active)	66,52
Loss [Rotor Cage] (EndRing Front)	6,13	Loss [Rotor Cage] (EndRing Front)	6,811
Loss [Rotor Cage] (EndRing Rear)	6,135	Loss [Rotor Cage] (EndRing Rear)	6,817
Loss [Total]	347,054	Loss [Total]	346,088

b) Changing only the rotor geometry (notches number and shape)

In the case of synergistic modification only at the level of the rotor armature (notches number and shape), the new distribution of the main losses within the engine is presented in Table 9.

Table 9. Distribution of losses within the structure of the induction motor - for changing only the rotor geometry - considering the variation with temperature

Losses developed for reference geometry Z1=18; Z2=26		Losses developed for changing only the rotor geometry Z1=18; Z2=22 (round/circular notches)	
Variable	Value [W]	Variable	Value [W]
Loss [Stator Copper]	176,8	Loss [Stator Copper]	174,6
Loss [Stator Copper] (Active)	93,61	Loss [Stator Copper] (Active)	92,49
Loss [Stator Copper] (EWdg Front)	41,57	Loss [Stator Copper] (EWdg Front)	41,07
Loss [Stator Copper] (EWdg Rear)	41,57	Loss [Stator Copper] (EWdg Rear)	41,07
Loss [Rotor Cage]	80,3	Loss [Rotor Cage]	79,79
Loss [Rotor Cage] (Active)	68,03	Loss [Rotor Cage] (Active)	72,84
Loss [Rotor Cage] (EndRing Front)	6,13	Loss [Rotor Cage] (EndRing Front)	3,472
Loss [Rotor Cage] (EndRing Rear)	6,135	Loss [Rotor Cage] (EndRing Rear)	3,48
Loss [Total]	347,054	Loss [Total]	344,423

Remark. Within the total losses, captured in tables 3-9, are integrated the main losses that vary with temperature and the constant value of losses in iron (from the stator yoke and stator and rotor teeth) that do not register variations with temperature, losses mentioned in Tables 1 and 2 (a constant value of 90 W).

4. Obtained results. Discussions

The results of the comparative analysis, summarized in Tables 3-9, can be viewed further easily, to highlight the particularities regarding the distribution of the main losses within the induction motor (and, by extrapolation, the energy efficiency/yield of this motor), through the graphical representations in Figures 5-7.

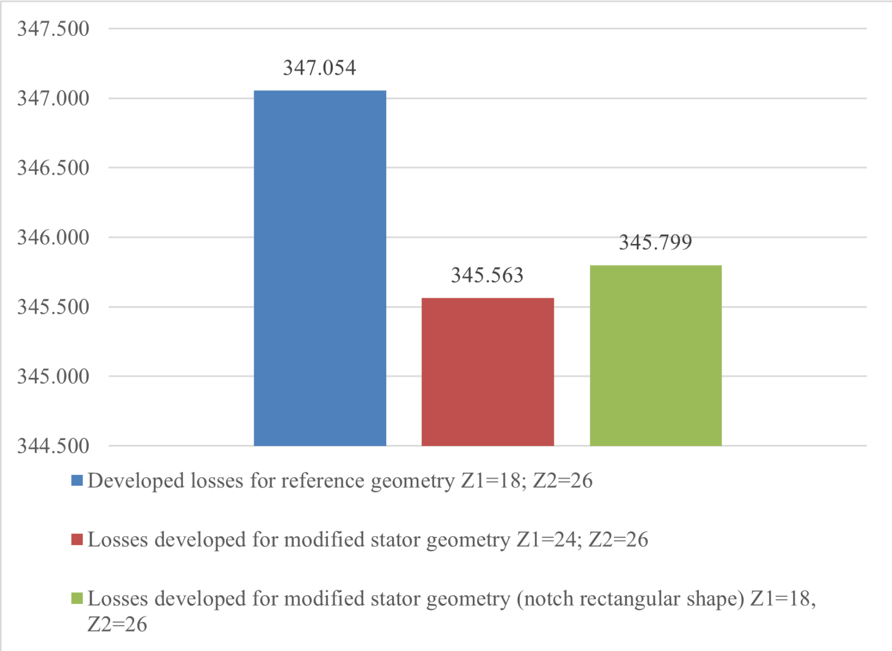

Figure 5. The Influence of stator geometry changes on induction motor losses

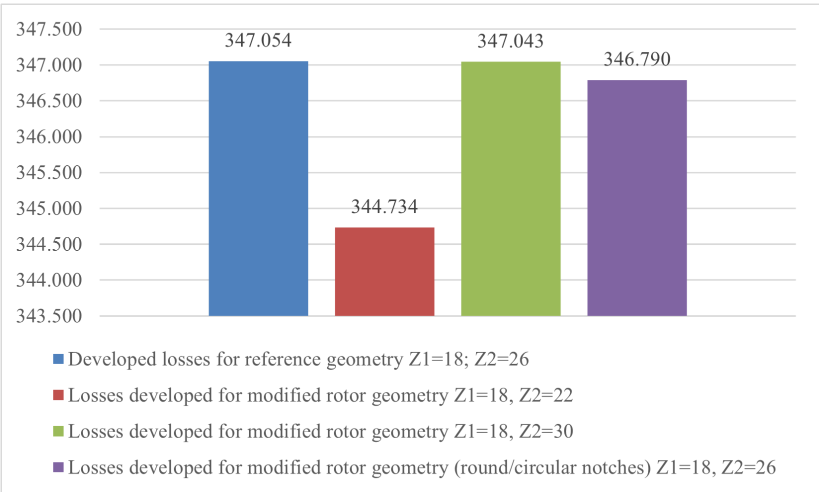

Figure. 6. The Influence of rotor geometry changes on induction motor losses

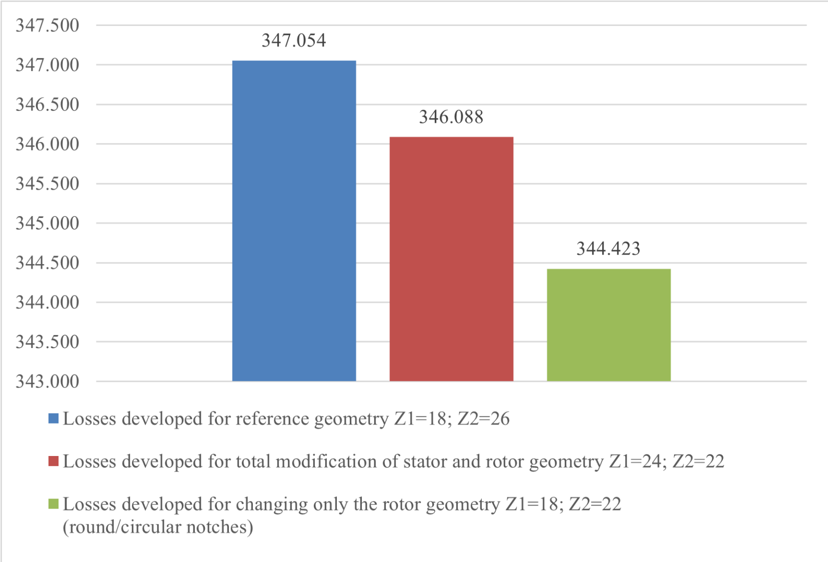

Figure 7. The influence of synergistic geometric changes on induction motor losses

This analysis shows that:

- Modification of the geometry of the stator and rotor armatures at the induction motor, for given technical and ventilation characteristics, leads to a modification of the level and the distribution of losses within the structure and, implicitly, to a change its energy efficiency.
- Unilateral changes in the geometry of the induction motor (of each armature, independently) slightly affect the level of losses and change the induction motor efficiency in a small proportion.
- Synergistic changes in the induction motor geometry affect to a greater extent the losses level developed within the structure and substantially modifies the induction motor efficiency.
- Rotor geometry modifications (unilateral or synergistic), at the induction motor, lead to a significant reduction of the motor losses level and, thus, to an efficiency increase.
- Changes in the geometry of the stator and rotor armatures significantly influence the losses in the windings and much less the losses in the ferromagnetic core.

5. Conclusions

Following the study undertaken, we can conclude:

- Increasing the energy efficiency of induction motors can be achieved, relatively easily, by radically changing the rotor geometry - as it resulted from the analysis carried out: in principle, in induction motors with a cage rotor, by changing the number of bars/notches rotors, but also by changing the geometry/shape of the notches of this armature.
- The geometric changes of the rotor armature certainly, unfortunately, also affect the technical characteristics of this motor and not only those of energy performance, because the torque developed by the induction motor strongly depends on the electrical resistance of the rotor cage, a resistance that changes, along with the change in the geometry of the notches and rotor teeth. As a result, in the design process, it is necessary to continuously weigh the technical performances (especially the torque developed by the engine) and those of energy efficiency.

Of course, this work opened a path, on which, along with companies that design and produce induction motors, concrete steps can be taken to develop, soon, induction motors that perform technically, economically and with a low impact on the environment, whilst also implementing the concept of saving electricity.

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Addresses:

- Conf. Dr. Eng. Ion Voncila, Dunarea de Jos University, Faculty of Automation, Computers, Electrical Engineering and Electronics, Str. Ştiinţei nr. 2, Galaţi - 800146, România, ion.voncila@ugal.ro (* *corresponding author*)
- Assist. Dr. Eng. Elena Selim, Dunarea de Jos University, Faculty of Automation, Computers, Electrical Engineering and Electronics, Str. Ştiinţei nr. 2, Galaţi - 800146, România elena.selim@ugal.ro
- S.L. Dr. Eng. Ion Paraschiv, Dunarea de Jos University, Faculty of Automation, Computers, Electrical Engineering and Electronics, Str. Ştiinţei nr. 2, Galaţi - 800146, România, ion.paraschiv@ugal.ro