Investigation for Losses of M19 and Amorphous Core Materials Asynchronous Motor by Finite Elements Methods

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***Abstract*—In this study, M19 steel and amorphous material asynchronous motors have been examined by finite elements methods with *v*/*f* controlling. Performances of the motors have been investigated by means of analysis. The losses of amorphous and M19 steel core motors are compared at higher and lower frequencies. If amorphous material is used within stator core, the mass of core, and net weight of the motor would be decreased at the same motor parameters. It has been reached that the amorphous material motors would be produced lighter than M19 steel ones in the research.**

Index Terms—**Amorphous and M19 steels, asynchronous motor, losses, performances, design, finite elements methods.**

I. INTRODUCTION

Increasing energy demands and need to energy efficiency, use of high efficient electrical machines has been inevitably become Since electric motors transform electric power to mechanical power, they also have mechanical losses in addition to electric losses. It is requested that such energy transformation would be realized with minimum energy loss. Therefore, asynchronous motor designs ought to be made as they shall give such good performances on values of maximum efficiency and the best torque.

Though values of middle and high frequency provide very important decrease at machine sizes, there are also losses which originate from such those frequencies. Progress in ferrite alloyed core materials (amorphous, and nanocyrstalline), have been provided designers to make big power, and small sized electrical machine designs and utilities. In case of amorphous material is used in production of motor and transformer, it is stated that 70 % decrease is seen in losses [1]. Mischler has studied two 60 *Hz* frequency asynchronous motors which have amorphous core and M22 siliceous sheet (electrical steel) from the aspect of their losses [2]. Jianwei and Ting have made a study of classical and amorphous core asynchronous motors at 50–60–100 *Hz* frequencies in terms of losses by using a software [3]. Comparing to traditional ones, amorphous machines have advantageous like decrease in their sizes, and working in high frequencies [4]. In another work, brushed, brushless DC and SR motors were developed with high torque, and small size [6].

In the study, the cores which were constructed with M19 and amorphous material have been examined and compared in terms of losses. Furthermore, *v*/*f* control for both of two machines has been realized by finite elements method; efficiency, torque, speed, core losses, and phase currents have been examined.

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II. SELECTION OF CORE MATERIAL FOR AN ASYNCHRONOUS MOTOR

The parameters which determine features of core material are given as magnetic permittivity, saturation point, residual magnetism, electric resistance and coercivity [5]. The features of M19 and amorphous core material used in the study are given in Table I and the curves of losses versus magnetic flux density at several frequencies for M19 and amorphous are given in Fig. 1 and Fig. 2.

TABLE 1. THE FEATURES OF M19 AND AMORPHUS MATERIALS.

Features of Core Material			
Alloy	Amorphous	M19 Steel	Units
Electric resistance	130	0.52	$\mu\Omega m$
Density	7180	7650	kg/m^3
Lamination factor	0.86	0.92	*mm*

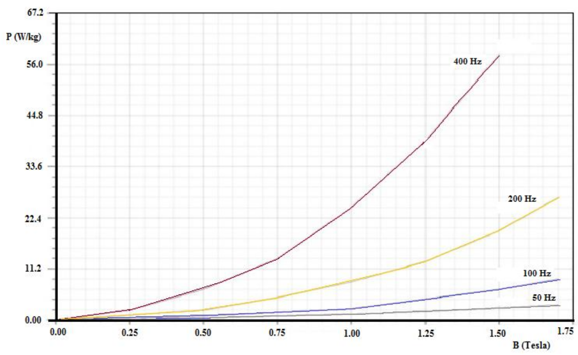

Fig. 1. The loss curves for M19 at several values of frequency versus magnetic flux density.

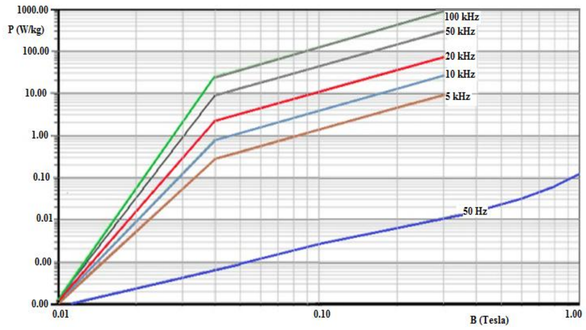

Fig. 2. The loss curves for Amorphous at several values of frequency versus magnetic flux density.

The change of losses has been given as logarithmically since that core losses are quite low.

III. ANALYSIS OF M19 AND AMORPHOUS ASYNCHRONOUS MOTORS BY FINITE ELEMENTS METHOD

In the frequency domain, loss separation is widely used with problems involving magnetic laminations. Loss separation breaks the total core loss into static hysteresis loss, classical eddy current loss, and excess loss [7]. They are given in (1)

$$P_v = P_h + P_c + P_e + P_a, \tag{1}$$

where P_v is the total core loss per unit volume, P_h is hysteresis, P_c and P_e are supplement eddy losses.

These losses are given in Eq. 2. Williams and et.all have stated that P_a is abnormal losses. It can be said that those losses are being occurred since eddy currents or problems at domain wall movement [8]:

$$\begin{cases} P_h = k_h f B_m^2, \\ P_c = k_c (f B_m)^2, \\ P_e = k_e (f B_m)^{1,5}, \\ P_v = k_h f B_m^2 + k_c (f B_m)^2 + k_e (f B_m)^{1.5} = \\ = K_1 B_m^2 + K_2 B_m^{1.5} \end{cases} \tag{2}$$

where k_h is hysteresis loss coefficient, k_c is eddy currents loss coefficient, k_e is supplement eddy core loss coefficient.

From (2), $K_1 - K_2$ coefficients and Eddy current losses coefficient are calculated as given in (3):

$$\begin{cases} K_1 = k_h f + k_c f^2, \\ K_2 = k_e f^{1,5}, \end{cases} \tag{3}$$

where $k_c = \pi\sigma\frac{d^2}{6}$, σ is conductivity, d is lamination thickness.

The loss coefficients belonging to core material can be found from the *B–P* curves shown in Fig. 1 and Fig. 2. The companies which produce core material generally present loss change curves depending upon frequency. If the f is called as the experienced frequency, and *B–P* curves belonging to more frequencies are benefitted in the calculation, the necessary core coefficients for the lost power are being calculated as minimizing at quadratic form. Furthermore, a new curve is being convergence as curve fitting to every *B–P* curve. As result of this, the coefficients at working frequency are being calculated optimum as minimizing the error criterion (*err*) [8], [9]. The criterion is given in (4)

$$err(k_h, k_c, k_e) = \sum_{i=1}^{m} \sum_{j=1}^{n_i} \big[P_{vij} - (k_h f_i B_{mij}^2 + \\ + k_c f_i^2 B_{mij}^2 + k_e f_i^{1.5} B_{mij}^{1.5})\big]^2, \tag{4}$$

where m is number of the lost curves, n_i is number of the point at i ordered loss curve.

The coefficients as a function of f_i versus B_{mt} which results P_{vi} can be calculated for every i point with help of the curve. They're given in (5)

$$k_e = \frac{K_2}{f_0^{1.5}} \text{ and } k_h = \frac{K_1 - k_c f_0^2}{f_0}. \tag{5}$$

The loss coefficients regarding to M19 and amorphous materials per meter cube which were calculated with more than one loss curves are given in Table II.

TABLE II. THE COEFFICIENTS FOR AMORPHOUS AND M18 STEEL.

Loss coefficients	Amorphous (W/m^3)	M19 Steel (W/m^3)
k_h	125.167	178.478
k_c	0.00235968	1.41304
k_e	0.534436	1.79322

The M19 and amorphous core motors are designed and analyzed by Rmxprt module [10]. Hence, model parameters are get ready for finite elements analyzing. The *ScaleFactor* is being changed in forms of (1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5) for parametric analyzing. Boundary conditions and current flowing through coil are given as model parameters. Thus, the designed system is serviced to presence. The system modelled is divided by triangular elements for mesh determination first and then finite elements network is created. The error is diminished with iterations as networks are healing during solution process. The designed motors' parameters are given in Table III.

TABLE III. MOTOR PARAMETERS.

Output power	7.5 *kW*	Type of load	Constant
Rated voltage	380 *V*	Temperature	75°*C*
Winding type	Wye	Stator slots	48
Number of	4	Rotor slots	44
Rated speed	1360 *rpm*	Outer diameter of stator	210 *mm*
Frequency	50 *Hz*	Inner diameter of stator	148 *mm*
Frictional loss	37 *W*	Core length	250 *mm*
Stray Loss	37 *W*	Air gap	0.35 *mm*

When the geometry changes, magnetic saturation and end-winding solutions should be effective in the fringing fields and the validity of the solutions in terms of both time and position should be clarified in 2 D designs [11]. The frequency domain can be calculated in terms of peak magnetic flux density B_m and frequency f [7]. The 2 D meshed network of the machine is obtained as shown in Fig. 3.

The core losses have been obtained between 3 – 0.5 *kWs* within 20 milliseconds. The losses at amorphous material might be obtained 10 times smaller than M19 core material.

The curves of input currents, torques, efficiency, and core losses versus *ScaleFactor* forms are given in Fig. 4–Fig. 6.

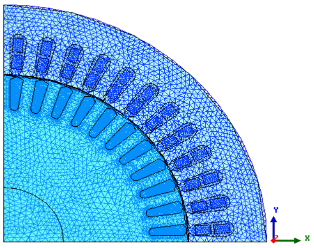

Fig. 3. The meshed dispersion of the designed machine.

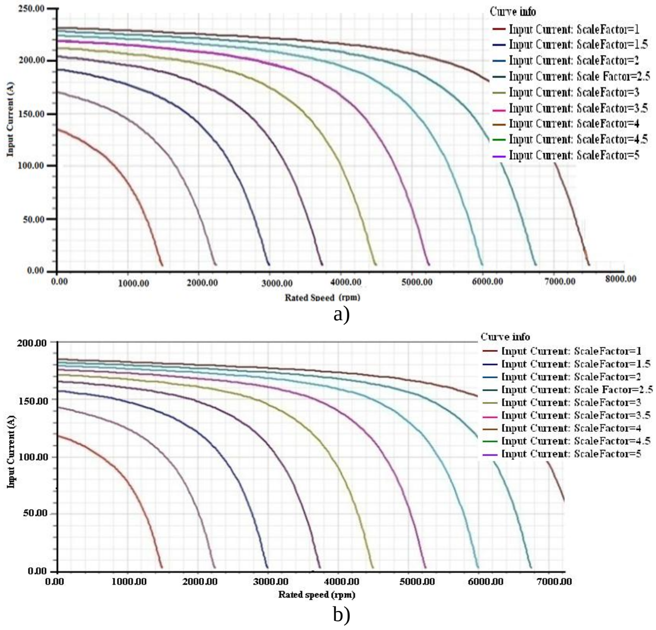

Fig. 4. The change of input current with *Scalefactor* versus rated speed for: a – M19; b – Amorphous material.

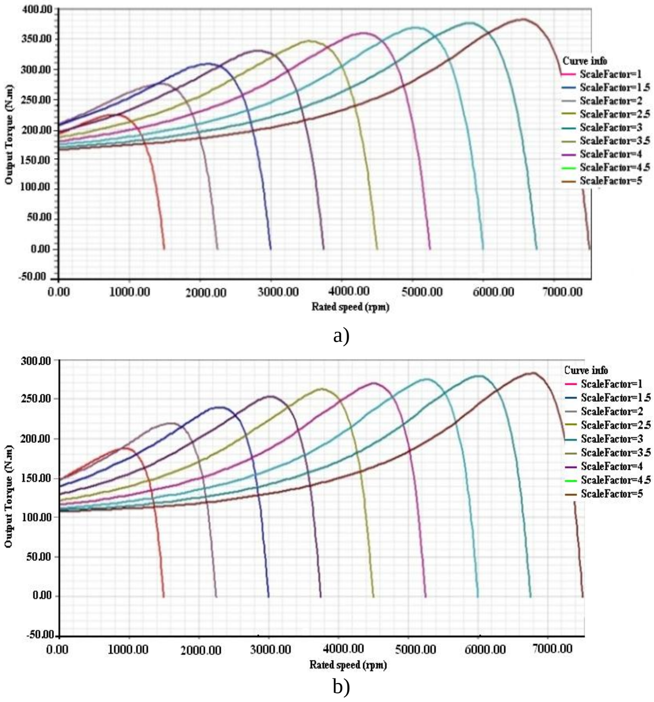

Fig. 5. The change of torque with *Scalefactor* versus rated speed for: a – M19; b – Amorphous material.

At low frequencies, it has been seen that both of two motors' torques are close to each others. However, when frequency goes up, amorphous core asynchronous motor's torque decreases. This is because of input current of amorphous core motor is smaller than M19 material motor. From Fig. 5, the efficiency at amorphous core motor is naturally increased, since core losses are decreased.

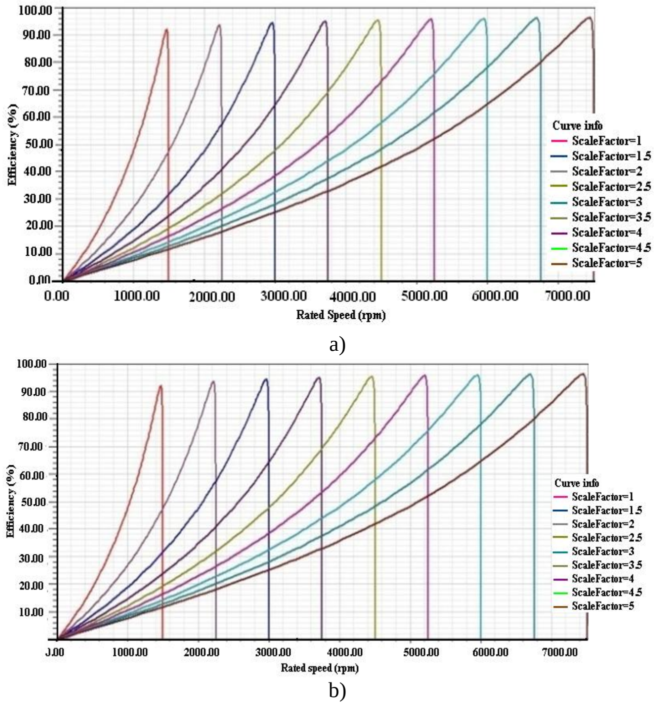

Fig. 6. The change of efficiency with *Scalefactor* versus rated speed for: a – M19; b – Amorphous material.

The mass values for both of two motors have been obtained as given in Table IV in the research. From the table, the amorphous core production is more lighter than M19 steel core production approximately 5 *kg*. The losses of iron core made by M19 and amorphous materials are given in Fig. 7. The figure shows that the losses at amorphous core regarding to M19 steel core increas when the frequency goes up.

TABLE IV. THE MASS VALUES OF THE DESIGNED MOTORS, IN (*KG*).

Material Consumption	Amorphous	M19 Steel
Rotor core steel consumption (*kg*)	26.5568	30.2693
Armature core steel consumption (*kg*)	43.4793	49.5574
Total net weight (*kg*)	47.0198	52.4646

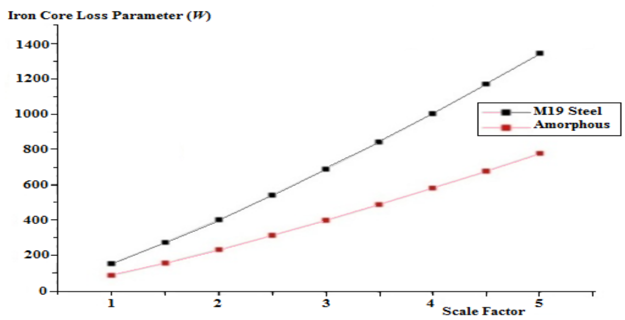

Fig. 7. The core losses versus *Scalefactor* of M19 and amorphous.

IV. CONCLUSIONS

In the study, amorphous and M19 steel material asynchronous motors have been investigated in terms of the losses. At higher frequencies, the losses of amorphous core are increased comparing to M19 steel core. It has been understood that the mass of amorphous core is being decreased. As result of this research, it is inferred that high frequency asynchronous motors provides advantageous in terms of the losses and sizes. When cost of amorphous material goes down, it is expected that high frequency and efficiency asynchronous motors would be produced easily.

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