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

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http://dx.doi.org/10.5755/j01.eee.18.9.2797

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 nanocrystalline), 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.

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>
<thead>
<tr>
<th>Features of Core Material</th>
<th>Amorphous</th>
<th>M19 Steel</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric resistance</td>
<td>130</td>
<td>0.52</td>
<td>( \mu \Omega \text{m} )</td>
</tr>
<tr>
<td>Density</td>
<td>7180</td>
<td>7650</td>
<td>kg/m³</td>
</tr>
<tr>
<td>Lamination factor</td>
<td>0.86</td>
<td>0.92</td>
<td>mm</td>
</tr>
</tbody>
</table>

Fig. 1. The loss curves for M19 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)

\[ P_s = P_h + P_e + P_m + P_a, \]

where \( P_s \) is the total core loss per unit volume, \( P_h \) is hysteresis, \( P_e \) and \( P_m \) are supplement eddy losses.

These losses are given in Eq. 2. Williams and et.al 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]:

\[
\begin{align*}
P_h &= k_h fB_m^2, \\
P_e &= k_e (\beta_m)^{1.5}, \\
P_m &= k_m f^2 B_m^2 + k_e (f B_m)^{1.5} = K_1 B_m^2 + K_2 B_m^{1.5},
\end{align*}
\]

where \( k_h \) is hysteresis loss coefficient, \( k_e \) is eddy currents loss coefficient, \( K_1 \) is supplement eddy core loss coefficient.

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

\[
\begin{align*}
K_1 &= k_h f + k_e f^2, \\
K_2 &= k_e f^{1.5},
\end{align*}
\]

where \( k_e = \frac{\pi \sigma d^2}{6} \sigma \) 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)

\[
\text{err}(k_h, k_e, k_e) = \sum_{i=1}^{m} \sum_{j=1}^{n_i} [P_{ij} - (k_h f B_{mi}^2 + k_e f^{1.5} B_{mi}^{1.5})]^2.
\]

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 \( f \) versus \( B_{mi} \) which results \( P_{ij} \) can be calculated for every \( i \) point with help of the curve. They’re given in (5)

\[
k_e = \frac{k_2}{k_1} \text{ and } k_h = \frac{k_1 - k_2 f^2}{f_0}
\]

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.

![Image](LEKTRONIKA IR ELEKTROTECHNIKA, ISSN 1392-1215, Vol. 18, No. 9, 2012)
The curves of input currents, torques, efficiency, and core losses versus \textit{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 \textit{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. 5. The change of torque with \textit{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>
<thead>
<tr>
<th>Material Consumption</th>
<th>Amorphous</th>
<th>M19 Steel</th>
</tr>
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<tbody>
<tr>
<td>Rotor core steel consumption (kg)</td>
<td>26.5568</td>
<td>30.2693</td>
</tr>
<tr>
<td>Armature core steel consumption (kg)</td>
<td>43.4793</td>
<td>49.5574</td>
</tr>
<tr>
<td>Total net weight (kg)</td>
<td>47.0198</td>
<td>52.4646</td>
</tr>
</tbody>
</table>

Fig. 6. The change of efficiency with \textit{ScaleFactor} versus rated speed for: a – M19; b – Amorphous material.

Fig. 7. The core losses versus \textit{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.

REFERENCES


