International Innovative Research Journal of Engineering and Technology
ISSN: 2456-1983 Vol: 2 No: 4 June 2017

Electromagnetic Analysis of Rounded Shape Core and Eight-Sided Polygon Core for Distribution Transformer

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Abstract: This paper gives the similar attractive review between the different sorts of wound center transformers to be specific eight sided polygon center and adjusted shape center transformer. These examinations are made with a specific end goal to know the best arrangement that outcomes in decrease of excitation current and whirlpool current misfortune which is a sort of center misfortune. The examination comes about that eight sided polygoncore transformer has more prominent attractive flux thickness, lessened whirlpool current misfortune and excitation current when contrasted with adjusted center transformer. These outcomes has been investigated to locate the best blending rate with a specific end goal to get the diminished excitation current and vortex current misfortunes utilizing a few evaluations of non-arranged AISI silicon steel materials. The results are acquired utilizing 2D FEM reproductions by considering the non-straight properties of the center.

1. INTRODUCTION

The adjusted shape center was created with decreased weight and size in the dissemination transformer. The lessening of weight and size limits the cost which is one of the real hugeness of adjusted shape center transformer [1]. A portion of the noteworthiness of adjusted shape center transformer is as follows: Distribution of flux thickness is expanded fit as a fiddle center when contrasted with stacked center. This is on account of the adjusted shape centers are comprised of constant strips with the end goal that the entire way of the moving course is usable and accordingly attractive flux immersion is extensively decreased. As there is consistency in attractive flux heading along the overlays and lessened weight, brings about diminished swirl current misfortune and excitation current. Rounded Shape center transformers are very basic in electronic industry in view of their enhanced effectiveness and execution [7]-[8]. In eight sided polygon center, every cover is cut into required length and every overlay is bowed at four corners. The overlays are organized as the most inside cover at the first and the outer overlay toward the end by the specialists. Presently eight sided Polygoncore was created from adjusted shape center with lessened weight and size by considering the all the advantages of adjusted Shape center [5]. In extra the diminishment of whirlpool current misfortune and excitation current is watched. The geometry and plan parameters of adjusted shape and eight sided polygon center are appeared in Fig.2. The window stature is h, window width is w, overlay width is p, center width is q, are the parameters of adjusted shape core. The outside edge tallness is h2, inside edge stature is h1, outside edge width is w2, inside casing width is w1,exterior corner length is hw2, inside corner length is hw1, center width is q1 and cover width is p are the parameters of eight sided polygon center [1] - [2[] and their qualities are executed in table2.
This paper approves the polygon by playing out a thorough electromagnetic correlation amongst polygon and adjusted shape centers, propelling with points of interest the attractive flux dispersion, excitation Current and whirlpool current misfortunes [6]. The numerical results were acquired from two-dimensional (2D) FEM recreations.

2. MAGNETIC ANALYSIS

Magnetic analysis is done using FEM and B-H curve is drawn for different materials. The B-H curve is shown fig1.

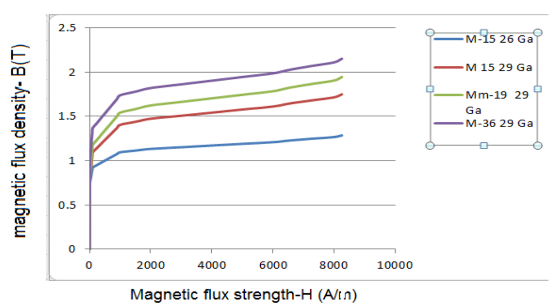

Figure 1. B-H Curve for different grades of electrical steel

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An electromagnetic analysis with FEM model is made in order to determine the magnetic flux distribution and to calculate the eddy current losses in rounded and eight sided polygon core [3]. The results were made using 2D FEM simulations by considering the grain oriented steels like M-15 26 Ga (1m), M-15 29Ga(1m) , M-19 29 Ga(1m), M-36 29 Ga(1m). Fig 1 shows the B-H curves for different non-oriented silicon steel . The distribution of magnetic flux density and eddy current losses are determined by the solution of vector potential formulation A in the frequency domain is given by[4]

$$(j\omega\sigma - \omega^2\varepsilon)A + \nabla \times (\frac{1}{\mu}\nabla \times A) = 0$$

Where, ε is the permittivity, μ is Tensor of the permeability of the different grain oriented silicon steel quality used σ is Conductivity. An important part in the eddy current calculation is skin depth δ. Skin depth δ is given by

$$\delta = \sqrt{\frac{1}{\pi f \mu \sigma}}$$

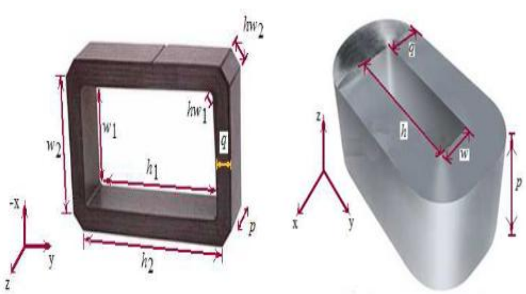

Figure 2. Magnetic model for eight sided polygon and rounded shaped core

The distribution of dissipated power is calculated from,

$$P = \frac{1}{2} Re[\sum_{i=1}^{n} (\rho_i J_{e_i}^{*} \cdot J_{e_i}) V_i]$$

Where, n is Number of elements, ρ Diagonal tensor of resistivity of the grain oriented silicon steel, J_{ei} is Eddy current density vector of the element i,V_i is element [9].
The eddy current density is the given by the formula,

$$J_{e_i} = -j\sigma\omega A_i = -\sigma \frac{1}{n} \sum_{i=n}^{n} N_A^T A_i$$

Where, N_A is element shape functions for the vector potential A.
FEM software is used to execute the simulations mentioned in this paper. It is essential to notice that mesh method is used before simulating in order to get the accurate results for losses and excitation current.

3. FINITE ELEMENT ANALYSIS

In the finite element analysis the original field problem domain is divided into a number of sub domains or elements. The potential distribution within each element is approximated by a polynomial (trial function) and a numerical solution to the field problem is then obtained with respect to some optimal criterion [2].
The following assumptions are made to determine the magnetic field distribution in the transformer. The magnetic field outside the motor periphery is negligible. The magnetic vector potential, A and the current density vector, J are invariant in the axial direction only. In the two dimensional analysis the end effects are neglected [2].
With the above assumptions the Maxwell's equation become,

$$\nabla \times H = J \qquad (3.1)$$

$$\nabla \cdot B = 0 \qquad (3.2)$$

The constituent relation is

$$B = \mu H \qquad (3.3)$$

Whereμ is the permeability of the magnetic material. By defining the magnetic vector potential, A as

$$B = \nabla \times A \qquad (3.4)$$

And by using Coulomb's convention, we assume that

$$\nabla \cdot A = 0 \qquad (3.5)$$

Equation (3.1) can be written as

$$\nabla \times \left[\frac{1}{\mu} B\right] = J \qquad (3.6)$$

Substituting equation (3.4) in equation (3.6)

$$\nabla \times \left[\frac{1}{\mu} \nabla \times A\right] = J \quad (3.7)$$

Expressing B in terms of its components in a two dimensional field,

$$\nabla \times A = \frac{\partial A}{\partial y}\vec{i} - \frac{\partial A}{\partial x}\vec{j} \quad (3.8)$$

Equation (3.7) can be written as

$$\frac{\partial}{\partial x}\left(\frac{1}{\mu}\frac{\partial A}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{1}{\mu}\frac{\partial A}{\partial y}\right) = -J \quad (3.9)$$

The electromagnetic system has three regions namely, iron or core region, air region and coil region [2]. In the stator and the rotor core regions where there are material non-linarites present due to saturation but have no excitation current density present [5], the equation (3.9) can be written as,

$$\frac{\partial}{\partial x}\left(\frac{1}{\mu}\frac{\partial A}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{1}{\mu}\frac{\partial A}{\partial y}\right) = 0 \quad (3.10)$$

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The winding regions carrying excitations but have no iron parts and hence equation (3.2) reduces to

$$\frac{\partial A}{\partial x^2}+\frac{\partial A}{\partial y^2}=-\mu_0 J \quad (3.11)$$

The equation (3.10), for the air gap regions where there are no current carrying conductors or iron parts, becomes

$$\frac{1}{\mu_0}\left[\frac{\partial A}{\partial x^2}+\frac{\partial A}{\partial y^2}\right]=0 \quad (3.12)$$

The equation (3.10) is the two dimensional nonlinear partial differential equation which is to be solved to get the magnet vector potential values when the excitation current density is specified.

4. RESULTS AND DISCUSSION

Fit as a fiddle center the thickness of the attractive flux is appeared in fig.4.For examination we have utilized diverse materials like M-15 26 Ga(1 m). The excitation current which is available fit as a fiddle center is settled with a specific end goal to get a uniform attractive flux thickness [10]. Essentially the attractive flux thickness is little and it can't be utilized as a part of the sides of the adjusted shape center so that the possibility of eight sided polygon center come into record. Fig 4 demonstrates the attractive flux dispersion fit as a fiddle center.

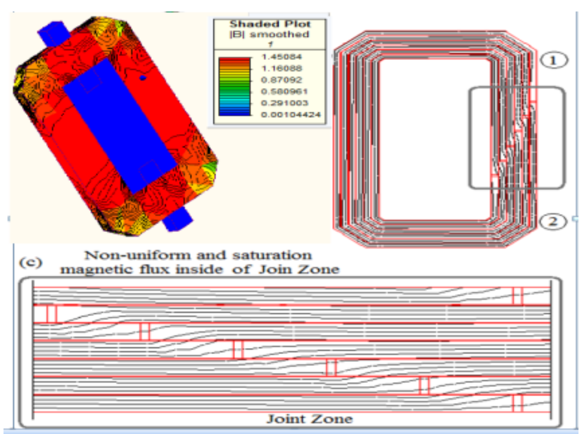

Figure 3. Eight sided polygon core with magnetic flux density and Joint zone

Fit as a fiddle center there is joint zone exhibit in it where the attractive flux is not uniform and mutilations will happen. The attractive flux circulation acquired in the adjusted shape center is contrasted and the eight sided polygon center utilizing a similar review material(M-15 26 Ga) and a similar excitation current.

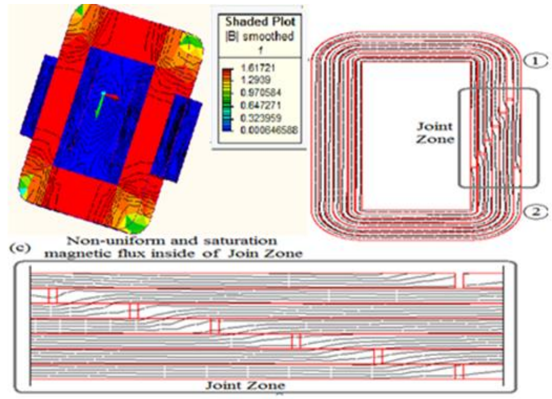

Figure 4. 7Rounded shape core with magnetic flux and joint zone

The eight sided polygon center is appeared in fig 3, it is obvious that the attractive flux thickness increments in eight sided polygon center regarding the attractive flux thickness of the adjusted shape center. By utilizing a similar excitation current the adjusted shape center creates an attractive flux thickness of B=1.6728T where as in eight sided polygon center it delivers an attractive flux thickness of B=1.4262T. From this it is obvious that the eight sided polygon center can deliver more prominent attractive flux thickness with a settled excitation current. The same attractive flux thickness is acquired in both the centers just when there is a decrease in the excitation current. This distinction in the excitation current is because of the size contrasts. This diminishment in the excitation current is because of the center length in a polygon is littlest than rounded and this creates the hesitance decrease of the center.

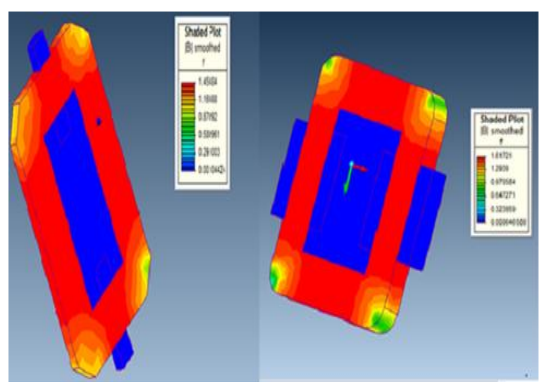

Figure 5. Comparison of rounded and polygon shape core

Correlation of adjusted and eight sided polygon center is appeared in fig5. From the examinations it is apparent that eight sided polygon center is having more attractive flux

International Innovative Research Journal of Engineering and Technology
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than fit as a fiddle center. Examination of vortex current misfortune and excitation current is made between both the type of centers and the qualities are beheaded in table 1. From the table it is clear that eight sided polygon shape center has less swirl current misfortune and less excitation current when contrasted with adjusted molded center for various evaluations of electrical steel.

Table 1. Comparison of magnetic flux density, excitation currents and eddy current losses in rounded and polygon

sl. no	parameters	M-15 26 Grade		M-15 29 Grade		M-19 29 Grade		M-36 29 Grade	
		polygon	rounded	Polygon	rounded	polygon	rounded	Polygon	rounded
1.	Excitation current	1.506	1.100	1.140	1.090	1.030	1.086	1.020	1.1070
2.	Magnetic flux	1.4468	1.67821	1.6246	1.67171	1.62262	1.6705	1.66381	1.7119
3.	Eddy current loss	4.2559	7.463	6.0156	8.0276	6.27171	8.3192	705812	9.3012

As indicated by the examination from the table 1 obviously eight sided polygon center transformer has more prominent attractive flux and less vortex current misfortune and excitation current when contrasted with adjusted shape center for various evaluations of electrical steel. Table 1 demonstrates the estimations of vortex current misfortunes and excitation current of both the sort of centers.

Table 1 demonstrates that for eight sided polygon center transformer have a swirl current loss of 7.569 for grain situated electric steel material, M-36 29 Ga which is of littler quality contrasted with different evaluations of electrical steel. The outcomes likewise demonstrate that M-19 29 Ga has less swirl current misfortune when contrasted with the over one. Additionally the material M-15 26 has less vortex current misfortune when contrasted with different materials. These outcomes demonstrates that for an assembling organization, eight sided polygon center transformer is great keeping in mind the end goal to acquire less excitation current and whirlpool current misfortune.

5. CONCLUSION

From the examination and reproduction result it is obvious that eight sided polygon center has more focal points contrasted with adjusted shape center. The eight sided polygon center has greater magnetic flux thickness due to the edges that are cut into required length in the overlay center. This is a result of the air crevices that are available toward the sides of the adjusted formed centers which are overcome by polygon center by cutting the edge of required length. As it requires less demanding assembling process allowing diverse evaluations of grain arranged electrical steels can be utilized as it lessens excitation current and swirl Current misfortunes. Result demonstrates that eight sided polygon center diminishes whirlpool current misfortune around 25.7% contrasted with adjusted shape center. The acquired outcomes are helpful amid center assembling process.

Table 2. Constant Values and Design Parameters of the Core

Design dimensions of transformer core values are in m

I	Parameters	Value	I	Parameters	Value
1	H	6	6	p	1
2	W	5	7	q	2
3	h_1	7	8	w_1	3
4	h_2	9	9	w_2	5
5	h_{w1}	1	10	h_{w2}	1

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