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Minimization of Eddy Current Losses in a Straight Rectangular Cross Section Conductor

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Abstract—To reach the goal mentioned in the title, an intuitive solution using two pieces of ferrite is first proven to be effective. Then, ferrite is removed and the externally applied field that minimizes losses is searched. This is done using a new optimization tool (GOT) and taking advantage of multipolar expansion of the external field.

I. INTRODUCTION

Increasing power efficiency is the main objective of power electronic designers. Wire related losses are a major concern in connecting conductors as well as inside transformers, especially at frequencies promoting eddy currents.

Due to its rotational invariance, losses due to skin effect of an isolate straight cylindrical wire can't be reduced. On the opposite, if the cross section of the wire is rectangular, external pieces of material can modify the field and the current repartition in a way such that losses are significantly reduced. The goal of this article is to find the external field shape that minimizes losses in this wire.

II. LOSSES REDUCTION IN COPPER FLAT RECTANGULAR SHAPED CONDUCTOR

A straight rectangular cross section wire made of copper is considered (Fig.1). It is supplied by a 1 A_{eff} 100 kHz current.

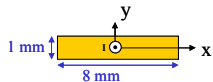


Fig.1. Rectangular shaped conductor

With only this conductor, copper losses are:

$$P = 6.9mW / m .$$

Previous studies [1] using FEM software Flux2D [2] showed that, with two pieces of ideal ferrite ($\mu_r = 2300$ like 3C90) put close to the wire as shown in Fig.2, copper losses can be reduced by 22% ($P = 5.34mW / m$)

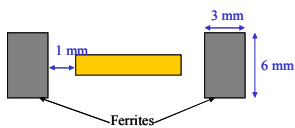


Fig.2. Losses reduction configuration

Ferrite modifies magnetic field around the copper and current density inside. To look for the minimum of losses, ferrite is replaced by two external current sources (Fig. 3): one in phase with wire total current, the other one in quadrature with it, in order to create an adjustable external inductor field. This field can be decomposed in Fourier series. For symmetry reasons, current sources only include even harmonics:

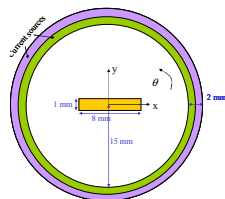


Fig.3. Cylindrical current densities

$$I_c = -I \cdot \left(1 + \sum_{k=1}^{\infty} (a_{2k} + i \cdot b_{2k}) \cdot \cos(2k\theta) \right) \quad (1)$$

III. OPTIMIZATION PROCESS

A. Global Optimization Toolbox

The FEM software is coupled with GOT (Global Optimization Toolbox) to achieve optimization. The method used is based on the creation of response surfaces [3] and a genetic algorithm is finally used.

B. Limited Search Area

Solution space is a huge one so optimization process needs a limited search area. In order to find a realistic one, field obtained in fig.2 is split in an emitted part and a received one, following a method presented in [4]. External field is then created only by current densities, flowing axially in the cylinders (fig.3), which first coefficient values are:

$$n = 2, \quad a_2 = 1.234 \cdot 10^5, \quad b_2 = -807 \quad (2)$$

IV. OPTIMIZATION RESULTS

Optimization is managed with only field harmonic 2 (coefficients a_2 and b_2). Losses have been reduced by 30% ($P = 4.9mW / m$). Comparing current densities of wire alone (fig.4) and of field submitted wire (fig.5) it appears that peaks are lower and current is more uniform in the last one.

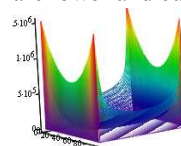


Fig.4. Initial Current density

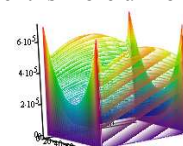


Fig.5. Current density (Optimized case)

Due to the 8 ratio of rectangle sides, currents are not easy to represent.

Square representation has been preferred.

Optimization with a higher number of field components will be presented in final article. Obtained field and currents densities will be analyzed.

V. REFERENCES

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