A novel 3D printed structure with encapsulated air gaps for power electronic component

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In high frequency inductors, fringing effect around air gaps could lead to a serious increase of AC copper loss. The addition of bridges allows to encapsulate the air gaps in the magnetic circuit. Representative cores were printed using Fused Deposition Modeling (FDM) process. A significant reduction of the fringing field (-30% near the edges of winding window) has been observed with finite element analysis.

Keywords: Additive manufacturing; Ferrite; Mn-Zn; Fringing effect; AC copper loss

1. Fringing effect and AC copper loss

Power electronics applications use gapped ferrite components to store the energy in the form of a magnetic field for large current amplitude values [1]. In the gap, the magnetic field does not pass through the air in a straight manner, but also extends around the gaps, generating a 3D field that may interact with the conductors located nearby. At high frequencies, the fringing field phenomenon may affect significantly current flow distribution, which isn’t homogenous anymore on the conductor cross section. The related losses are proportional to the square of the magnetic field. New magnetic circuit structures have been suggested to reduce the fringing field in literature. The first, called quasi-distributed air gap, consists in considering several air gaps of reduced size [2]. The second, eliminates the air gaps by the addition of low permeability materials in the magnetic flux path [3]. In order to reduce the magnetic field crossing the conductors, a new magnetic circuit structure additively manufactured is presented.

2. 3D printed magnetic circuit with encapsulated air gap

In this contribution, we design a new structure that was manufactured using a Mn-Zn ferrite from Japan Metals and Chemicals (Z70-L2G) by Fused Deposition Modeling. This new magnetic circuit encapsulates the air gaps and allows the analysis of the channelling of the fringing field. A distributed air gap structure has been considered as a reference case.

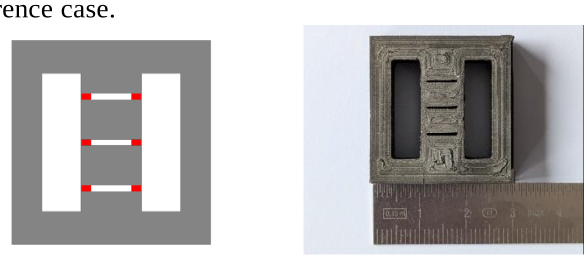

Figure 1 : Distributed air gap magnetic circuit with the added bridges (red) and the printed geometry

The only difference between the two considered structures is related to the addition of bridges around the air gaps (Figure 1), all the other geometrical parameters are the same. Using finite element analysis (FEM), the fringing field of the two magnetic circuits was analysed to determine how it might affect conductors losses.

3. Results

A FEM study was carried out on the fringing field amplitude in the winding window. The amplitude of the orthogonal component of the field was reduced by about 30% close to the winding window’s edges (Figure 2). We could expect a significant reduction of conductors AC resistance and a better filling factor. This result shows the interest of this kind of structure. Copper and iron losses obtained by simulation and measurements will be presented in the full paper.

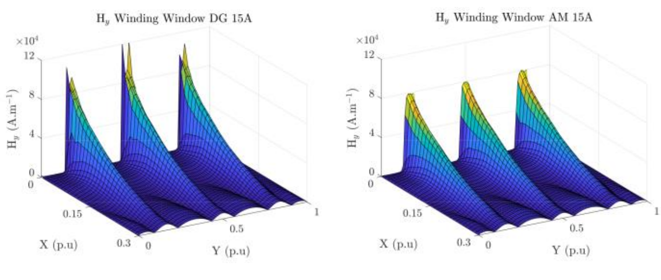

Figure 2: Orthogonal component of magnetic field in winding window for both structure

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