Fringing Effect Losses

The fringing effect is a phenomenon in which the magnetic field circulating inside a magnetic core is deformed when it reaches a discontinuity in the material, which usually results from the insertion of air gaps along the magnetic path,

This deformation is represented as a swollen volume which increments the stores energy in the air gap, and it provokes an increment in the magnetizing inductance due to this extra energy storage.

More accurately, this discontinuity provokes a leakage of part of the H field circulating through the magnetic core, with the whole gap creating a residual H field that expands to the whole winding window and whose strength is inversely proportional to the distance from the source, the air gap.

This H field, which can be quite strong in the vicinity of the gap, when it crosses a conductive volume, induces eddy currents at the switching frequency of the magnetic field, proportional to the perpendicular conductive area, which in turn generates ohmic losses and heat in the conductive materials.

In a magnetic component, these conductive materials near the air gap are usually the wires of the windings, which will have increased winding losses in all the turns, although for turns that are not close to the air gap these losses will be negligible. There are several rules of thumb in the literature about the distance for which the losses start to be negligible, but the reality is that this distance depends on the strength of the H field inside the core (which in turn depends on the number of turns and the current through them), the gap length and the relative orientation of the wires in respect to the air gap

The calculations of these effect are done following the model proposed by Waseem Roshen [1]. In his paper, Roshen derives the magnetic field horizontal and vertical component produced by the air gap in each point of the window, and then applies Snelling's eddy-current losses formula [2] to calculate the induced power losses in each conductor based on its coordinates inside the winding window. The author expands his work to round conductors in a posterior paper [3]

[1] (W. A. Roshen, "Fringing Field Formulas and Winding Loss Due to an Air Gap," in IEEE Transactions on Magnetics, vol. 43, no. 8, pp. 3387-3394, Aug. 2007, doi: 10.1109/TMAG.2007.898908.).

[2] E. C. Snelling, Soft Ferrites: Properties and Applications, U.K., London:Butterworth, 1988.

[3] W. A. Roshen, "High-Frequency Fringing Fields Loss in Thick Rectangular and Round Wire Windings," in IEEE Transactions on Magnetics, vol. 44, no. 10, pp. 2396-2401, Oct. 2008, doi: 10.1109/TMAG.2008.2002302.

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