The Influence of Core Shape and Material Nonlinearities to Corner Losses of Inductive Element

M. Puskarczyk[1], B. Jamieson[1], W. Jurczak[1]

[1]ABB Corporate Research Center, Kraków, Poland

Abstract

Power losses in an inductor or transformer are often determined using loss equations for uniform magnetic materials under specified excitation conditions. In a real device, sharp corners in the magnetic core will cause enhancement effects and a non-uniform flux profile, leading to variations in the core magnetization and higher losses than in a bulk material. Determining more precisely the losses in such an application can provide an important insight into the effects of geometry on core performance and ultimately can be used for advanced magnetics design to compensate for to corner effects. COMSOL Multiphysics® is used to analyze the flux distribution, magnetization and loss spectrum in the material throughout the square corner region (Figure 1).

Two COMSOL interfaces were used: the Electrical Circuit interface and the Magnetic Field interface. The power supply of the investigated magnetic element was made using the elements (equations) provided by the Electrical Circuit interface to ensure the desired amplitude and phase of the source. Passive electrical components together with voltage or current source can model various types of loads or the real network which powers the investigated element. This simulation setup enables investigation of the magnetic element in conditions close to its nominal operating conditions. The inductive element itself was modeled as a distributed fields model, coupled with the electrical circuit. This method of analysis takes into account the impact of the geometry of the core.

As a result of the simulation we obtain the time waveforms of magnetic flux density across the corner regions. This allows us to make the frequency analysis of magnetic flux density and the frequency analysis of the corner power losses. Other useful outputs of the simulation are the time waveforms of currents and voltages of the inductive elements. These values can be measured in real device (a prototype) what is a simple way to validate the simulation model.

COMSOL Multiphysics® was used to calculate the frequency spectrum of magnetic flux density in the region of a ferromagnetic core with a square corner, showing the flux enhancement and damping due to sharp corners in the core. COMSOL modeling confirms the field enhancement effects in the inner corner region and the reduction of the field in the outer corner region [1]. The distribution of the flux in the corner region is modeled and shows that the frequency spectrum of the flux is not constant across the whole corner but rather varies as a function of position within the corner. This frequency spectrum can be used to determine a loss

spectrum for the material in a corner, showing that higher harmonics are more significant in the inner corner region corresponding to the areas of increased flux. Taking into account the losses across the whole corner region, this loss spectrum can be used to create a modified Steinmetz equation [2] for core loss in a ferromagnetic material, resulting in an equation which additionally encapsulates the additional losses in a real core due to the effects of flux enhancement in sharp corners.

Reference

[1] F. Brailsford, V. R. Mazza, The alternating magnetic flux distribution in right-angled corners of transformer laminations. An Experimental Investigation, The Institution of Electrical Engineers' Paper No, 3870 S, Ap, 1962
[2] A. Goldman, Magnetic components for power electronics, Kluwer Academic Publishers, 2002

Figures used in the abstract

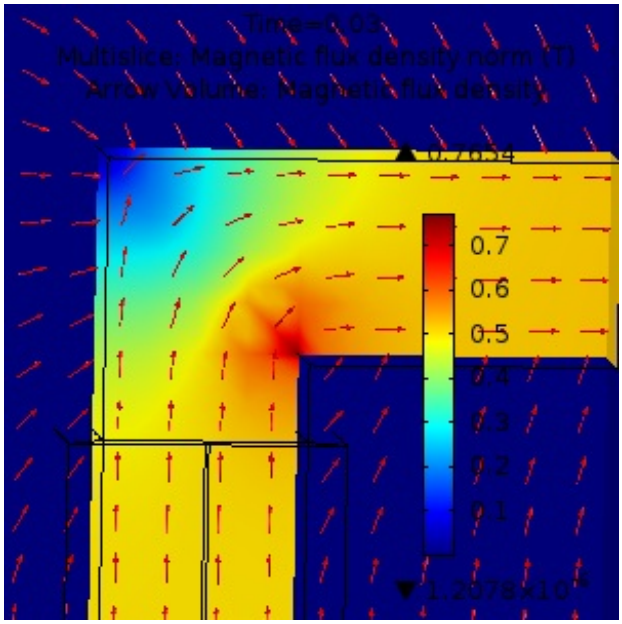

Figure 1: Magnetic flux density across the square corner of the ferromagnetic core