

Title : A modelling tool for ferrite MnZn design - Losses and dimensional resonance according to size and physical properties

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Short abstract:

A 2D simplified model (magnetic formulation) is used to characterize the size and physical properties dependence of total power losses in a MnZn ferrite material at a given frequency around 300 kHz. The application is a high power induction system. The aim is to have guidelines for the design of the ferrite blocks constituting the magnetic circuit and their thermal management in order to avoid overheating and Curie temperature overrun, beyond which the material lose its ferrimagnetic properties .

Keyword : ferrite MnZn , dimensional resonance, losses

Abstract :

Soft MnZn Ferrite are now more and more used for high power and frequency applications: inductors, transformers... due to its high magnetic permeability and low power losses. But at frequency around several hundred kHz, additional power losses need to be considered if large ferrite cores are used. In that case, manufacturer's Steinmetz law are not sufficient for a right power losses assessment. A contribution due to significant eddy currents needs to be added. In addition to the combination of a high equivalent dielectric constant and high permeability, dimensional resonance is introduced for the sizes of the ferrite blocks currently in use, resulting in a significant increase in losses.

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The magnetic circuit is made of an assembly of ferrite blocks distributed around the external side of the coil in an induction furnace. The magnetic flux canalization improves the efficiency of the furnace and reduced non desired coupling on metallic external pieces.

For this 2D approach, a cross section of one rectangular ferrite block perpendicular to the magnetic flux is considered. The COMSOL model is defined with a magnetic formulation: the physics interface solves Maxwell's equations formulated using the magnetic field as the dependent variable (Faradays law). A sinusoidal magnetic field of peak value ' H_0 ' is imposed along the external boundary. For each parametric case (function of thickness, relative permeability, permittivity or electrical conductivity), this value is set to maintain a constant magnetic flux inside the section of the ferrite block (flux ' ϕ_0 ' in Weber). The norm value of the magnetic flux (ϕ_0) was preliminarily calculated from a 3D complete model representing the whole induction device. This modelling approach was validated by a comparison between magnetic field and power losses distribution in the cross section of ferrite block between 2D and 3D model for a same magnetic flux.

The Figure 1a shows the density distribution of power losses (Steinmetz law and induced current losses) in the cross section of the ferrite core. Figure 1b shows a large increase of the losses with the

thickness due to the dimensional resonance effect and the contribution of eddy currents for large thickness.

To minimize power losses and avoid this resonance effect, the ferrite core cross section is divided into four different parts (along the length) with an insulating gap between each parts. The same parametric study demonstrated that such segmented-cross section avoids the resonance effect and leads to low losses with a reduced sensibility to ferrite physical properties. These findings have helped to design a compact and reliable industrial device.

Figures:

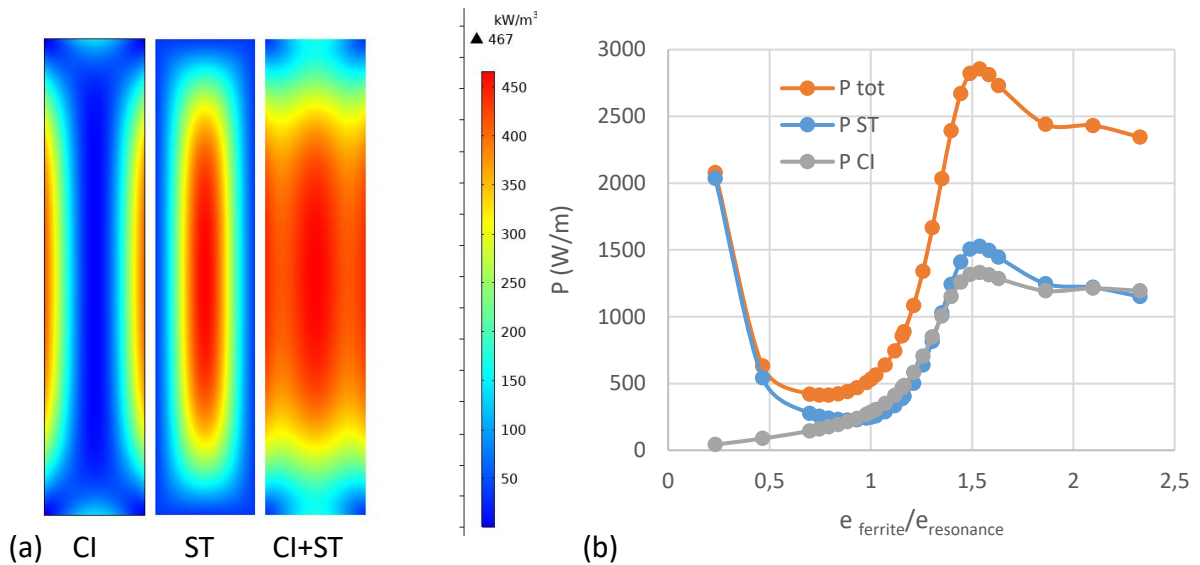


Figure 1 : (a) : Power loss density (kW/m³)-CI=losses from induced current, ST: from Steinmetz law, or global losses-thickness : $e=0.75 e_{resonance}$ – (b): Power loss (W/m) evolution vs ferrite block thickness - $f\sim 300kHz$ - Length= $3.5 e_{resonance}$.

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