New mathematical approach using fractional derivatives to take into account excess losses in magnetic materials

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Accurate prediction of magnetic circuit dynamical behaviour constitutes a fundamental problem for the design and the optimization of electromagnetic devices. The representation of dynamical effects due to eddy currents with a macroscopic model [1] is usually well admitted and adopted by researchers and electrical engineers. On the other hand, macroscopic modelling of microscopic dynamical effects due to wall motions which induce the so called excess losses, always exhibits interests of various research workers [2]-[6].

This paper proposes a new mathematical approach for the modelling of the dynamical microscopic effects. This approach is based on a fractional derivative formulation. This fractional term is used to describe the excess field contribution (1):

$$Hexc(t) = \lambda . \frac{d^{\alpha} B(t)}{dt^{\alpha}} . \qquad (1)$$

The fractional derivative model has already been used with success to model hysteresis on a large frequency bandwidth of ferroelectric ceramics (1mHz < f < 10Hz) [7]. In the case of magnetic materials the fractional formulation is required to describe excess losses.

The new model is implemented and tested by considering a magnetic sample magnetized by a sine flux. An analytical study is carried out and gives results which are in a good agreement with the well known Bertotti's results related to the frequency relation of the excess energy [2].

Finally, comparisons between simulations and large number of experimental results performed on a SiFe sample magnetized by a varying frequency sine flux will be considered as validation of the new model.

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