Effect of magnetic material degradation on the optimal design parameters of electromagnetic devices

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Electromagnetic devices (EMDs) are normally designed based on the properties of the used magnetic material provided by the electrical steel manufacturers. However, it is well-known that the characteristics of magnetic materials inside EMDs are altered during the production of these devices. Mechanical stresses due to electrical steel cutting, clamping and shrink fitting cause a dramatic deterioration of the magnetic material properties (N. Takahashi *et. al.*, "Effect of shrink fitting and cutting on iron loss of permanent magnet motor", JMMM, vol. 320, pp. 925-928, 2008). Consequently, the designed EMD based on the original magnetic material may not achieve the targeted performances.

In this paper, we investigate the effect of magnetic material degradation on the optimal design parameters of EMDs. The proposed methodology is a two-level scheme. The first level is to identify the accurate magnetic material properties inside the studied EMD using a coupled experimental-numerical electromagnetic inverse problem, which has been recently developed (A. Abdallh and L. Dupré, "Magnetic material characterization using an inverse problem approach", book chapter in Advanced Magnetic Materials, ISBN 978-953-51-0637-1, InTech, 2012). Based on the recovered material characteristics, e.g. single-valued *B*-*H* curve and loss parameters, an optimization problem is formulated to modify the design strategy of the studied EMD in order to reach specific performances.

Specifically, in this paper, an asynchronous machine is redesigned by changing some design parameters, i.e. stack length, number and cross section of the excitation windings, for compensating the effect of the magnetic material degradation in order to reach predefined particular performances, i.e. efficiency and overload capacity. To this end, an optimization problem is solved by minimizing iteratively the following multi-objective function:

$$\widetilde{\mathbf{x}} = \arg\min_{\mathbf{x}} OF(\mathbf{x}), \qquad OF(\mathbf{x}) = \{OF_1(\mathbf{x}),\ OF_2(\mathbf{x})\}$$
$$OF_1(\mathbf{x}) = \parallel \eta_s(\mathbf{x},\ \widetilde{\mathbf{u}}) - \eta_t \parallel^2, \ \ OF_2(\mathbf{x}) = \parallel \xi_s(\mathbf{x},\ \widetilde{\mathbf{u}}) - \xi_t \parallel^2$$

with $\mathbf{x}$ being the vector containing the design parameters, i.e. $\mathbf{x} = [l,\ n,\ s]$, where l, n, and s are the stack length, number and cross section of the excitation windings, respectively. η_t and ξ_t are the target efficiency and overload capacity of the motor. η_s and ξ_s are the corresponding simulated quantities using the material parameters $\widetilde{\mathbf{u}}$ recovered from the inverse problem.