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Optimization of ferrite structures in inductive power transfer system for electric vehicles

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Abstract—The paper presents a fast multiobjective optimization procedure to improve the design of inductive power transfer systems for electric vehicles. It relies on the combination of metamodeling techniques with a topology optimization process. The approach is applied to a practical system developed in the laboratory. Numerical predictions show that the global volume of ferrite can be strongly reduced while keeping rather the same transmission performances as the initial structure. The influence of a conductive shielding placed above the receiver is also analyzed.

I. INTRODUCTION

The use of a resonant inductive power transfer (RIPT) system seems an effective technology for the growth of electric vehicles (EVs). Although RIPT systems are now widely studied, there are still several challenges in designing the coupler. Up to now, there is no comprehensive methodology allowing a fast, reliable, and efficient design and optimization of a coil system for RIPT systems [1].

A 3D computational approach gives reliable results about the electrical parameters (mutual inductance, transmission efficiency) and the magnetic parameters (magnetic flux density leakage) around the system, but it may lead to heavy computations that have to be repeated for each new configuration that is highly dependent on various parameters: the size of coils, geometrical characteristics of the system (e.g., ferrite plates, shielding plates), possible misalignment between transmitter and receiver while charging. In [2], a fast and efficient modeling methodology in order to assess the efficiency of RIPT systems was proposed to manage EMC constraints in EVs. The introduction of metamodeling techniques (surrogate models based on polynomial chaos expansions) allows to manage the variability of design parameters describing the electromagnetic problem and to quantitatively determine the contribution of each design variable to the observed output. It allows to perform a fast multiobjective optimization taking into account both the performances of the system (including ferrite and shielding) and the cost. However, the optimization procedure, based on an evolutionary algorithm does not allow to modify the topology of the structure and the shape of ferrites structures (rectangular or circular) and limits the possible shapes.

In this paper, topology optimization is combined with the metamodels previously developed. The interest of the proposed approach is to modify the initial shape of the ferrite plates and to introduce holes in the plates. Such optimization allows to decrease the weight of the ferrite material (and the major cost) while providing better performances of the magnetic coupler. The approach is applied in the case of a practical inductive power transfer system developed in the laboratory.

II. RESULTS AND CONCLUSIONS

The solid isotropic material with penalization (SIMP) method, which is today the most commonly used due to its easy and intuitive implementation, is adopted to arrange the ferrite distribution [3]. The optimization process leads to remove the ferrite from the center and the edges of the ferrite plates, no matter the constraint of the ferrite volume ratio (figures 1 and 2). Arranging the ferrite plates with this algorithm can facilitate around 40% reduction of the ferrite volume. Also, it keeps around the initial performances with an approximate 10% reduction in the mutual inductance. This optimization procedure was also applied in the case of a conductive shielding above the magnetic coupler. It is shown that the shield has a clear impact on the ferrite arrangement at the receiver side. Numerical results will be presented at the conference.

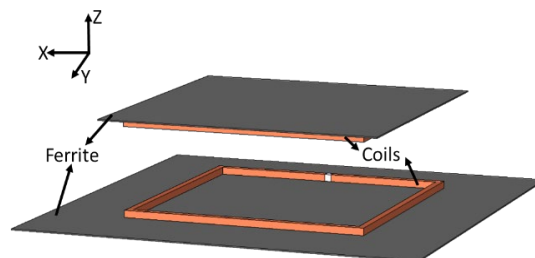


Fig. 1. Initial ferrite volume

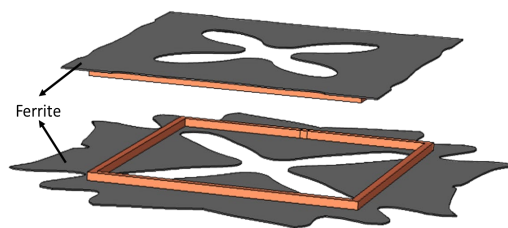


Fig. 2. Structure with 40% reduction of the ferrite volume

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