A Novel Scheme for Material Updating in Source Distribution Optimisation of Magnetic Devices using Sensitivity Analysis

Dong-Hun Kim[1], Jan K. Sykulski[1] and David Lowther[2]
[1]School of Electronics and Computer Science, University of Southampton
Southampton, SO17 1BJ, UK, E-mail: dh29kim@dreamwiz.com, jks@soton.ac.uk
[2]Department of Electrical and Computer Engineering, McGill University
Montreal, Quebec, H3A 2A7Canada, E-mail: david.lowther@mcgill.ca

***Abstract* – A novel material updating scheme, which does not require intermediate states of a material used, is presented for the source distribution optimisation problems. A mutation factor to determine a degree of topological changes in the next design stage on the basis of a current layout accelerates the convergence of an objective function. Easy implementation and fast convergence of the scheme are verified against a previously published MRI dipole magnet design problem.**

INTRODUCTION

Topology Optimization (TO), which originated in the structural mechanics community, has also been successfully applied to finding the distribution of materials and sources in electromagnetic systems [1], [2]. However, application of TO in electromagnetics poses additional challenges in respect of source distributions given by current densities and permanent magnetization. Moreover, from the point of view of the adjoint system of the sensitivity analysis, while the permeability of the primary system strongly distorts the adjoint field distribution, the magnetic sources do not affect the fields because they are replaced by air regions. This implies that a different approach – especially in the material updating scheme – should be taken when solving source distribution problems. This paper introduces a very fast and efficient TO algorithm for such problems.

A NOVEL MATERIAL UPDATING SCHEME

Based on the density method, design variables can be represented as:

$$\mathbf{J}(x,y) = \mathbf{J}_s p^n \tag{1}$$

where p is the normalized design variable ($0 \le p \le 1$) and n is the penalty factor ($n>1$). However, in our approach, p is forced to be either a void (0) or a solid (1) and n is set to be 1 in the overall design procedure. Therefore, this scheme does not require the rather complicated constraint penalty terms, which enforce the intermediate values of design variables to be either 0 or 1. Assuming the desired volume V_o of a whole design space to be given, the proposed iterative process is as follows:

1) Solve the primary and adjoint systems, successively.
2) Compute design sensitivity using the analytical formula.
3) Update material density P ($P_{i+1}=P_i+\alpha\Delta P$): Calculate a mutation factor γ_{i+1} proportional to a norm of the objective function. Inner loop: Search α to satisfy $V_{i+1}/V_o \le \varepsilon_1$ and $\gamma'/\gamma_{i+1} \le \varepsilon_2$ where γ' is calculated according to a transient value of α.
4) Enforce each design cell (p) to be either 0 or 1.

EXAMPLE

The proposed scheme, combined with a commercial finite element code, was applied to a test problem the specification of which may be found in [2]. After only 8 iterations, the field intensities within 2% of the desired value of 36.26 A/m were accomplished as demonstrated in Fig. 1. Figure 2 shows the optimised coil and associated magnetic flux distribution; to achieve this result would normally necessitate more than 100 iterations using the existing material updating schemes. This result demonstrates therefore that it is possible to optimise the coil distribution without the usage of invalid states between void and solid; considerable savings in computer times may thus be achieved and some of the complicated implementation issues may also be avoided.

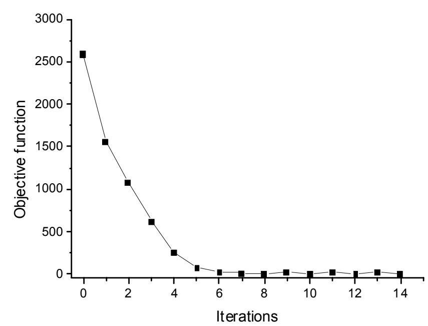

Fig. 1. Convergence of the proposed scheme.

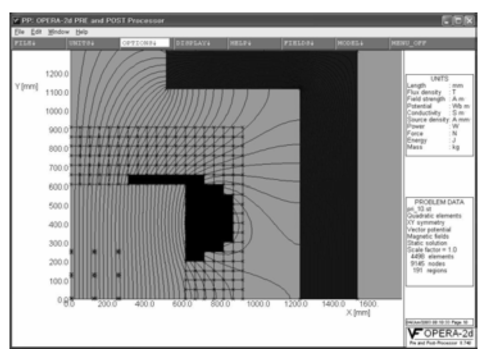

Fig. 2. Optimized current and flux distribution after 8 iterations.

REFERENCES

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