COMSOL Multiphysics® Simulation Integrated Into Genetic Optimization Algorithm

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Abstract

The general topic of this work is the development of a useful tool for designing and performance optimization of thermoelectric micro-generators (µTEGs).

Introduction:
A µTEG is a device able to generate an electric potential when it is exposed to a temperature gradient due to the thermoelectric Seebeck effect [1]. To fabricate high efficiency µTEG, it is necessary not only to achieve thermoelectric material structure with excellent properties, but also to design the optimal geometry of the µTEG itself [2,3]. For this reason prediction of thermoelectric performance parameters by numerical methods is an inherent part of µTEG development and allows for time- and cost-saving assessment of material combinations and variations of crucial design parameters such as shape, TE material length/width and thermal coupling. Considering the complexity of a µTEG devices and its numerous affecting factors, the clarity and the flexibility of a mathematical treatment comes to the fore. Over the last decade, several approaches based on commercial finite element modeling (FEM) software has been used to analyze the performance of µTEGs [3,4].

Use of COMSOL Multiphysics®:
In the present work, it will be shown an innovative methodology to design high performance µTEGs, joining the power of multi-physics simulation [5] with the modern optimization approach of genetic algorithms [6, 7]. It's based on software interaction between COMSOL Multiphysics® and MATLAB® and it allows to perform:
• finite element numeric device simulation
• architecture design and geometry device optimization

COMSOL Multiphysics® is used to simulate the device by means of a set of specific thermoelectric equations in order to predict the available electric power density [5]. A device 3D model has been implemented in a suitable parametric form enabling to evaluate the impact of various geometric configuration and different materials.

During the optimization process implemented in MATLAB®, COMSOL Multiphysics® is invoked at every step of the genetic evolutionary process in order to evaluate the physics performances of each set of parameters, and in particular to compute the electric power density generated by the device (the genetic algorithm fitness function).

Results:
The main result of this paper is a multi-objective optimization tool: it's a very powerful instrument that helps scientists to automatically find the best parameters of their models. Computational effort depends on the number of variables and on the desired accuracy level. This methodology has been applied for devices performance optimization within an industrial research program focused on the development of μTEGs based on innovative proprietary materials. Here it will be described the use of the tool on a simple case study geometry of a μTEG by using literature values of the physical variables of the thermoelectric material that cannot be given for confidentiality reasons.

Conclusion:
This tool can be applied in a very wide range of complex problems, to simulate, optimize and improve system design especially when numbers of parameters and constraints increase.

Reference

[1] A. F. Ioffe, Semiconductor thermoelements and thermoelectric cooling, Rev. and supplemented for the English ed. London,: Infosearch, 1957.

[2] Chris Gould and Noel Shammas, “A Review of Thermoelectric MEMS Devices for Micro-power Generation, Heating and Cooling Applications”, Micro Electronic and Mechanical Systems, Kenichi Takahata (Ed.), ISBN: 978-953-307-027-8, InTech, (2009). Available from: http://www.intechopen.com/books/micro-electronicand-mechanical-systems/a-review-of-thermoelectric-mems-devices-for-micro-power-generation-heating-andcooling-applications.

[3] Bottner, H. “Thermoelectric micro devices: current state, recent developments and future aspects for technological progress and applications”, Proceedings ICT '02. Twenty-First International Conference on Thermoelectrics - 25-29 Aug. 2002.

[4] D. Ebling, K. Bartholomé, M. Bartel, M. Jägle, “Module Geometry and Contact Resistance of Thermoelectric Generators Analyzed by Multiphysics Simulation”, Journal of Electronic Materials, vol. 39, Issue 9, 1376-1380 (2010).

[5] COMSOL Multiphysics® Documentation, www.comsol.com

[6] E. Dilettoso, S. A. Rizzo, N. Salerno, "SALHE-EA: a New Evolutionary Algorithm for Multi-Objective Optimization of Electromagnetic Devices", Intelligent Computer Techniques in Applied Electromagnetics, Sławomir Wiak, Andrzej Krawczyk and Ivo Dolezel (Eds.), Springer-Verlag, vol. 119, 37-45 (2008).

[7] E. Dilettoso, N. Salerno, "A Self-Adaptive Niching Genetic Algorithm for Multimodal Optimization of Electromagnetic Devices", IEEE Transactions on Magnetics, vol. 42, n. 4, april, 2006, pp. 1203-1206.