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Numerical Modeling and Design of Thermoelectric Cooling Systems and Its Application to Manufacturing Machines

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In this work the properties of thermoelectric modules (TEMs) and their behavior have been numerically modeled. Moreover, their applications very often require modeling not only of the TEM but also of the working environment and the product in which they will be working. A clear example is the fact that TEMs are very often installed with heat-dissipating elements such as fans, heat sinks, and heat exchangers; thus, the module will only work according to the heat dissipation conditions that these external sources can provide in a certain environment. In this context, analytic approaches, even though they have been proved to be useful, do not provide enough, accurate information in this regard. Therefore, numerical modeling has been identified as a powerful tool to improve detailed designs of thermoelectric solutions. This paper presents numerical simulations of a TEM in different working conditions, as well as with different commercial dissipation devices. The objective is to obtain the characteristic curve of a TEM using a valid numerical model that can be introduced into larger models of different applications. Also, the numerical model of the module and different cooling devices is provided. Both of them are compared against real tested modules, so that the deviation between them can be measured and discussed. Finally, the TEM is introduced into a manufacturing application and results are discussed to validate the model for further use.

Key words: Numerical modeling, cooling, industrial application

INTRODUCTION

Understanding the behavior and functioning of a thermoelectric module (TEM) is a process that requires deep analysis based on very different disciplines and on very different properties of the module and its parts, such as electrical, magnetic, mechanical, and physical properties.[1] On the other hand, use of TEMs in different products produces effects that can be considered to be mainly thermal and mechanical. Due to this fact, modeling the behavior of a TEM to analyze its effect on the component in which it is designed to be assembled, complicated as it may be to introduce every discipline involved in its behavior, in most cases requires only modeling of the two above-mentioned properties. The objective of this paper is to present and discuss a finite-element (FE) model developed to be flexible and quick to allow the user to introduce it into larger models, whole-machine models in some cases, but still be able to accurately predict the thermal and mechanical behavior of the module and its effect on the surrounding components. Therefore, the main goal of this study is to introduce a model that can simulate accurately what happens when a TEM is introduced into any system, rather than describe precisely the different phenomena going on inside the module.

Over the years, many attempts have been made to model the behavior of TEMs via analytic expressions;[2]

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