Modélisation numérique et optimisation des matériaux à changement de phase : applications aux systèmes complexes

Doctorant·e

BOUGUILA MAISSA

Direction de thèse

EL HAMI ABDELKHALAK (Directeur·trice de thèse)
BEN SOUF MOHAMED AMINE (Co-directeur·trice de thèse)
HADDAR MOHAMED (Co-encadrant·e de thèse)

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Rapporteurs de la thèse

BAREILLE OLIVIER MAITRE DE CONFERENCES DES UNIVERSITES HDR Ecole Centrale de Lyon
MEZLINI SALAH PROFESSEUR Ecole Nationale d'Ingénieur de Monastir

Membres du jurys

BAREILLE OLIVIER, MAITRE DE CONFERENCES DES UNIVERSITES HDR, Ecole Centrale de Lyon
BEN SOUF MOHAMED AMINE, PROFESSEUR, Ecole Nationale d'Ingénieurs de Sfax
BEN TAHAR MABROUK, PROFESSEUR DES UNIVERSITÉS, Université de Technologie de Compiègne
EL HAMI ABDELKHALAK, PROFESSEUR DES UNIVERSITÉS, INSA de Rouen Normandie
HADDAR MOHAMED, PROFESSEUR, Ecole Nationale d'Ingénieurs de Sfax
MEZLINI SALAH, PROFESSEUR, Ecole Nationale d'Ingénieur de Monastir
SAOUAB ABDELGHANI, PROFESSEUR DES UNIVERSITÉS, Université Le Havre Normandie
VERNIERES LAMIAE, MAITRE DE CONFERENCES DES UNIVERSITES HDR, INSA de Rouen Normandie

Abstract

Phase-change materials exhibit considerable potential in the field of thermal management. These materials offer a significant thermal storage capacity. Excessive heat dissipated by miniature electronic components could lead to serious failures. A cooling system based on phase-change materials is among the most recommended solutions to guarantee the reliable performance of these microelectronic components. However, the low conductivity of these materials is considered a major limitation to their use in thermal management applications. The primary objective of this thesis is to address the challenge of improving the thermal conductivity of these materials. Numerical modeling is conducted, in the first chapters, to determine the optimal configuration of a heat sink, based on the study of several parameters such as fin insertion, nanoparticle dispersion, and the use of multiple phase-change materials. The innovation in this parametric study lies in the modeling of heat transfer from phase-change materials with relatively high nanoparticle concentration compared to the low concentration found in recent literature (experimental researchs). Significant conclusions are deducted from this parametric study, enabling us to propose a new model based on multiple phase-change materials improved with nanoparticles (NANOMCP). Reliable optimization studies are then conducted. Initially, a mono-objective reliability optimization study is carried out to propose a reliable and optimal model based on multiple NANOMCPs. The Robust Hybrid Method (RHM) proposes a reliable and optimal model, compared with the Deterministic Design Optimization method (DDO) and various Reliability Design Optimization methods (RBDO). Furthermore, the integration of a developed RBDO method (RHM) for the thermal management application is considered an innovation in recent literature. Additionally, a reliable multi-objective optimization study is proposed, considering two objectives: the total volume of the heat sink and the discharge time to reach ambient temperature. The RHM optimization method and the non-dominated sorting genetics algorithm (C-NSGA-II) were adopted to search for the optimal and reliable model that offers the best trade-off between the two objectives. Besides, An advanced metamodel is developed to reduce simulation time, considering the large number of iterations involved in finding the optimal model.