Deliverable #1: Needs Assessment

Team 9 – Phase Change Material Transient Heatsink for Power Semiconductor

Sponsor:
Unison Industries

Industry Advisor:
Kevin Walker[1]

Faculty Advisor:
Dr. Kunihiko Taira[2]

Team Members:
Daniel Canuto[3]
Kegan Delinger[4]
Joseph Rivera[5]

Due Date: September 27, 2012

[1]Principal Engineer, Electrical Hardware & Reliability, Unison Industries (kevin.walker@unisonindustries.com).
[2]Assistant Professor, Mechanical Engineering, Florida State University (ktaira@fsu.edu).
[3]Undergraduate, Mechanical Engineering, Florida State University (dc10g@my.fsu.edu).
[4]Undergraduate, Mechanical Engineering, Florida State University (kjd09g@my.fsu.edu).
[5]Undergraduate, Mechanical Engineering, Florida State University (jwr09@my.fsu.edu).

Contents

1.0 Problem Statement

The objective of this senior design project is to create a heatsink for power semiconductors in aerospace applications. In order to accommodate transient thermal loading conditions encountered in such applications, the heatsink will incorporate a phase change material in order to store thermal energy from the power semiconductors during those periods of the duty cycle in which convective heat transfer rates are low.

2.0 Background

From the sponsor's project description:

"Among the electrical products Unison Industries designs and produces for the jet engine industry are ignition units and power regulators which contain power semiconductors. Thermal management of these is a critical part of the design process, maintaining the devices within their reliable operating limits under varying power dissipation levels and ambient conditions. Operating overloads and thermal transients in the ambient environment can be particularly challenging, often adding size and weight to the system."

From the project description, it can be seen that there is a need for a highly-reliable heat dissipation solution for power semiconductors in jet engine systems. As a result of their application, one can imagine that these semiconductors experience many transient thermal loading conditions, such as startup periods and variable atmospheric conditions. Consequently, in designs that use finned heat sinks for thermal management, there may be situations in which high power dissipation rates couple with low convective heat transfer rates to result in unacceptable temperature increases within the semiconductors.

To supplement the convective heat rejection offered by traditional finned heat sinks, this project aims to create a hybrid heat sink that will thermally couple the fins of such a heat sink to a phase-change material (PCM). The PCM will have a melting temperature within the operating temperature range of the semiconductors, and will thus be able to absorb thermal energy as latent heat. In this manner, thermal energy will be able to leave the semiconductors even during periods of low convective cooling, thus maintaining them at a more desirable temperature. Once convective cooling rates rise, the thermal energy stored in the PCM will be conducted through the fins and rejected to the ambient environment through convection.

It should be noted that this hybrid method of thermal management has already been tested and proven as an improvement to finned heat sinks[1,2,3]. The main challenge in the case of this project comes as a result of the area of application: since this heatsink is intended for aerospace platforms, it is necessary that it achieve its goals without significantly adding to an aircraft's size and weight.

3.0 Objectives

The most important objectives for our team to achieve are as follows:

1. Identify preferred phase change material(s) for the heatsink, given that the operating temperature range will be 115 – 125°C.
2. Creation of an analytical model that will simulate the heatsink's performance under various thermal loadings
3. An experimental rig for validation of the analytical model

4.0 Methodology

Based on the objectives outlined in Section 3, our design process is essentially broken down into three phases: background research, modeling, and prototyping/validation. These phases are further outlined below. Numbers contained in square brackets (i.e., **[1]**) are links to the aforementioned objectives.

4.1 Background Research

During this phase, we aim to:

- Conduct a literature search to find relevant modeling and analysis techniques
- Conduct a patent search and discuss our results with FSU's patent attorneys to ensure that our design does not infringe on existing intellectual property
- Identify potential materials for use as PCMs **[1]**

4.2 Modeling

Once we have gained a sufficient knowledge base, we will be able to:

- Determine the equations needed to sufficiently model the thermodynamics of our system
- Determine the design parameters that will control our heatsink's performance
- Create simulations of individual heatsink designs using variations of our design parameters **[2]**
- Use the results of our simulations in concert with a weighted decision matrix to select a design for prototyping

4.3 Experimentation/Verification

Once we have selected a design for prototyping, we will:

- Work with either the College of Engineering or Unison to manufacture our heatsink **[3]**

- Acquire either a power semiconductor or an equivalent simulator of its thermal loading and integrate it into our heatsink **[3]**
- Install temperature monitoring systems for the power semiconductor, heatsink, and ambient environment **[3]**
- Collect and analyze temperature data to compare the prototype's performance to its theoretical capacity
- Use our experimental results to revise our design rules and (if time permits) create further prototypes

5.0 Expected Results

By the end of the year, it is expected that our team will have a functional heatsink design that can be further developed for integration into aerospace electronics applications. We are also expected to provide parametric design rules so that our work can be applied to sizing heatsinks for other applications. The experimental rig is expected to have a working model of our design attached to either a power semiconductor or a device capable of simulating the thermal loading that the power semiconductor would create. While the rig need not have the heatsink packaged in its final configuration, it should be able to demonstrate the design's capacity by monitoring temperatures of the simulated device, the heatsink, and the surrounding environment.

6.0 Constraints

Time: Our entire team is composed of full-time students who also hold part-time positions. As such, it will be difficult not only to put a sufficient amount of work into our design, but also to coordinate our schedules for tasks that will require the entire team. To assist in alleviating the scheduling issue, we have created a Google Calendar that lists all of our individual obligations, in order that we can anticipate them and schedule tasks around them. Furthermore, we are using a project planning software known as OmniPlan to create Gantt charts that track our project progression and task responsibilities.

Budget: Our project has been allocated $2,000 by Unison, and our design/testing must stay within this limit. As such, we will have to ensure that any purchases we make are necessary to the completion or improvement of our project objectives, and that we make cost-conscious decisions when choosing between design or component alternatives.

7.0 References

[1]Fossett, A. J. et. al., "Avionics Passive Cooling With Microencapsulated Phase Change Materials," *Transactions of the American Society of Mechanical Engineers*, Vol. 120, 1998, pp. 238-242.
[2]Krishnan, S., Garimella, S. V., and Kang, S. S., "A Novel Hybrid Heat Sink using Phase Change Materials for Transient Thermal Management of Electronics," *IEEE Transactions on Components and Packaging Technologies*, Vol. 28, 2005, pp. 281-289.
[3]Leland, J. and Recktenwald, G., "Optimization of a Phase Change Heat Sink for Extreme Environments," PhD thesis, Portland State University, Mechanical Engineering Department.