18. DESIGN AND OPTIMIZATION OF HEAT SINKS

Course Leaders: Marc Hodes – Tufts University and Georgios Karamanis –Transport Phenomena Technologies, LLC.

Course Objective:
This course will provide the audience with an understanding of heat sink design and optimization in the context of the thermal management of electronics. The course will have two parts. The first part will begin with an overview of common methods to manufacture heat sinks such as extrusion, die casting and forging. Each method will focus on their advantages and disadvantages with respect to cost and fin geometry. Attention will then shift to the theory of spreading resistance and how it can be calculated in order to properly size the thicknesses of the bases of heat sinks. Next, the theory of the operation of heat pipes in tubular and flat (vapor chamber) configurations will be presented along with their roles in smoothing out temperature gradients in the fins and bases of heat sinks.

In the second part of the course, single-phase conjugate heat transfer, where conduction in the heat sink is coupled to convection in the coolant, i.e., air or water, flowing through the heat sink will be highlighted. We will discuss why the constant heat transfer coefficient assumption tends to be an invalid one in real heat sinks by using specific examples. Then, the use of computational fluid dynamics (CFD) to compute conjugate Nusselt numbers will be considered. The course will conclude with a discussion of how to embed pre-computed results for conjugate Nusselt numbers and dimensionless flow resistances for heat sinks in flow network models (FNMs) of circuit packs such as blade servers. Finally, how to use a multi-variable optimization scheme to optimize the geometry (fin thickness, spacing, height, length, say) of an array of heat sinks in a circuit pack represented by an FNM model with embedded tabulations of CFD results to represent heat sinks will be discussed.

Course Outline:
1. Introduction of the Instructors and Course
2. Manufacture of Heat Sinks
3. Spreading Resistance: Theory and Practice
4. Heat Pipes: Theory and Practice
5. Conjugate Nusselt Numbers
6. Computing Conjugate Nusselt Numbers by CFD
7. Flow Network Modeling (FNM)
8. Multi-Variable Optimization (MVO)
9. CFD-FNM-MVO Hybridization to Optimize Heat Sink Arrays
10. Conclusion

Who Should Attend:
Engineers and technical managers who are involved in packaging technology development that necessitates an understanding of heat sink design and optimization in the context of the thermal management of electronics should attend.

Bio 1:
Professor *Marc Hodes* received his BS, MS and PhD degrees in Mechanical Engineering, the latter from MIT in 1998. He held a succession of appointments at Alcatel-Lucent’s (now Nokia’s) Bell Laboratories from Postdoctoral Scientist to Manager of a Thermal Management Research Group between 1998 and 2008, when he joined Tufts University’s Department of Mechanical Engineering. He holds 14 issued US Patents, most related to thermal management, and has nearly 50 publications related to heat and mass

transfer in archival journals. Professor Hodes is known internationally in the thermal management community and has delivered the short entitled *Thermoelectric Modules*: *Principles and Research* at multiple ITherm meetings in the past. He teaches Fluid Mechanics and Heat Transfer at the undergraduate level and Thermal Management of Electronics, Advanced Heat Transfer and Analytical Transport Phenomena at the graduate level. His current research interests concern apparent slip on super hydrophobic surfaces, supercritical drying of aerogels and conjugate heat transfer. His work at Tufts has been sponsored by, e.g., NSF, DARPA, DoE, Huawei and Google.

Bio 2:

Georgios Karamanis**,** received his Diploma and M.S. in Mechanical Engineering from Aristotle University of Thessaloniki (2013) and Tufts University (2015), respectively. He will receive his PhD in Mechanical Engineering from Tufts University in the summer of 2018. His MS and PhD theses concern the optimization of heat sinks for the thermal management of electronics. He has expertise in analytical, numerical and experimental aspects of convective transport as evidenced by his 5 publications in peer-reviewed journals such as the *ASME Journal of Heat Transfer* and the *Journal of Fluid Mechanics*. Mr. Karamanis has extensive experience in using commercially-available computational fluid dynamics (CFD) codes such as FLUENT and Comsol and regularly adds sophisticated user-defined subroutines to them. He also writes his own CFD code when warranted and is well versed in the formulations of flow network modeling (FNM) and multi-variable optimization (MVO) routines and numerical methods in general. He too has experience in writing Graphical User Interfaces (GUIs). In the Fall of 2017, he cofounded Transport Phenomena Technologies, LLC with Professor Hodes.