Parametric Analysis and Optimization of Microstructured Heat Transfer Surfaces using a Validated CFD Model

Danielle Taylor, Dan Faulkner, and Reza Shekarriz
MicroEnergy Technologies, Inc.
3525 SE 17th Ave., Portland, OR 97202
Voice: (503) 234-2747 Email:danielle.taylor@microet.com

We report on a CFD modeling tool developed to optimize thermal resistance while minimizing pressure drop for novel three-dimensional micro-heat transfer structures. Previous work in this area has shown that pin-fin heat sink designs provide significantly better thermal performance over conventional parallel microchannels, without adding large pressure drops to the system. The pin-fin features increase convective heat transfer by maximizing heat transfer surface area and disrupting the laminar boundary layer. The effect of these heat transfer enhancing features can be investigated with this CFD-based design tool.

We have developed a CFD optimization template to evaluate the heat transfer enhancement and pressure drop for any heat sink geometry. For a given geometry, this CFD optimization model uses the Powell optimization algorithm. The Powell method is a multi-variable optimizer where it searches for the best result for each design variable. Each single-variable problem is solved using a one-dimensional optimizer. The single-variable results are used to find the new search direction. This process is repeated until there is minimal improvement to the design. Improvement of the design is quantitatively evaluated by a function that minimizes pressure drop and minimizes thermal resistance. Experimental methods were also used to investigate the validity of these CFD results.

The first heat sink design we have pursued is a pin-fin heat sink design, where the pins have a diamond-shaped cross section with variable aspect ratio. The CFD model optimized the heat sink geometry by optimizing thermal resistance and minimizing the pressure drop across the heat sink. Using these design variables, a heat sink was fabricated and tested. Experimental results were shown to agree with our CFD results and in general validated our approach. These results verify that our CFD optimization template can be used as a design tool in the future for other complicated three-dimensional microstructured heat sinks.