



SIMULATION OF A MICRO JET COOLING ARRAY

Pierre Montanier
M.S. Candidate

Faculty Advisor: Dr. Nikitopoulos

ABSTRACT

New generation micro-electronic chip devices are more powerful, and they produce more heat. Hence, there is a need for micro cooling systems for removing the heat from these micro-chips. We will present numerical simulations of the flow and heat transfer in a novel impingement heat exchanger developed by International Mezzo Systems Inc. and named Micro Jet Cooling Array (MJCA). More specifically we will quantify the heat transfer capability and pressure drop characteristics of the MJCA in the laminar operating range and examine the effect of some relevant design parameters.

The MJCA is basically an array of impingement jets, which cool the surface requiring thermal protection. The novelty of the MJCA is not the impingement jet array, but the provision of a coolant return path around each jet, which does not interfere with the impingement flow. Thus the coolant can escape without disrupting the highly efficient impingement region with a cross flow.

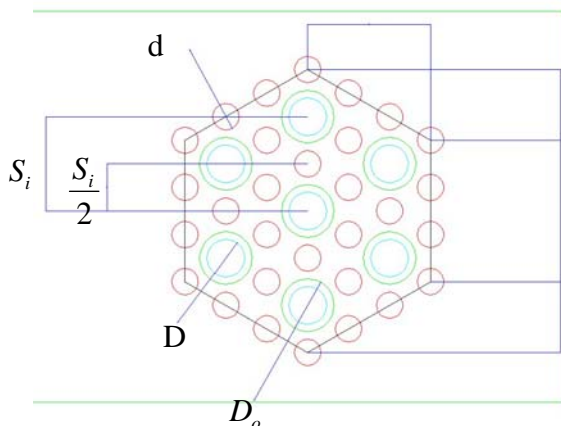


Figure 1: Top view of the simulated MJCA module; $d = 350 \mu m$, $D = 500 \mu m$, $D_o = 700 \mu m$ and $S_i = 1250 \mu m$

The device is made by a combination of the LIGA micromachining process and Laser Ablation. Figure 1 shows the top view of the basic hexagonal MJCA module used for the numerical simulations. The maximum dimension (diagonal) is $3S_i = 3,750,500 \mu m$ and the diameter of an impingement jet is $D = 500 \mu m$. Moreover, the bottom plate of the array separating the impingement region from the outflow (coolant return) region is perforated by return holes whose diameter is $d = 350 \mu m$. Jets and holes are arranged in a hexagonal structure, for instance, each jet is surrounded by six other jets to form a hexagon and between two jets there is one returned hole.

Initially some test simulations have been made on a single jet cooling system, varying the inlet Reynolds number in the laminar regime to examine its effect on the heat transfer coefficient and compare with estimates from simple theory of heat transfer in the neighborhood of a stagnation region. These simulations solved the Continuity, Navier-Stokes and Energy equations and were conducted with a fixed and uniformly distributed heat flux as a boundary condition. This gave a basic idea of how the impingement cooling method works and the difference between employing variable or fixed coolant thermophysical properties.

Numerical simulations were then made on the actual geometry of a MJCA prototype still employing the uniform heat flux boundary condition. The relationship between the heat transfer rate and the inlet Reynolds number was established for the MJCA system. For instance, at an inlet Reynolds number of 1033, the area-averaged heat transfer coefficient on the cooling surface was $9.9 W \cdot cm^{-2} \cdot K^{-1}$ and the area-averaged Nusselt number was 155520. Figure 2 shows the heat transfer distribution on the cooling surface for this case.

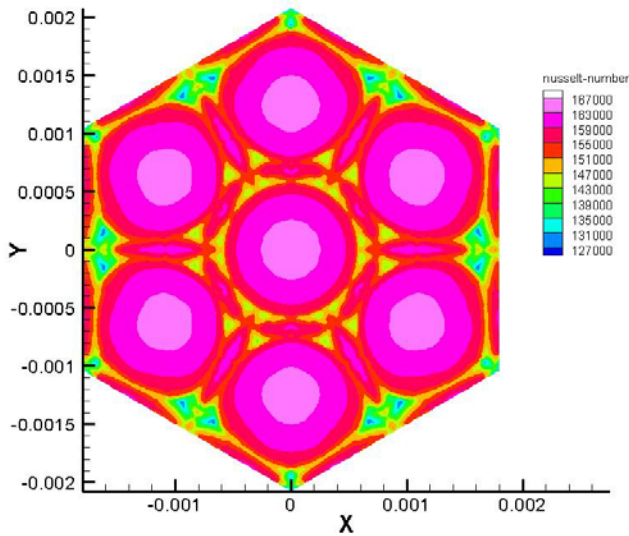


Figure 2: Nusselt number distribution on the impingement-cooled surface for the inlet $Re=1033$ case with returned holes

The simulations included variation of parameters such as impingement region height, Reynolds number, and heat flux. Three different geometries were examined. Apart from the prototype geometry, one reduced the distance of the impinging jets from the cooled surface and the other removed the perforated wall separating the impingement region from the coolant return region. When the original MJCA was simulated with no wall separating the outlet region from the impingement area, performance was enhanced. In fact, this system presents the lowest pressure drop through the device and has the same heat transfer rate on the cooling surface. Moreover, the heat transfer performance of the MJCA with the smaller impingement region was also better in terms of a higher Nusselt number.

ACKNOWLEDGMENTS

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