8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

FINITE ELEMENT MODELLING OF MICRO HEAT PIPES

***Meysam Rahmat [1] and Pascal Hubert [2]**

[1] Department of Mechanical Engineering, McGill University
817 Sherbrooke St. West, Montreal,
Quebec, Canada, H3A 2K6
meysam.rahmat@mcgill.ca

[2] Department of Mechanical Engineering, McGill University
817 Sherbrooke St. West, Montreal,
Quebec, Canada, H3A 2K6
pascal.hubert@mcgill.ca

Key Words: *Two-phase flow, Heat transfer, Phase change, Finite element, Modelling.*

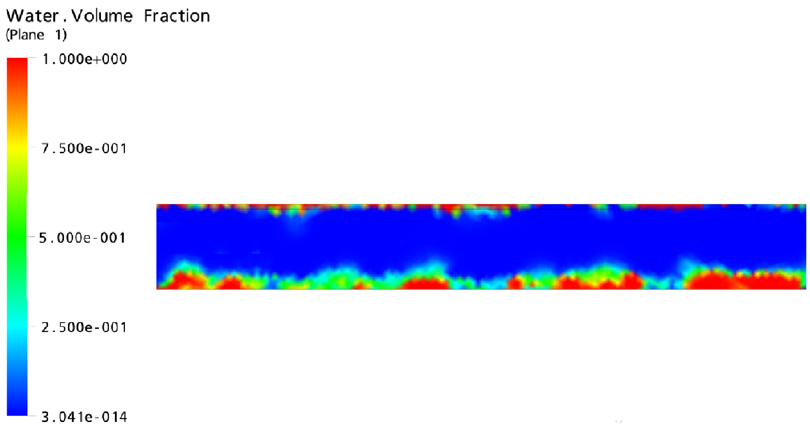
ABSTRACT

Two-phase flow in a micro heat pipe [1] was simulated using finite element analysis. Physical behaviour of the system, including phase change and accumulation of the liquid in the corners, was captured according to the experimental results in the literature. Effective thermal conductivity, pressure and velocity field were investigated within the micro heat pipe. Good correlation between the simulation results and the experimental investigations demonstrated the models validity and precision. The proposed approach could be used to design new micro heat pipe architectures and reduce the need for further costly experiments and complicated mathematical modelling.

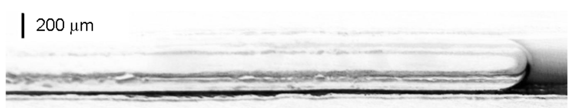
A micro heat pipe is a single channel containing two phases of a working fluid moving in opposite directions. The channel cross-section is usually triangular, since the sharp corners are required for the micro heat pipe to operate properly. The vaporization of the working fluid in the evaporator section absorbs heat from the heat source. The vapour moves towards the condenser, where it releases its latent heat to the heat sink. The sharp edges function as arteries to bring back the liquid from the condenser to the evaporator, as a result of capillary pressure difference. That causes continuous liquid and vapour flows in opposite directions.

A convergence analysis was performed, in order to study the capability of ANSYS CFX–5.7.1 finite element code to simulate the fluid flow/heat transfer phenomenon in micro heat pipes. The analysis showed that the stability of the results was affected by boundary conditions. It was noticed that models with higher thermal gradient lead to higher instabilities. However, by adjusting the simulation parameters, such as the number of iterations and residual target, a reasonable runtime and accuracy were achieved.

The models helped understanding the detailed heat and mass transfer phenomena at the micro scale. The liquid accumulation in the sharp corners was accurately captured by the model, and the phase change process within the microchannel was successfully modelled. Figure 1 shows the two phases of the working fluid in an operating micro heat pipe. Figure 1–a illustrates the water volume fraction in the evaporator section on the plane of symmetry along the axial direction of the microchannel; while the result of experimental investigation is shown in Figure 1–b. Once the model qualitatively predicted the physics of the problem, the analysis was expanded to predict the characteristic micro heat pipe operating parameters quantitatively. The pressure difference between the evaporator and the condenser was predicted and was compared to the literature. The velocity field, also, was determined for both liquid and vapour phases and demonstrated a good agreement with the results of experimental investigations in the literature.



(a)



(b)

Figure 1: a) Water volume fraction in the evaporator section in the plane of symmetry. **b)** Experimental observation of the two phases interface [2].

One very important issue in micro heat pipe operation is its thermal performance under overloading conditions. When the thermal load applied to the system exceeds the maximum heat transport capacity of micro heat pipe, a dry-out phenomenon happens and the thermal performance decreases dramatically. Dry-out phenomenon was simulated by defining an effective length to express the maximum distance that the micro heat pipe can transport the heat. Furthermore, the effect of liquid filling ratio on the micro heat pipe effective length was considered. The validated model was able to predict the behaviour of micro heat pipe appropriately, and demonstrated the capability of a commercial finite element software to simulate a two-phase fluid flow/heat transfer problem.

REFERENCES

[1] T. P. Cotter. “Principles and prospects for micro heat pipes”, *5th International Heat Pipe Conference*, Tsukuba, Japan, (1984).

[2] R. Nicolas, *Fabrication de microcaloducs par écriture directe*, Montreal, McGill University: 35, 2007.