Numerical Investigation of Heat Transfer of Aluminum Metal Foam Subjected to Pulsating Flow

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Abstract

The rapid development of electronic devices leads to more demand for efficient cooling techniques. At conventional scale, there are many cooling configurations have been done; however, the studies in cooling techniques at micro scale are still limited. For modern electronic devices, the average dissipation heat can be up to 25 W/cm2; however, the conventional natural or forced convection cooling methods are only capable of removing small heat flux per unit temperature difference about 0.001 W/(cm2.°C) by natural convection to air, 0.01 W/(cm2.°C) by forced convection to air, and 0.1 W/(cm2.°C) by forced convection to liquid [1]. Therefore, it is important to look for new methods of cooling the modern high-speed electronic components.

Among the heat transfer enhancement configurations, one of the promising techniques is using porous media subjected to flow pulsation, pulsation flow or oscillating flow will achieve uniform temperature distribution along the surface contrary to the steady flow which achieves high temperature difference.

In present work, numerical studies have been investigated to study the heat transfer characteristics of aluminum porous metal foam subjected to both steady and oscillating flow using COMSOL Multiphysics® software. Time average local surface temperature distributions and local Nusselt numbers were illustrated. For electronic cooling applications, time-averaged quantities are more important than instantaneous quantities. As instantaneous higher power dispersion or temperature increasing may not damage the electronics components, but a long period of higher temperature will decrease their performance or even destroy them.

The Reynolds number and the heat flux supplied to metal foam are varied in the range of Re =26-70 and q"=0.8-2.6 W/cm2, respectively. Brinkman equations and energy equations have been used to describe the fluid flow and the heat transfer of metal foam, respectively. The numerical results have been compared with experimental data presented by Fu et al. [2] who used aluminum metal foam subjected to both steady and oscillating air flow.

It is found that numerical results have good agreement with experimental data with a maximum relative errors for steady flow of 2% , and for oscillating flow of 1%. It is observed that steady flow condition, the time averaged local temperature increased with the increase of axial position, the decrease in Reynolds number, or the increase in heat flux as shown in Figure 1. It is seen that the surface temperature approaches a constant value as the flow reached the fully developed

range. For oscillating flow, due to the reversing flow direction, there are two thermal entrance regions in the test section which have more mixing and more heat transfer rate. The local temperatures near both entrances are lower than that at the center of the test section as shown in Figure 2. The maximum temperature point occurs at the center of the foam and decreasing uniformly to both entrances.

Reference

1. M. Mahalingam and H. Berg, "Thermal Trend in Component Level Packaging," Int. J. Hybrid Micro electron., pp. 1–9 (1984).

2. H. Fu et al., "An Experimental Study of Heat Transfer of a Porous Channel Subjected to Oscillating Flow," Trans. of the ASME, vol. 123, pp.162-170 (2001).

Figures used in the abstract

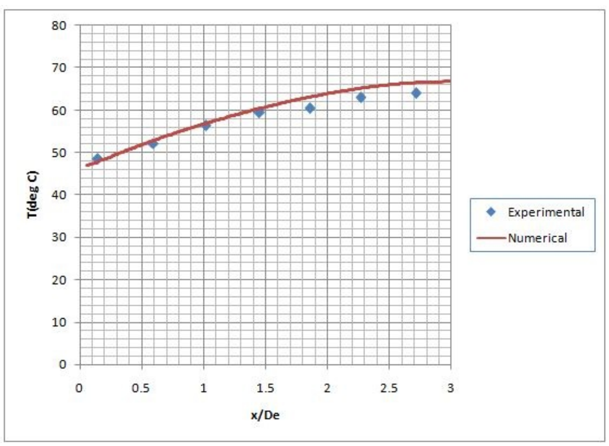

Figure 1: Local temperature distribution along surface at q"=0.8W/cm2 and Re=37.

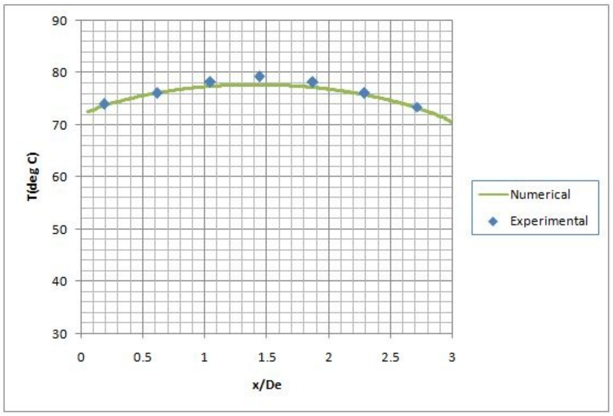

Figure 2: Local temperature distribution along surface at q"=0.8W/cm2 and Re=28.