Converging on Electronics Cooling Technology

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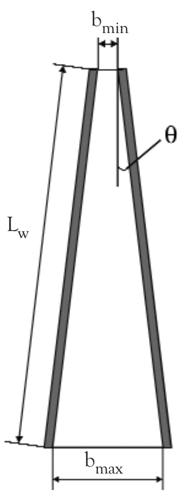
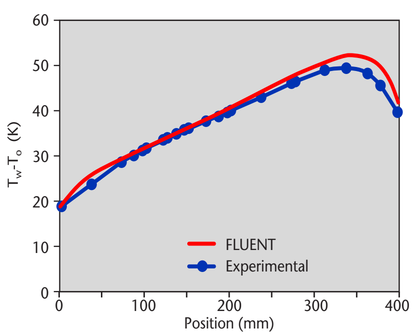
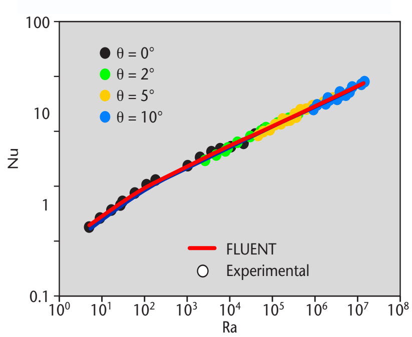


The convergent channel geometry



Comparison of numerical and experimental wall temperature profiles



Comparison of numerical and experimental correlations for Nusselt number as a function of Rayleigh number for the average channel gap

COOLING TECHNOLOGY for electronic equipment and components requires an in-depth knowledge of heat transfer phenomena. The main aim is to maintain a relatively constant component temperature equal to or lower than the manufacturer's maximum specified service temperature, to ensure system performance and reliability. Natural convection in air is important because of its simplicity and reliability. It is the only heat transfer mechanism in the event of a primary forced convection cooling failure, even though its applications are limited to moderate heat fluxes. The design of thermal control systems based on natural convection is therefore an appealing prospect. Particular interest has been devoted to channel configurations, with one interesting variation being the heat transfer in a convergent channel between two uniformly heated plates [1, 2].

A CFD study of convergent channels under a range of conditions has been performed using FLUENT. The transient calculations of momentum and heat transfer included radiation, simulated using the discrete transfer radiation model (DTRM). The channels are characterized by the ratio of the plate length, L_w, to the minimum separation at the top of the channel, b_{min}, along with the angle that the plates make with a vertical line, θ. For one particular geometry with L_w/b_{min} = 40.6 and θ = 10°, two uniform wall heat flux values, q_Ω, of 30 and 220 W/m², were used to test for grid dependence. The results indicated that a grid-independent solution could be obtained with 200 x 400 elements. In order to estimate the influence of the number of rays used in the DTRM calculation, a configuration with L_w/b_{min} = 10.2 and θ = 10° with q_Ω = 30 and 220 W/m², was examined. Comparison of the Nusselt numbers predicted for various polar and azimuthal discretizations indicated that a 6 x 6 ray discretization should be used to carry out the complete analysis. A large rectangular plenum was positioned at the bottom and top of each convergent channel studied to approximate the free-stream condition of the flow far away from the region of thermal disturbance induced by the heated plates.

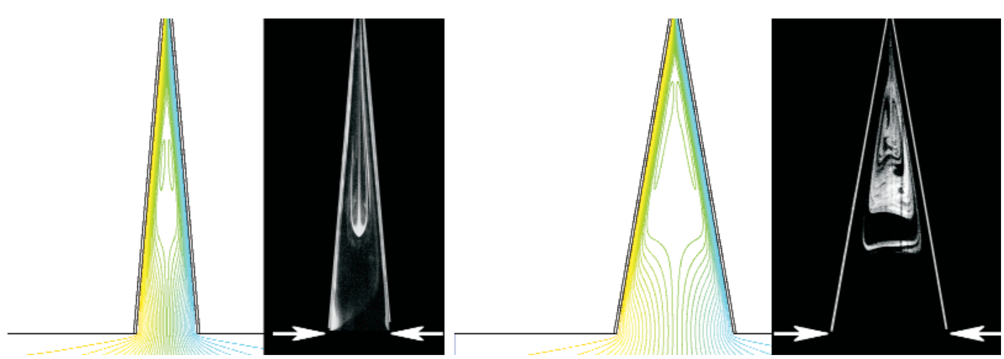
The results of several simulations were encouraging. Using a wall emissivity of 0.9, wall temperature profiles for the case of L_w/b_{min} = 58.0, q_Ω = 220 W/m² and θ = 10° were created. The comparison between the numerical and experimental data showed good agreement with a maximum percentage discrepancy of about 7%. The average Nusselt number evaluated numerically and the experimental correlation were found to be in very good agreement as well. The correlations for average Nusselt numbers in terms of Rayleigh numbers were evaluated in the ranges: $5.0 < Ra < 1.5 \times 10^7$, $10 < L_w/b_{min} < 60$, and $0° \leq θ \leq 10°$, using the average channel gap.

Photographs of experimental visualizations were also compared to the CFD calculations. These were found to be in good qualitative agreement with the numerically predicted flow fields, with very similar flow patterns observed. For the case of θ = 5°, part of the smoke is adjacent to the wall and the flow is laminar, while in the central zone of the channel recirculating zones are detected. For θ = 10°, a greater stagnation zone is present in the center. ■

References:

1 Manca, O.; Morrone, B.; Nardini, S.; Naso, V. Natural Convection in Open Channels. In *Computational Analysis of Convection Heat Transfer*, Sunden, B.; Comini, G., Eds.; WIT Press: Southampton, U. K., 2000, pp 235-278.

2 Bejan, A.; da Silva, A.K.; Lorente, S. Maximal Heat Transfer Density in Vertical Morphing Channels with Natural Convection, *Numer Heat Tran A*, **2004**, *45*, 135-152.



Qualitative comparison of the predicted flow field with smoke visualization for two channel configurations: 5° (left) and 10° (right)