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Jet impingement cooling of triangular ribbed surface with bottom exit grill (Category-Engineering)

KEYWORDS: Jet impingement, Reynolds number, Computational Fluid Dynamics

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ABSTRACT *Jet impingement is a technique used widely for electronics cooling. The parameters of importance are Reynolds number, geometry configuration of the jet impingement. In the present work, a geometrical configuration of triangular ribbed surface is chosen, conditioned air is supplied as jet from the top while the bottom exit grills are used for exhaust of the spent air. The analysis is carried out using Computational Fluid Dynamics based analysis using FLUENT software and is validated against the experimental results.*

1.0 INTRODUCTION:
Jet impingement cooling process received a great attention due to high rate of heat transfers and simple geometries. Many prior studies are mostly on jet impinging over flat and smooth surface. Review of the experimental work on heat transfer to impinging jets is reported by Livingood and Hrycak (1970), Martin (1977). Among the jets, researchers like Wadsworth and Mudawar (1990) and Arquis et. al. (2007) opine that planar jets offer better controllability and cooling. In view of this, for current research topic, a geometrical configuration with ribbed surfaces and bottom grill is under investigation, the heating is provided at the bottom wall and cooling is provided from the jets at top, the effects of conjugate conduction-convection is investigated.

2.0 MATHEMATICAL AND NUMERICAL FORMULATION:
Geometrical configuration under consideration is represented in Fig. 1. There is a heated surface at bottom having a ribbed configuration. There are slot inlets and outlets as indicated in the Figure. The geometry is assumed sufficiently long in third direction and two-dimensional analysis is applicable. All dimensions in Fig. 1 are in centimeters.

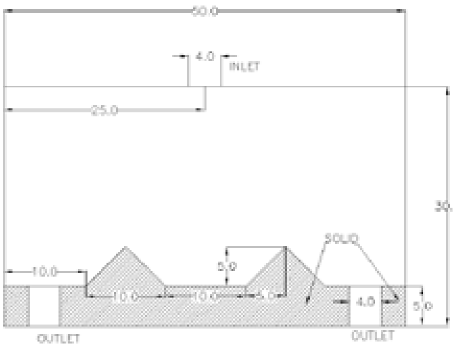

Fig.1 Geometry and computational domain (All dimensions in centimeter)

To analyze the flow and temperature distributions in geometry, one needs to solve momentum (Navier-Stoke's equations), continuity and energy transport equation. These partial differential equations are to be solved with appropriate boundary conditions. For simplicity the analysis is assumed to be 2D.

Continuity Equation: $\partial u/\partial x + \partial v/\partial y = 0$ (1)

X-direction momentum equation:

$$\rho Du/Dt = - \partial p/\partial x + \mu(\partial^2 u/\partial x^2 + \partial^2 u/\partial y^2) + \rho g_x \quad (2)$$

Y-direction momentum equation:

$$\rho Dv/Dt = - \partial p/\partial y + \mu(\partial^2 v/\partial x^2 + \partial^2 v/\partial y^2) + \rho g_y \quad (3)$$

Energy equation (As applied to solid and fluid):

$$\rho C_p DT/Dt = k(\partial^2 T/\partial x^2 + \partial^2 T/\partial y^2) \quad (4)$$

The above set of governing equations is supplied with following boundary conditions:

1) At inlet v= vin and T= Tin
2) At outlet pressure is anchored to atmospheric pressure.
3) At the bottom wall, an uniform heat flux of 10 Watt per m2 is applied.
4) At solid-fluid walls, no temperature jump and heat flux continuity is applied. For walls, no slip and no permeability boundary conditions are applied as usual.

The set of governing equations along with boundary conditions are simultaneously solved using numerical algorithms in FLUENT. The convective terms are approximated by 2nd order upwinding and diffusive terms are approximated by central differencing. SIMPLE algorithm is used to handle pressure-velocity coupling (Patankar, 1980). Tests are carried for various grid sizes and grid independence showed the grid size of 5 mm is sufficient for analysis.

Bottom solid plate is made up of Aluminium and heat flux of 10 Watt per sq m is applied and various results are obtained.

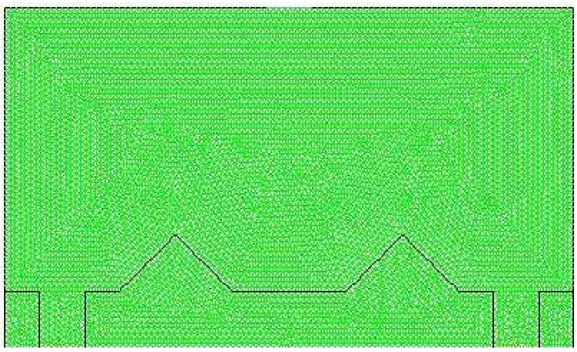

Fig.2 Mesh of the computational domain

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3.0 RESULTS :

Interest of engineer in such problems is to know the maximum temperature, Fig.3 depicts variation of maximum temperature rise (measured with respect to temperature of inlet stream) with inlet velocity. It can be observed that for low inlet velocities, the temperature rise is significant and it drops as velocity keeps increasing. Maximum temperature is about 3 to 4 degrees higher than that of the inlet temperature

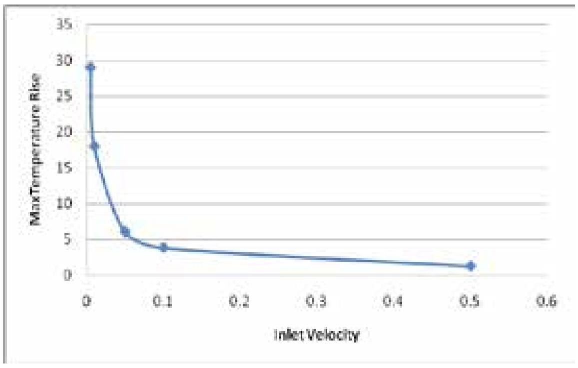

Fig.3 Variation of maximum temperature rise with inlet velocity

Hydrodynamic characteristics of the problem is measured by variation of friction factor dimensionless pressure drop v/s Reynolds number. Dimensionless pressure drop is equivalent to skin friction coefficient.

$$f= \Delta p^* = \Delta p/ (\rho V^2_{in}) \quad (5)$$

$$Re = \rho V_{in} H/\mu \quad (6)$$

where ρ and μ are density and viscosity, dimension H which is height of the enclosure is chosen for non-dimensionalization. This variation is depicted in Fig 4. The variation of friction factor indicates laminar-turbulent transition. Skin friction coefficient (f) reduces till certain Reynolds number and change its trend of variation after a range of Reynolds number, this is attributed to the laminar-turbulent transition.

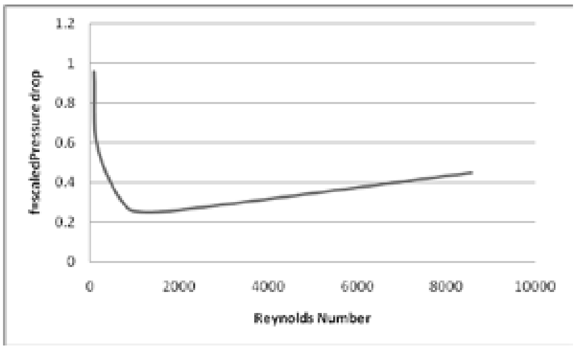

Fig.4 Variation of friction factor (f) or scaled pressure drop with Reynolds number

4.0 CONCLUSIONS:

The current research demonstrates:

1) With the increase in intensity of forced convection, there is increase in heat transfer, there is drop in maximum temperature attained.
2) After certain Reynolds number regime changes from laminar to transition and transition to turbulent.

REFERENCE 1) Livingood, J.N.B., Hrycak, P.(1970). Impingement heat transfer from turbulent air jets | to flat plates – a literature survey. NASA Technical Memorandum (NASA TM X-2778). | 2) Martin, H.(1977). Heat and mass transfer between impinging gas jets and solid | surface. Adv. Heat Transfer 13, 1–60. | 3) Wadsworth, D.C., Mudawar, I. (1990). Cooling of multiple electronic modules by means of confined two-dimensional jets of dielectric liquid. Int. J. Heat Mass Transfer 112, 891–898. | 4) E. Arquis , M.A. Rady, S.A. Nada (2007). A numerical investigation and parametric study of cooling an array of multiple protruding heat sources by a laminar slot air jet, Int J . Heat and Fluid Flow,28,787-805. | 5) S.V. Patankar, (1980) Numerical Heat Transfer and Fluid Flow. McGraw-Hill, New York