Indian Journal of Engineering

ANALYSIS

ISSN 2319 – 7757 EISSN 2319 –7765

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Publication History
Received: 29 April 2016
Accepted: 26 May 2016
Published: 1 July 2016

Citation
Anu Nair P, Anoop G Das, Ajish Soman. Experimental investigation for natural convection heat transfer between two vertical plates with symmetric heating in vertical channel. *Indian Journal of Engineering*, 2016, 13(33), 469-476

EXPERIMENTAL INVESTIGATION FOR NATURAL CONVECTION HEAT TRANSFER BETWEEN TWO VERTICAL PLATES WITH SYMMETRIC HEATING IN VERTICAL CHANNEL

ANU NAIR.P[1], ANOOP G DAS[2], AJISH SOMAN[3]

Assistant Professor,

Department of Mechanical Engineering,

Gurudeva Institute of Science and Technology,

Payyapady, Kottayam District, Kerala

Corresponding author Email:anunair67@gmail.com

Abstract

The thermal problems of most electronic components have been solved in recent year. Passive cooling of electronic component by natural convection heat transfer has major advantage of no vibration, least expensive and most authentic method of heat rejection. The parameters frequently considered are: Nusslet Number, Rayleigh number and the distance between heat sources. The present work discuss about natural convection in a vertical channel with single heat source.. In this work two experiments were conducted. viz. Natural convection in a two parallel vertical plate and natural convection in a vertical channel with single heat source. The experimental setup has been designed and fabricated. In the first case, experimentally the Nusslet Number and Rayleigh Number were calculated and compared with the value available from correlation and found to be in reasonably good agreement. In the second case, experimentally obtain an optimum location for a single heat source in vertical channel and correlation is developed for nusslet number in terms of Rayleigh number and aspect ratio.

Keywords: Natural Convection; Vertical Plate; Height Ratio; Aspect Ratio.

1. INTRODUCTION

Natural convection flow with internal object in vertical channel is encountered in several technological application such as heat dissipation in electronic circuits, refrigerators, heat exchangers, nuclear reactor fuel elements, and dry cooling towers, where power distribution and location of discrete heat source are very important, natural convection is the only mode of heat transfer mode in the case of artificial cooling failure. In these equipments, the source of heating, in general is either due to volumetric heat generation or due to surface heat fluxes. For instance, electronic equipment generates heat, which can be expressed in terms of volumetric heat generation. Volumetric heat generation in nuclear fuel rods is due to nuclear reaction. The present work is related to natural convection in a typical geometry of an electronic chip undergoing heating. From heat transfer point of view, the electronic chip is modeled as a heat source. In this geometry, the location of heat source placed an important role in the natural convection heat transfer. Detail knowledge of heat transfer characteristics of such geometries is an essential requirement for the optimal design of these equipments.

The objective of the present work is to experimentally obtain an optimal location for a single heat source.

Elenbass [1]conducted experimental work in laminar natural convection heat transfer in smooth parallel plate vertical channel was investigated and reported a detailed study of the thermal characteristics of cooling by natural convection.R.A. Wirtz [2] have considered a geometry with constant heat sources placed over the entire length of the wall. Since the geometry cannot simulate discrete placement of chips, a number of discrete heat sources placed over a wall was considered by, Chen Linhui et al [3].Bodia andOsterle [4] conducted numerical analysis on free convection heat transfer for development of boundary layer between parallel isothermal vertical plates and get result for velocity, temperature and pressure variation throughout the flow field .The numerical method used is hybrid finite difference method.

More recent investigations for free convection in vertical channels are presented in [5,6] for symmetric and asymmetric heating conditions, respectively again, heat transfer characteristics were provided on an average basis. Schlieren optical technique has been extensively used for the measurement of local heat transfer coefficients where water as working fluid[7] . Finally Numerical value is compared with experimental result and found to be reasonably good agreement. From literature survey it can be inferred that free convection in vertical channel geometry with discrete heat source has considerable attention. This geometrical configuration has physical relevance with respect to electronic chip placement. Hence, the natural convection heat transfer by discrete heat sources placed in vertical channel is taken as the topic of present research work. The purpose of this paper is to find optimum location of single heat source in vertical channel.

2. EXPERIMENTAL METHODOLOGY

2.1 NATURAL CONVECTION OVER A VERTICAL ISOLATED PLATE

Experimental apparatus has been specially planned and formulated to carry out investigations on electronics devices. The experimental setup consist of an apparatus, Data Acquisition System, Computer, T-Type Thermocouple and AC power supply whose schematic diagram is as shown in Fig. 1The apparatus consists of a heat source placed inside large rectangular box opened top and bottom to simulate natural convection condition. Rectangular box has a dimension of 500 x 500x 1000 mm. The three sides of the rectangular box are made up of plywood and are supported by slotted L-Angle. The fourth side is made up of acrylic sheet to have visibilityThe central heat source plate, by itself, is an assembly of two aluminium plates of dimensions 250 x 50 x 3 mm with a flat heater formed by winding a nichrome wire over a mica sheet and mica sheets on either side of nichrome wire. The surface of the central plate those are exposed to the ambient are given a suitable surface treatment like polishing by buffing. On the other side of the aluminium plate, i.e. on the side not exposed to the ambient, two blind holes of 1.5 mm width and 1.5 mm deep, are drilled at the points of temperature measurement, into which thermocouples are fixed. The bead of the thermocouples is attached to the slot in the aluminium plate by using thermobond. Thermobond is inorganic low expansion cold setting cement. Thermobond is ideal adhesive cement for applications which require high resistance to electricity, chemicals and thermal shocks. It is suitable for a service temperature of 1250^0C. Fig2 shows the plates that form the central plate, along with the thermocouples fixed at their respective position and taken out along the grooves for large and small heat source respectively.

In these experiments temperatures were measured using T-type thermocouple which can withstand up to 400^0C. Thermocouples thus fixed were laid into grooves, milled on the same side as that of the blind holes and taken out of the plate. As it could be seen there are 8 holes on each of the plate which house the screws that are used in fastening the plate together after the heater is sandwiched in between the plates. The whole assembly was highly polished on its outer surface to obtain an emissivity of 0.05.

FIG. 1 PHOTOGRAPHIC VIEW OF THE EXPERIMENTAL SETUP

FIG. 2 CENTRAL PLATE HEATER

At the two corners of the final heater assembly, two metal strips are attached, one on each side of the plate heater assembly. The plate heater assembly is thus hung vertically using Teflon rods through thin metal strips. Teflon wire used has 10mm diameter and 5m length. The Teflon rods and the metal strips serve the purpose of minimizing the conduction losses. The Teflon rods in turn fastened to slotted L-Angle.The Teflon rods pass through holes in the slotted L-Angle ,above which there is a hexagonal nut, which facilitate the adjustment of the position of the central plate The lead wire from all the thermocouples is connected to a Data acquisition system. Data acquisition system consists of a temperature scanner having 40 channels, accuracy±0.1K.The heater assembly is heated by using a regulated DC power supply, 0-600V,0-1.5A.

2.2 INVESTIGATION OF FREE CONVECTION HEAT TRANSFER IN VERTICAL CHANNEL WITH TWO PARALLEL PLATE

FIG. 3 PHOTOGRAPHIC VIEW OF THE EXPERIMENTAL SETUP

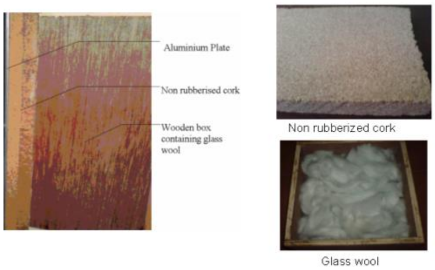

FIG. 4 ADIABATIC PLATE ASSEMBLY

In this second experiment natural convection in a vertical channel with single discrete heat source placed at different locations is considered. The geometry considered in the present study is a heated plate kept in between two adiabatic side plates, all parallel and vertical, with side plates symmetrically spaced from the central plate. Central heat source and its positioning mechanism is same as that used in first experiment. The side adiabatic plate assembly is fixed to the slotted L-angle. The entire setup is placed inside large rectangular enclosure which opens at the top and bottom to isolate experiment from external disturbances. The central heat source is hung vertically using Teflon rods through thin metal strips. Teflon wire used has 10mm diameter and 5m length. The Teflon rods and the metal strips serve the purpose of minimizing the conduction losses. The Teflon rods pass through holes in the slotted L-Angle, above which there is a hexagonal nut, which facilitate the adjustment of the position of the central plate so as to align it with respect to the side plate. Side adiabatic plate assembly consists of aluminium plate, non rubberised cork and wooden box containing glass wool. It is as shown in Figure 7.The side aluminium plates are of dimension 250 x250 x 3mm and highly polished to obtain the lower emissivity. As in the case of central plate, blind holes of 1.5 mm width and 1.5 mm deep, are drilled at the points of temperature measurement, into which thermocouples are fixed. The non rubberized cork sheet of one inch thickness and having the thermal conductivity of 0.044 W/mK forms the first layer of insulation. The plates are fixed to wooden boxes by inserting non rubberized cork in between them in order to minimize conduction of heat from the aluminium plate to the wooden box. The wooden box is filled with the glass wool with small air gap to simulate adiabatic condition. Glass wool insulation has very low thermal conductivity 0.04 W/mK. Each of the adiabatic plate assembly is fixed to slotted L-Angle.

2.3 EXPERIMENTAL PROCEDURE FOR FREE CONVECTION HEAT TRANSFER IN VERTICAL CHANNEL WITH DISCRETE HEAT SOURCE

In this experiment two geometrical parameters are defined such as Aspect Ratio = H/L and Height Ratio = (b+s)/L for specifying the position of central heat source with respect to side adiabatic plates. The procedure for the second experiment is first fixing up the spacing between the sides plates i.e. Aspect ratio and placing heat source at the mid plane in between the plates. For a fixed aspect ratio experiments were repeated by changing the height ratio. Then for a fixed height ratio experiments were repeated by changing the aspect ratio. A stabilized power input through a regulated DC power supply is supplied to the heater. All measurements are done after the system reached steady state conditions, which typically took four hours for each set of reading. The mean of the temperature of the central plate and side plates so obtained is made use of for the computation of the radiative and convective heat transfer rates, the average heat transfer coefficient and the Nusselt number. The experiment is repeated for different power inputs, i.e., for the different temperatures of the central plate.

3. RESULT AND DISCUSSION

3.1 INVESTIGATION OF NATURAL CONVECTION OVER A VERTICAL ISOLATED PLATE

The problem of free convection in a vertical plate was studied experimentally. These results are compared with the standard correlation for vertical channels in laminar region developed by Churchill and Chu . Fig.5 shows the Comparison of Nusslet number in an isolated vertical plate. When input power of heater increases convective heat transfer coefficient by experiment increases. When input power increases, it will increase the temperature of the horizontal plate, which increases the heat transfer coefficient and there by increases the Nusselt number. When power input increases, the convective heat transfer coefficient by correlation and numerical shows a downward trend. This is because of two reason (1)the horizontal dimension of the heat source is small the viscous forces try to predominate over the buoyant forces, causing a Rayleigh number decreases and therefore decrease in Nusselt number (2) the temperature increases beyond a particular value

Fig.6 shows the radiation heat transfer and convective heat transfer is depending strongly on surface temperature of the plate. The energy emitted depends on (1)the temperature of the body and (2) nature of radiating surface of the body. Both Convective and Radiative heat transfer increases non linearly with increase in plate temperature.. At low temperature, radiation may be significant. So we expect that radiation heat transfer is directly proportional to temperature (i.e, Q α T^n for free convection, where 1.2<n<1.33 and Q α T^4 for radiation)

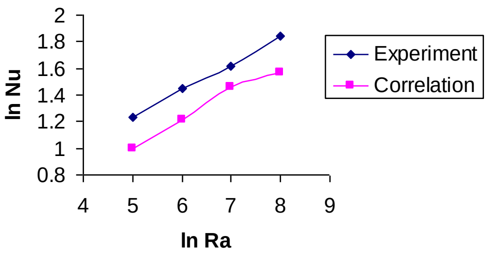

FIG. 5 COMPARISON OF NUSSELT NUMBER IN AN ISOLATED VERTICAL PLATE

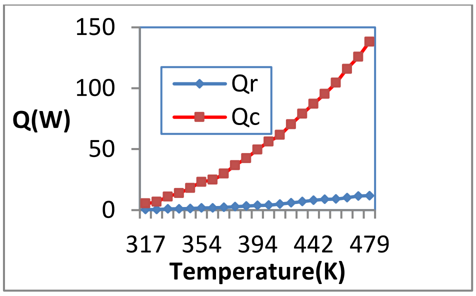

FIG.6 VARIATION OF POWER WITH SURFACE TEMPERATURE

3.2 INVESTIGATION OF FREE CONVECTION IN A VERICAL CHANNEL WITH HORIZONTAL HEAT SOURCE AT DIFFERENT HEIGHT RATIO

The problem of natural convection in a vertical channel with single heat source was studied experimentally.

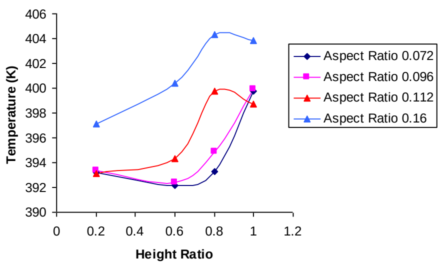

FIG.7 VARIATION OF TEMPERATURE WITH HEIGHT RATIO FOR DIFFERENT ASPECT RATIO

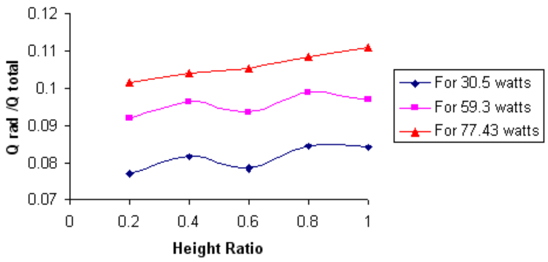

FIG.8 VARIATION OF Q_{RAD}/Q_{TOTAL} WITH HEIGHT RATIO FOR DIFFERENT POWER INPUTS

A typical variation of temperature on the heat source as a function of location of heat source for height are given in Fig.7. For the cases so far tested, it can be seen that at low aspect ratio the change in temperature by placing the heat source from bottom to middle of the channel is very small. But at these aspect ratios the temperature increases drastically when the heat source is moved from middle to top of the channel. At higher aspect ratio the trend changes drastically with the temperature of the heat source continuously increase from bottom to the top of the channel. Therefore at low aspect ratio the heat source can be placed any where in between the bottom and the middle of the channel, and at higher aspect ratio it should be placed only at the bottom of the channel so as to have maximum heat transfer.

The Fig.8 shows the variation of Q_{rad} / Q_{total} with height ratio for various power inputs. For 59.3 and 30.5 watts the radiation contribution decreases at the middle of the channel. Even though shape factor increases at the middle position, it has less effect compared with the surface temperature. Decrease in surface temperature at the middle position is due to maximum heat transfer at that position. Flow may be fully developed at middle position when velocity of flow is low i.e. at low power watts. At higher power input the velocity of flow is very high, the surface temperature increases uniformly from bottom to top of the channel.

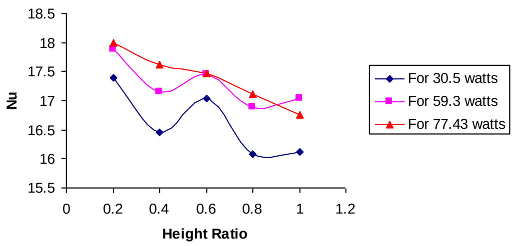

FIG.9 VARIATION OF NUSSELT NUMBER WITH HEIGHT RATIO FOR DIFFERENT POWER INPUTS

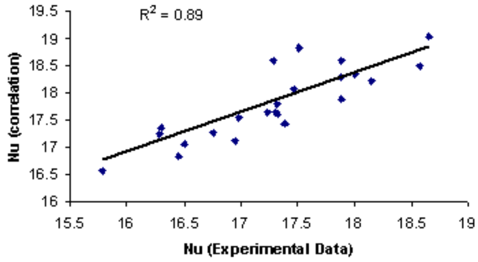

FIG.10 VARIATION OF EXPERIMENTAL NUSSLET NUMBER WITH CORRELATION NUSSLET NUMBER.

Fig.9 shows the variation of Nusselt number with the height ratio. For 30.5 and 59.3 watts the Nusselt number increases the middle of the channel shows maximum heat transfer occur at that position. At higher power input buoyancy force is high which increases the flow velocity which in turn increases the wall friction. Due this high wall friction the air temperature increases which decreases the heat transfer rate from the surfaces. So the Nusselt number shows the downward trend at higher power inputs. A correlation for Nusselt number in terms of Rayleigh number and aspect ratio was developed as shown in equation 3. The average R^2 value is found to be 0.89 shows closeness of the experimental values with the correlation.

$$\mathbf{Nu = 0.22\ Ra^{0.32} AR^{-0.08}} \qquad \text{……..(1)}$$

4. CONCLUSION

The Validation of Natural convection heat transfer in a two parallel Vertical plate and investigation of natural convection in vertical channel with heat source have been conducted. In the first case, the Nusslet Number and Rayleigh number were determined experimentally and compared with the value available from correlation and found to be in good agreement. The second experiment shows that the Maximum amount of heat transfer occur when horizontal heat source is placed at the bottom portion of the vertical channel by experimentally.

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