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HEAT TRANSFER ENHANCEMENT BY USING NANOFLUID JET IMPINGEMENT

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ABSTRACT

Impinging jets have received considerable attention during the last decade. The reason is mainly due to their inherent characteristics of high rates of heat transfer besides having simple geometry. Thus most practical applications of jet impingement occur in industries where the heat transfer requirements have exceeded capacity of ordinary heating and cooling techniques. In this paper heat transfer and fluid flow due to the impingement of vertical circular single jet on a horizontal heated surface is investigated experimentally. The flow is turbulent and a uniform temperature is applied on the target surface. Different particle volume fractions, jet flow rates, jet nozzle diameters, Reynolds number and various geometric ratios have been considered in order to study the behavior of the system in terms of local Nusselt number and convective heat transfer coefficient. The experimental results indicate that using nanofluid as a heat transfer carrier can enhance the heat transfer process. It is found that the local heat transfer coefficient express Nusselt number as a function of nozzle exit Reynolds number and also nozzle to plate spacing and of the radial displacement from the stagnation point.

keywords--Jet impingement, Forced convective Heat transfer, Heat transfer enhancement, Nanofluids, Nanoparticles, Alumina-Water Nanofluid.

INTRODUCTION

This work presents and discusses the results of an impinging circular jet working with a mixture of water and Al_2O_3 nanoparticles are investigated. The flow is turbulent and a constant heat flux is applied on the heated plate. The heat transfer between a vertical round alumina-water nanofluid jet and a horizontal circular round surface is carried out. The experiment is focused on the verification of the jet effect on the distribution of local heat transfer coefficient on the impinged target surface. The effect of flow in jet to test plate distance are also examined at various intersect spacing (Z/D). And it is found that the convective heat transfer coefficient is maximum in the stagnation region but gets decreases in wall jet region.

Liquid Impingement Jets Using Nanofluids

In recent years, breakthroughs in manufacturing processes have permitted the creation of solid particles down to the nanometer scale, which in turn has resulted in the birth of a new and rather special class of fluids, called ‘nanofluids’[1,2]. These fluids constitute a very interesting alternative for electronic cooling applications [3]. The term ‘nanofluids’ usually refers to a mixture composed of a saturated liquid with extremely fine nanoparticles in suspension. Many experimental studies revealed that these innovative working fluids have an extremely high enhancement in thermal conductivity, convective heat transfer coefficient and CHF in boiling heat transfer [4].It should be mentioned that there is a clear lack of data regarding nanofluid behavior in real thermal applications and some other important issues like the unknown long term effects due to the temperature on the stability and suspension of these special mixtures. In recent years, a few studies on impingement jets using nanofluids have been performed. We believe that a combined system including impingement jets and nanofluids can remove the large amount of heat generated by surfaces in industrial applications such as high performance microelectronic chips. Yimin and Li [5] in their work presented a procedure for preparing a nanofluid which is a suspension consisting of nanophase powders and a base liquid. By means of the procedure, some sample nanofluids are prepared. A theoretical model is proposed to describe heat transfer performance of the nanofluid owing in a tube, with accounting for dispersion of solid particles. The results shown that the nanofluids show great potential in enhancing the heat transfer process. One reason is that the suspended ultra-fine particles remarkably increase the thermal conductivity of the nanofluid. Shekhar and Nishino [6] has studied the Upward, laminar, axis symmetric, pipe-issued, submerged impinging jets, with the water as the working fluid, are numerically investigated. When the H/D of the flow was reduced, the jet impinged onto the impingement surface with a larger velocity (due to the pre impingement jet's smaller viscous diffusion), which increased the heat transfer coefficient and the skin-friction coefficient in the forced-convection region, but the local temperature remained almost constant. In the dead zone, on the other hand, the flow properties were affected by both the wall-jet momentum and the degree of interaction between the separated flow and the base surface. When the interaction was weak, the heat transfer coefficient and the skin friction coefficient both increased with the increased impingement velocity, whereas the surface temperature decreased. Ishigai S. [7] studied experimentally the flow and heat transfer of an impinging round jet over a horizontal plate. They compared their experimental measurements of the film thickness with the theoretical predictions of Watson [8]. There was a good agreement between the two solutions near the center of the jet, but as the radial location increases, the difference becomes wider. Zhao and Masuoka [9] have investigated flow and heat transfer due to liquid jet impingement on a circular surface. They have studied the heat transfer between small jets of 0.9 and 2 mm and a disk of 10 mm diameter. Baonga et al. [10] investigated liquid film, hydraulic jump and local heat transfer distributions along the radial direction of a circular disk. For jet Reynolds number in the range of 1,050 to 9,000, and for each nozzle diameter, the difference between the stagnation and average Nusselt numbers decreases significantly for higher Reynolds number. When the jet Reynolds number increases, the average heat transfer coefficient increases because of the increase in the liquid flow rate. Furthermore, Teamah and Farahat [11] have investigated both the heat transfer and fluid flow due to the impingement of vertical circular water jet on a horizontal heated surface numerically and experimentally. However, the hot surface used in their experiment was square of 0.95 m side. There are few models available for the average liquid jet impingement Nusselt number along circular disks; such models are those given by [9] and [11]. Integral analysis method was used by [9] to solve the flow along the radial direction of the circular disk. NGUYEN et al. [12] in this paper have experimentally studied the heat transfer enhancement provided by the 5% particle volume fraction Al_2O_3-water nanofluid, under the configuration of an evacuated impinging jet system. Results have also shown that for the range of parameters studied, the surface heat transfer coefficient seems to do not change much with respect to the nozzle-to-surface distance. Hosseinalipour et al. [13] in this study, the problem of laminar impinging jet flows of nanofluids has been numerically investigated. Results, as obtained for water-Al_2O_3 mixture, show an enhancement of heat transfer rate due to the presence of nanoparticles in the base fluid. However, inclusion of particles in the flow increases shear stress and pressure drop. Paisarn and Somchai [14], in this paper, the jet liquid impingement heat transfer characteristics in the mini-rectangular fin heat sink for the central processing unit of a personal computer are experimentally investigated. The experiments are tested with three different channel width heat sinks under real operating conditions: no load and full load conditions. It is found that the central processing unit temperatures obtained from the jet liquid impingement cooling system are lower than those from the conventional liquid cooling system; however, the energy consumption also increases. The results of this study are of technological importance for the efficient design of cooling systems of personal computers or electronic devices to enhance cooling performance. It should be noted that for electronic chip cooling by nanofluids impingement jets, the use of an array of jets is important and more interesting because of the desired uniform temperature distribution on electronic chip. However, no study using an array of jets involving nanofluids is available.

EXPERIMENTAL SETUP

In general, experimental results are required for supplementing the analysis by providing certain basic data or parameters that cannot be predicted precisely, for verifying the analytical/numerical predictions and also for evaluating the overall performance of a system configuration so as to check effects of various parameters. For this work an experimental test rig was designed in order to find the effect of flow rate, nozzle spacing from plate surface and different nanofluid concentrations to measure the effects of these parameters on heat transfer. Figure 3.1 shows the experimental set up for plate, heater & mica sheet and thermocouples. Mica sheets act as an electrical insulator. Heater plate is sandwiched between two mica sheets to avoid hazards. This whole assembly is enclosed in thin metal sheet and Cu plate is placed above this. Eight thermocouples are attached as shown in the figure to the Cu plate from center and 17.5 mm distance apart. One side of thermocouple wire is brazed to Cu plate. Other side of thermocouple wire is attached to the temperature indicator.

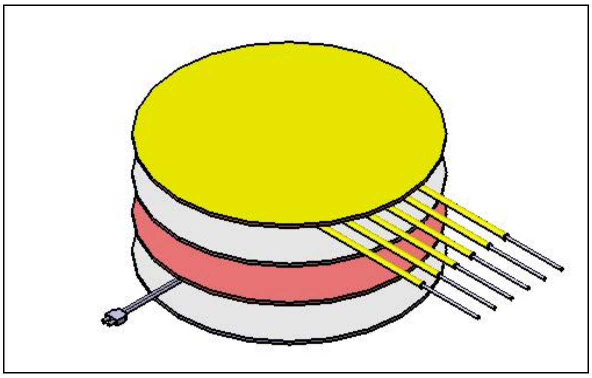

Figure 2.1 Cu Plate, Heater and Mica Sheet Assembly

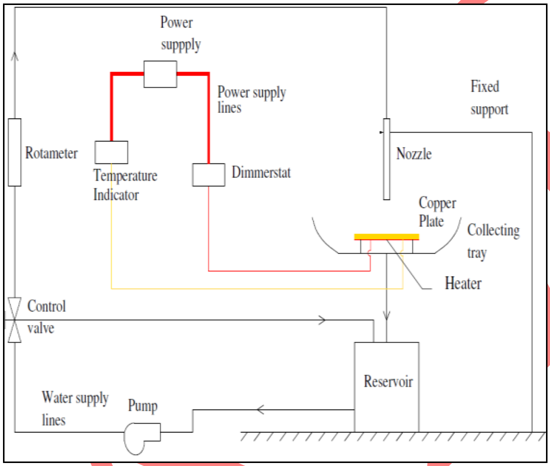

Figure 2.2 Schematic of Experimental Test Setup

Experiments were performed for characterization of heat transfer and effect of various parameters on local convective heat transfer coefficient. A schematic of the experimental setup is shown in figure 2.2. The setup was implemented with a suitable instrument to control and measure the different variable affecting phenomena.

2.1 Experimental Procedure

1. Fill the water/nanofluid in the acrylic tank.
2. Attach the nozzle of required diameter. Adjust the distance between nozzle exit and plate surface. 3. Readings are to be taken at Z/D= 2, 4, 8, 12, 16 and 18.
4. Switch on the pump and adjust the flow rate. Readings are to be taken at 2, 3 or 4 lpm. Adjust flow rate by using control valves and knobs on rotameter.
5. Now switch off the pump.
6. Switch on the heater by adjusting voltage of dimmerstat current. Keep it constant throughout the experimentation. Heat the Cu plate upto 60°C. As soon as Cu plate gets 65°C switch off the heater.
And start the pump.
7. Note down the readings from the digital indicator after 4 seconds at 8 different locations on plate.

8. Now switch off the motor and repeat same procedure for different flow rate and Z/D distance.
9. Same procedure is repeated for different concentrations of nanofluid.

RESULTS & DISCUSSIONS

3.1 Heat Transfer Characterization of Liquid Jets

The Nusselt number is a measure of dimensionless heat transfer coefficient. The heat transfer coefficient is a relationship between the heat flux and the temperature difference between the target surface and the liquid. The heat transfer coefficient has a complex dependence on many variables, such as the fluid properties and the flow velocity. For a single nozzle, the corresponding heat transfer correlations are expected to be of the form

$$Nu = Nu\,(Re, X/D, Z/D) \qquad (3.1)$$

Where, Nu is the average Nusselt number, Re is the Reynolds number, X is the radial distance, *D* is diameter of the nozzle and Z is the height of the nozzle.

The numerical analysis of heat transfer is performed in order to study the influence of various Reynolds numbers. Nusselt number on the stagnation point (*Nu*) is determined from the local heat flux q, the average water temperature at the local surface (T_{wa}) and the inlet jet water temperature (T_i).

$$Nu_d = \frac{hD}{k} \qquad (3.2)$$

Where, *h* is the local heat transfer coefficient, *D* is the hydraulic diameter and *k* is the thermal conductivity of the water. And *h* is given as

$$\boxed{h = \frac{q}{(T_{wa} - T_i)}} \qquad (3.3)$$

3.2 Effect of *Z/D* ratio on Heat Transfer Coefficient at Different Flow Rates at stagnation point

3.1.1 0.1% *Φ*

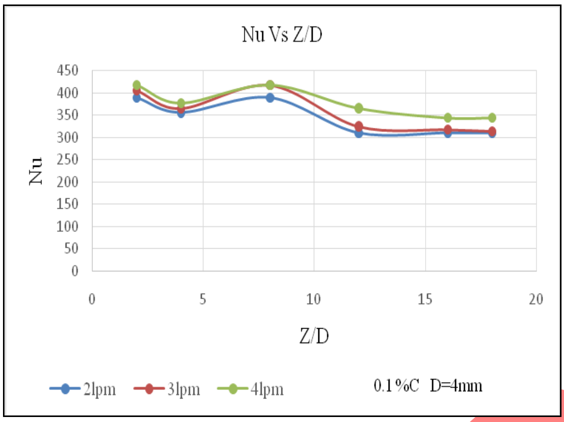

Figure 4.1 Stagnation Nu for different flow rates at various *Z/D* (0.1% *Φ*)

The variation of Nusselt number in liquid jet impingement when Al2O3 nanofluid has concentration of 0.1% is shown in figure 3.1 at varying *Z/D* ratios of 2, 4, 8, 12, 16, 18 and flow rates of 2, 3 and 4 lpm and diameter of nozzle (D) 4mm. The figure 3.1 shows that *Z/D* ratio is not having that much of influence on heat transfer coefficient or Nusselt number from 12 to 18. It is maximum in between *Z/D* 2 to 8. Influence of *Z/D* on nusselt number is almost same for flow rates ranging from 2 lpm to 3 lpm. For the 4 lpm flow rate heat transfer coefficient is having maximum value than 2 & 3 lpm.

3.1.2 0.2 % *Φ*

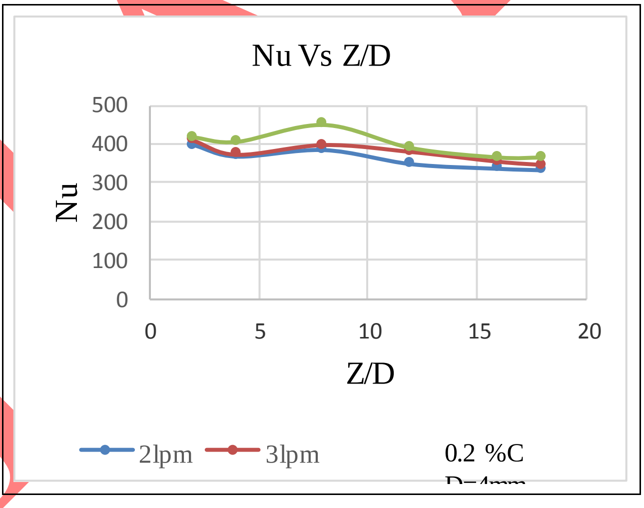

Figure 4.2 Stagnation Nu for different flow rates at various *Z/D* (0.2% *Φ*)

The variation of Nusselt number in liquid jet impingement when Al2O3nanofluid has concentration of 0.2% is shown in figure 3.2 at varying *Z/D* ratios of 2, 4, 8, 12, 16, 18 and flow rates of 2, 3 and 4 lpm and diameter of nozzle (*D*) 4mm. The figure 3.2 shows that *Z/D* ratio is not having that much of influence on heat transfer coefficient or Nusselt number from 12 to 18. It is maximum in between *Z/D* 2 to 8. Influence of *Z/D* on nusselt number is almost same for flow rates ranging from 3 lpm to 4 lpm. For the 4 lpm flow rate heat transfer coefficient is having maximum value than 2 & 3 lpm.

3.1.3 0.5 % *Φ*

The variation of heat transfer coefficient in liquid jet impingement when Al2O3 nanofluid has concentration of 0.5% is shown in figure 3.3 at varying *Z/D* ratio of 2, 4, 8, 12, 16, 18 and flow rates of 2, 3 and 4 lpm and nozzle diameter (*D*) 4mm.The figure 3.3 shows that *Z/D* ratio is not having that much of influence on heat transfer coefficient from 8 to 18. It is maximum in between *Z/D* 2 to 4. Influence of *Z/D* on heat transfer coefficient h is almost same for flow rates ranging from 3 lpm to 4 lpm. For the 4 lpm flow rate heat transfer coefficient is having maximum value than 2 & 3 lpm. Heat transfer coefficient is maximum at *Z/D* = 8.

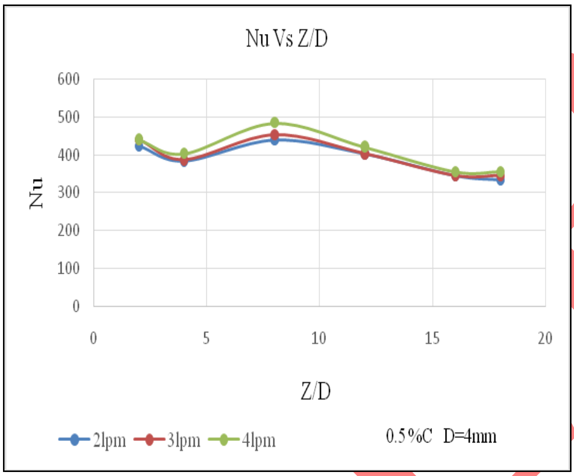

Figure 4.3 Stagnation Nu for different flow rates at various *Z/D* (0.5% *Φ*)

3.1.4 Water The variation of heat transfer coefficient in liquid jet impingement when water is used as impingement liquid is shown in figure 3.4 at varying *Z/D* ratio of 2, 4, 8, 12, 16, 18 and flow rates of 2, 3 and 4 lpm and *D* = 4 mm. The figure 3.4 shows that *Z/D* ratio is not having that much of influence on heat transfer coefficient from 8 to 18. It is maximum in between *Z/D* 2 to 8. Influence of *Z/D* on heat transfer coefficient h is almost same for flow rates ranging from 3 lpm to 4 lpm. For the 4 lpm flow rate heat transfer coefficient is having maximum value than 2 & 3 lpm. Heat transfer coefficient is maximum at *Z/D* = 8.

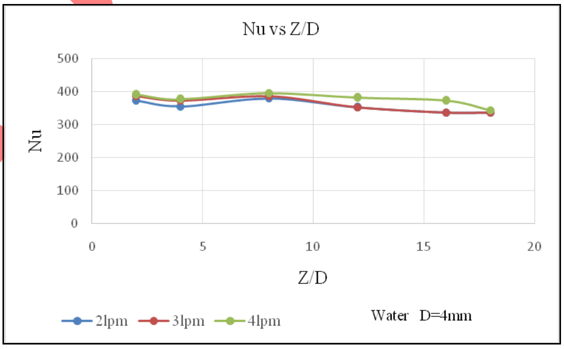

Figure 4.4 Stagnation Nu for different flow rates at various *Z/D* (Pure Water)

3.2 Effect of Radial Distance on Heat Transfer Coefficient

3.2.1 0.1% *Φ*

The variation of heat transfer coefficient in liquid jet impingement when Al2O3 nanofluid of concentrations 0.1% is shown in figure 3.5 at constant *Z/D* = 8, flowrate of 2, 3 & 4 lpm and nozzle diameter (*D*) 4 mm.Variation in *h* is shown radially from stagnation point. The figure 3.5 shows that heat transfer coefficient goes on decreasing as we move outerside from stagnation point. Variation in flow rate has more influence on heat transfer coefficient. Heat transfer coefficient has maximum value at all radial points for flow rate of 4 lpm. Heat transfer coefficient is found to be reduced by 50% at end point than at the stagnation point for 2 lpm. Similar results were observed for 3 & 4 lpm.

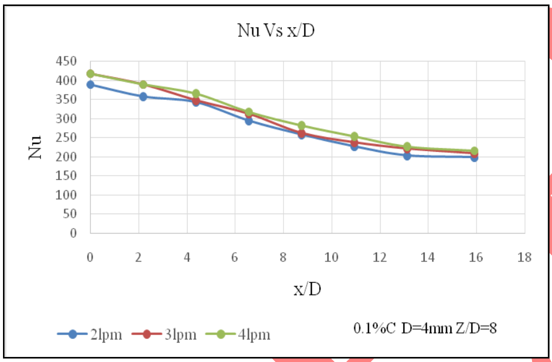

Figure 4.5 Local *Nu* at Free Jet, Impinging and Wall Jet Regions at *Z/D* = 8 (0.1% *Φ*)

3.2.2 0.2 % *Φ*

The variation of heat transfer coefficient in liquid jet impingement when Al2O3 nanofluid of concentrations 0.2% is shown in figure 3.6 at constant *Z/D* = 8 , flowrate of 2, 3 & 4 lpm and nozzle diameter (*D*) 4 mm.Variation in *h* is shown radially from stagnation point. The figure 3.6 shows that heat transfer coefficient goes on decreasing as we move towards the outerside from stagnation point. Variation in flow rate has more influence on heat transfer coefficient. Heat transfer coefficient has maximum value at all radial points for flow rate of 4 lpm. Heat transfer coefficient is found to be reduced by 50% at end point than at the stagnation point for 2 lpm. Similar results were observed for 3 & 4 lpm.

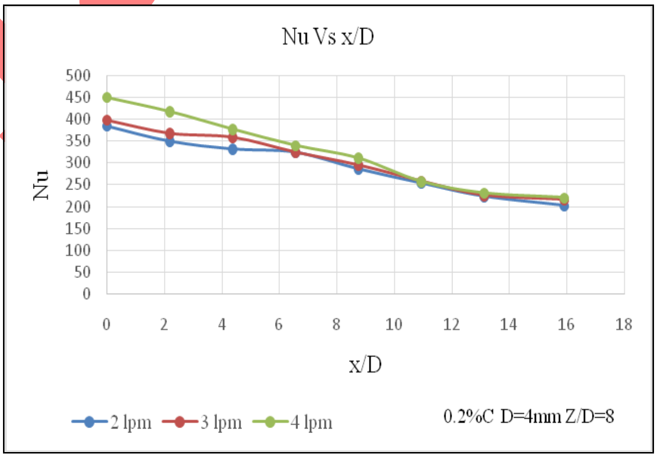

Figure 4.6 Local *Nu* at Free Jet, Impinging and Wall Jet Regions at *Z/D* = 8 (0.2% *Φ*)

3.2.3 0.5% Φ

The variation of heat transfer coefficient in liquid jet impingement when Al2O3 nanofluid of concentrations 0.5% is shown in figure 3.7 at constant *Z/D*=4, flowrate of 2, 3 & 4 lpm and *D* = 4mm.Variation in *h* is shown radially from stagnation point. The figure 3.7 shows that heat transfer coefficient goes on decreasing as we move outerside from stagnation point. Variation in flow rate has more influence on heat transfer coefficient. Heat transfer coefficient has maximum value at all radial points for flow rate of 4 lpm. Heat transfer coefficient is found to be reduced by 50% at end point than at the stagnation point for 2 lpm. Similar results were observed for 3 & 4 lpm.

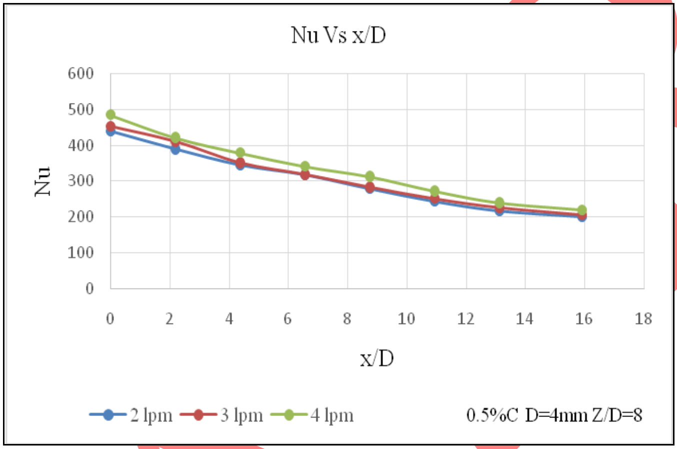

Figure 4.7 Local *Nu* at Free Jet, Impinging and Wall Jet Regions at *Z/D* = 8 (0.5% Φ)

3.2.4 Water

The variation of heat transfer coefficient in liquid jet impingement when water is used as impingement liquid is shown in figure 3.8 at constant *Z/D*=8, flowrate of 2, 3 and 4 lpm and *D* = 4 mm. Variation in *h* is shown radially from stagnation point.The figure 3.8 shows that heat transfer coefficient goes on decreasing as we move outerside from stagnation point. Variation in flow rate has more influence on heat transfer coefficient. Heat transfer coefficient has maximum value at all radial points for flow rate of 4 lpm. Heat transfer coefficient is found to be reduced by 50% at end point than at the stagnation point for 2 lpm. Similar result is found for 3 and 4 lpm.

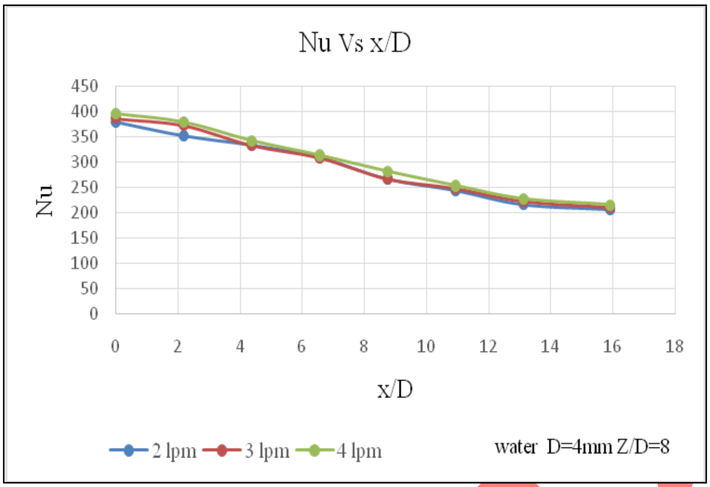

Figure 4.8 Local *Nu* at Free Jet, Impinging and Wall Jet Regions at *Z/D* = 8 (Water)

3.3 Effect of Z/D Variation along Radial Distance

In Figure 3.9, 3.10, 3.11, and 3.12, the stagnation Nusselt number is plotted at a nozzle to plate spacing at *Z/D* = 2 to *Z/D* = 18. It is observed that with the increase in Re, the heat transfer at the stagnation region increases at a given nozzle to plate spacing. This result is due to the cooling stagnation area being larger at higher Reynolds number.

3.3.1 0.1% *Φ*

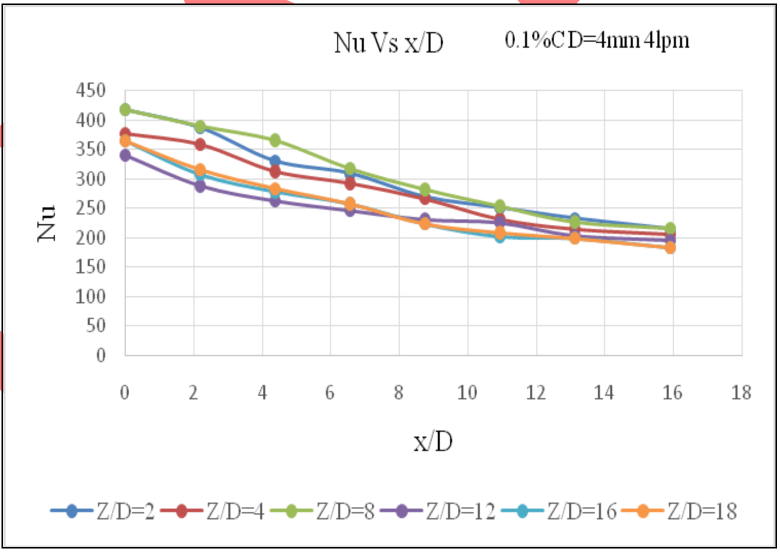

Figure 4.9 Local Nu at Free Jet, Impinging and Wall Jet Regions (0.1% *Φ*)

3.3.2 0.2% *Φ*

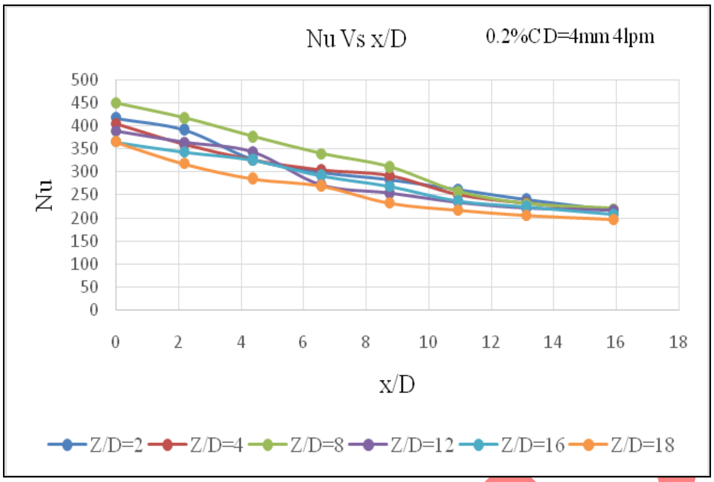

Figure 4.10 Local Nu at Free Jet, Impinging and Wall Jet Regions (0.2% Φ)

4.4.1 0.5% Φ

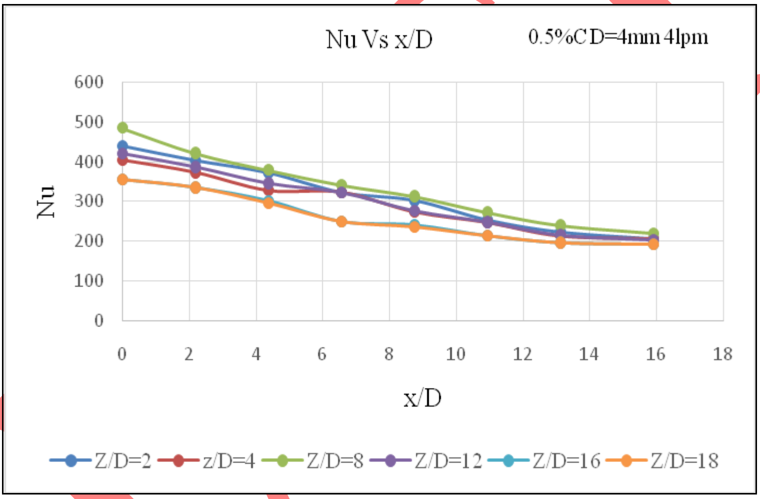

Figure 4.11 Local Nu at Free Jet, Impinging and Wall Jet Regions (0.5% Φ)

3.3.4 Water

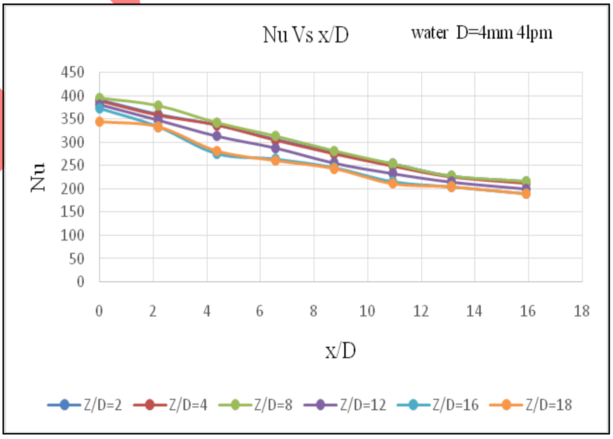

Figure 4.12 Local Nu at Free Jet, Impinging and Wall Jet Regions (Water)

3.3 Effect of Different Liquid on Heat Transfer Coefficient

The variation of heat transfer coefficient in liquid jet impingement when water, Al2O3 Nanofluid concentrations 0.1%, 0.2% and 0.5% is shown in figure 3.13 at constant *Z/D*=8, flowrate of 4lpm and D=4mm. Variation in h is shown radially from stagnation point. The figure 3.13 shows that heat transfer coefficient increases as the concentration of nanofluid increases. Value of h for all parameters goes on decreasing as we move outside from stagnation point**.**

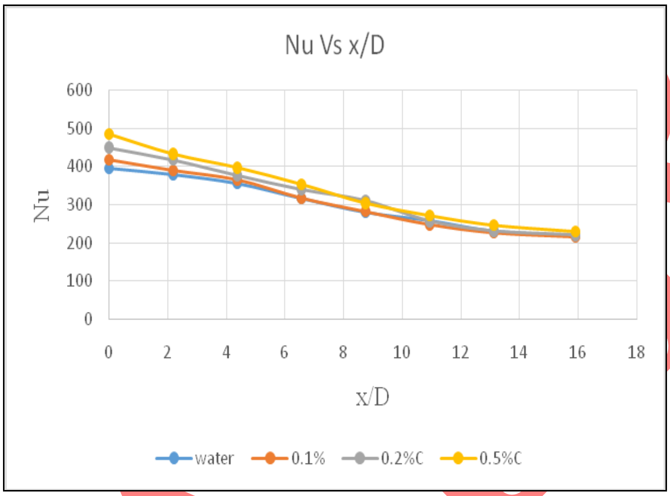

Figure 4.17 Effect of Different Liquid on Heat Transfer Coefficient

CONCLUSION

In the present work, experimental study for enhancement of heat transfer using nanofluid jet impingement has been conducted. The experiments are conducted for various configurations of concentration of nanofluid, flow rates, spacing between nozzle and target surface.

The temperatures are measured with J-type thermocouple at specified locations. By measuring these temperatures convective local heat transfer coefficients are evaluated at different locations of test surface. Z/D ratio is varied from 2, 4, 8, 12, 16 & 18. Results of variation in local heat transfer coefficient (*h)* are obtained by changing different parameters are presented.
The following conclusions were drawn from the experimental study.

- For 0.1, 0.2 & 0.5% concentrations *h* increases by 24%, 33% & 44% than water respectively at stagnation point. Thus, as nanofluid concentration increases heat transfer coefficient increases.
- Distance from stagnation point increases local convective heat transfer coefficient decreases.
- Local heat transfer coefficient at stagnation point is more by 50% as compared to the heat transfer coefficient at outermost point. Thus heat transfer coefficient is found to be decreased from stagnation point to outer location of test surface.

- Effect of spacing on local heat transfer coefficient is predominant in Z/D = 2 to 8 & as the spacing increases between 12 to 18, *h* decreases slowly. Thus to obtain maximum heat transfer spacing distance to diameter ratio is in between 2 to 8.
- As the flow rate increases from 2 lpm to 4 lpm, increase in heat transfer coefficient is 3 to 5%. Thus flow rate plays an important role on heat transfer coefficient enhancement.
  The data presented in this section provides support for designing liquid jet impingement as an efficient cooling technique for various industrial as well as in electronic equipment.

4.1 Future Scope

1. Current study is carried out at 8 different locations of test surface, but for better results number of locations can be increased for more accuracy.
2. Various concentrations can be studied, rather than concentrations that are used in the current investigation.
3. The present works can be extended for the computational analysis for future study.
4. Different nanofluids can used for the experimentation purpose and to obtain maximum heat transfer coefficient.
5. Thus exactly calculating effect of different parameters on convective heat transfer coefficient, maximum heat transferred technique can be used in cooling of PC and other small electronic components.

REFERENCES

[1] Lee, S. and Choi, S. U. S., "*Application of metallic nanoparticle suspensions in advanced cooling systems*", ASME Publications, PVP 342/MD 72, pp. 227-234 (1996).

[2] Wang, Xiang-Qi and Mujumdar, A. S., "*A review on nanofluids - Part I: Theoretical and numerical investigations*", Brazil Journal of Chemical Engg., Vol. 25, no. 4,p. 613-630,(2008).

[3]Keblinski, P., Eastman, J. A. and Cahill, D. G., "*Nanofluids for thermal transport*", Materials Today, pp. 36-44 (2005).

[4]Sung, M. K. and Mudawar, I., "Single-phase hybrid micro-channel/micro-jet impingement cooling", International Journal of Heat and Mass Transfer, vol. 51, pp. 4342-4352 (2008).

[5] Yimin Xuan , Qiang Li, "*Heat transfer enhancement of nanofluids*", International Journal of Heat and Fluid Flow 21 58-64, (2000).

[6] Chandra Shekhar, Koichi Nishino, "*Oscillation and heat transfer in upward laminar impinging jet flows*", International Journal of Heat and Fluid Flow 50 (2014) 316–329

[7] Ishigai S: Heat transfer of the impinging round water jet in the interference zone of film flow along the wall. Bulletin of the JSME 1977, 20(139):85-92.

[8] Watson E, "*The radial spread of a liquid jet over a horizontal plane*", Journal of Fluid Mech 1962, 20: part 3, 481-499.

[9] Zhao Y, Masuoka T., "*Conjugated heat transfer on a horizontal surface impinged by circular free-surface liquid jet*", JSME International Journal Series B 2002, 45(2):307-314.

[10] Baonga J, Louahlia-Gualous H, Imbert M., "*Experimental study of the hydrodynamic and heat transfer of free liquid jet impinging a flat circular heated disk*", Applied Thermal Engineering 2006, 26:1125-1138.

[11] Teamah M, Farahat S., "*Experimental and numerical heat transfer from impinging of single free liquid jet*", Alexandria Engineering Journal 2003, 42(5):559-575.

[12] C. T. NGUYEN, G. LAPLANTE, M. CURY, G. SIMON, *"Experimental Investigation of Impinging Jet Heat Transfer and Erosion Effect Using Al2O3-Water Nanofluid*", International Conference on FLUID MECHANICS and AERODYNAMICS (FMA'08) Rhodes, Greece, August 20-22, 2008.

[13] S. M. Hosseinalipour , P.R. Mashaei and K.Esmailpourheat, *"Heat Transfer Enhancement Using Nanofluids In Laminar Impinging Jet Flows*", International Fluid Dynamics Conference Fd2010-26-28 Oct. Shiraz University Shiraz Iran.

[14] Paisarn Naphon , Somchai Wongwises, "*Investigation on the jet liquid impingement heat transfer for the central processing unit of personal computers*", International Communications in Heat and Mass Transfer 37 (2010) 822–826.