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Heat Transfer Enhancement Using Al2O3 Nano-Fluid by Jet Impingement

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Abstract-*Heat transfer is a basic thermal process which is part of thousands of natural and man made processes. The attempts of increasing heat transfer of a device or processes by providing external aid are known as a heat transfer enhancement. Impinging jets have received considerable attention in the last decade. Fluid flow and transfer of heat because of the impingement of a vertical circular single jet on a horizontal heated surface is also investigated experimentally. Experimental investigation to study the heat transfer between the vertical round aluminum oxide-water nano-fluid jet and horizontal circular round surface is carried out at the same time. Different jet flow rates, jet nozzle diameters and three nano particle concentrations (0.1%, 0.2%, 0.3% respectively) are used. The experimental results show that using nano-fluid as a heat transfer carrier can enhance the heat transfer process. For the same Reynolds number, the experimental data show an increase in the Nusselt numbers as the nano particle concentration increases. It is also found that presenting the data in terms of Reynolds number at impingement jet diameter can take into account on both effects of jet heights and nozzle diameter.*

Keywords—Heattransfer, Jet impingement,Nano-fluids,Aluminum oxide

I. INTRODUCTION

Impinging jets have been used to transfer heat in diverse applications that also include drying of paper and cooling of turbine blades. There are many methods to improve heat transfer efficiency. Some methods are utilization of extended surfaces, application of vibration of the heat transfer surfaces and usage of micro channels. Heat transfer efficiency can also be improved by increasing the thermal conductivity of the working fluid, injection or suction of the fluid andby applying electrical or magnetic fields. Nano-fluids, heat transfer is an innovative technology which can be used to enhance the heat transfer. The term nano-fluids refer to a new kind of fluid produced bysuspending nano particles in the base fluid. High thermal conductivity of solids can be used to increase the thermal conductivity of a fluid by adding small solid particles to that fluid. The Impinging liquid jet is an established technique to provide high local heat transfer coefficients between the impinged liquid and a surface. Transfer of heat between vertical round alumina-water (Al_2O_3) nano-fluid jet and horizontal circular round surface is done. The experiment focuses on the validation of the jet effect over the distribution of the local heat transfer coefficient over impinged target surface. Effect of flow in jet for testing plate distance is also examined at various intersect spacing (Z/D). It is found that convective transfer of heat coefficient is maximum in the stagnation region and gets decreases in the wall jet region.

II. LITERATURE REVIEW

Recently, the number of research paper has been published on the heat transfer enhancement by using nano-fluids and liquid jet impingement in different heat exchanging devices, among this Al_2O_3 is one of the most common and inexpensive nano particle used by many researchers in their experimental investigations on liquid jet impingement is reviewed and is categorized as experimental, numerically and analytically. Some of this work is highlighted as follows.

Javadi et al. (2013) they reported improved heat exchanger performance by increasing the overall heat transfer as well as minimizing pressure drop. Nano-fluids with higher thermal conductivity and better thermo-physical properties can be applied in heat exchanger to increase the heat transfer rate. . Al_2O_3, $SiO_2$and TiO_2 were applied in a plate heat exchanger and effects on the thermo physical properties and heat transfer characteristics are compared with base fluids. [11]

Hussein et al.(2014)theystudied experimentally and numerically reviewed the nanoparticles as additives. They studied the computational simulations and found that most of them are in agreement with results of experiments. Smaller particle sized additives found to enhance heat transfer rate thanthat of the larger sized.[5]

Peyghambarzadeh et al. Conducted experiments on forced convective heat transfer of water based nano-fluids has been experimentally compared to that of a pure water in an automobile radiator with the different concentrations of nano-fluids. Effect of fluid inlet temperature in the radiator on the heat transfer coefficient has analyzed by changing temperature. Results demonstrate that increasing fluid circulating rate can also improve the transfer of heat performance while the fluid inlet temperature of the radiator has trivial effects [12].

Abide Zeitoun and Mohamed Ali (2012) they carried out heat transfer between a vertical round alumina-water nano-fluid jet and a horizontal circular round surface. Parameters studied are different jet flow rates and jet nozzle diameters and various circular disk diameters and three nano particle concentrations of aluminum oxide Al_2O_3 (0, 6.6 and 10% respectively). Their experimental results reinstated that using nano-fluid as a heat transfer carrier can enhance the heat transfer process. They also found that the Nusselt number (up to 100 % in some higher concentrations) increases with an increase in the nano particle concentration for the same Reynolds number. [1]

Jun-Bo Huang et. Al Numerical simulation of confined impinging circular jet working with the mixture of $Al_2O_3$and water nanoparticle was checked while experimenting. Flow is turbulent and constant heat flux was applied on the heated plate. A two-phase mixture model approach has been adopted. Different nozzle-to-plate distance, nano particle volume concentrations and Reynolds number have been considered to study the thermal performances of the system in terms of local, average and stagnation point Nusselt number. [2]

III METHODOLOGY

Development of experimental setup.

- Variation in local heat transfer coefficient according to change in radial distance.
- Studying the effect of flow rate variation on the local convective heat coefficient.
- Study of the effect of change in nozzle spacing from impinging plate and exit of the nozzle on the convective heat transfer coefficient.
- The study of heat transfer enhancement using different concentrations of nano-fluid instead of water.
- Viewing results to identify the effects of these parameters on the convective heat transfer coefficient.
- Experimental work using Copper plate and Al_2O_3.
- Data reduction and calculations of heat transfer coefficients.

A. Experimental Setup

Experimental results are required for supplementing analysis by providing the certain basic information or parameters that cannot be predicted in detail for checking the analytical or numerical predictions and also for evaluating the overall performance of a system configuration so as to check effects of various parameters. An experimental test rig was designed so as to find out the effect of flow rate, nozzle spacing from plate surface and different nano-fluid concentration for measuring the effects of these parameters on transfer of heat. Figure 1. Shows the experimental setup for plate, heater and mica sheets and thermocouples. Mica sheets act as an electrical insulator. Heater plate is and switched between two mica sheets to avoid hazards. This whole assembly is enclosed in a 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 10 mm distance apart. One side of thermocouple wire is brazed to Cu plate. The other side of thermocouple wire is attached to the temperature indicator. Experiments were performed for characterization of heat transfer and the effect of various parameters on local convective heat transfer coefficient. A schematic of the experimental setup is shown in figure 1. The setup was implemented with a suitable instrument to control and measure the different variable affecting phenomena.

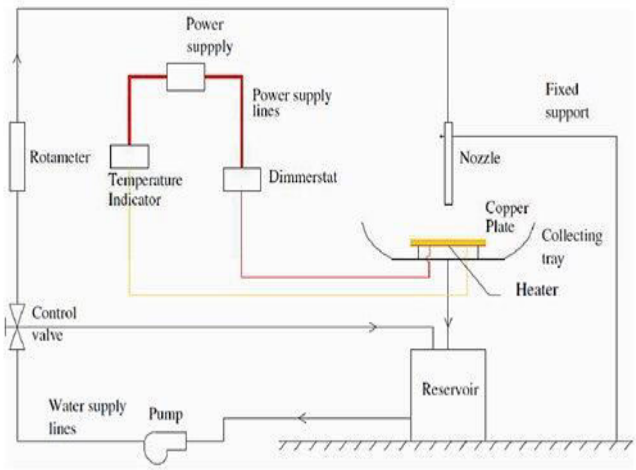

Figure 1: Schematic arrangement of experimental setup.

B.Experimental Procedure

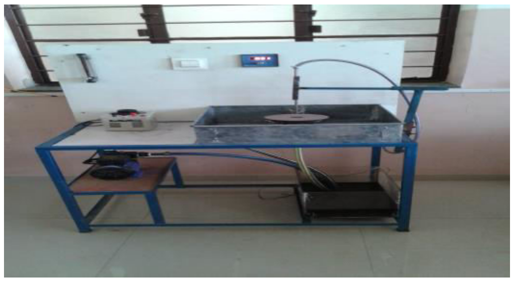

Figure 2: Experimental setup

1. Fill the water/nano-fluid in the acrylic tank.
2. Attach the nozzle of the required diameter. Adjust the distance between nozzle exit and plate surface. Readings are to be taken at Z/D= 2, 4, 6,8,10 and 12.
3. Switch on the pump and adjust the flow rate. Readings are collected during 2, 3, 4 lpm. Adjust flow rate by using control valves and knobs on Rotameter.
4. Now switch off the pump.
5. Clean the Cu plate with neat and clean cloth.
6. Switch on the heater by adjusting the voltage of dimmer stat current. Keep it constant throughout the experimentation. Heat the Cu plate up to 60^{o}C. As soon as Cu plate gets 60^{o}C switch off the heater.
7. Now start the pump.
8. Note down the readings from the digital indicator after 4 seconds at 8 different locations on the plate.
9. Now switch off the motor and repeat same procedure for different flow rate and Z/D distance.

10. The same procedure is repeated for different concentration of nano-fluid.

IV. RESULTS AND DISCUSSION

1.Effect of Z/D ratio on heat transfer coefficient at different flow rates at stagnation point

1.10.1% Φ

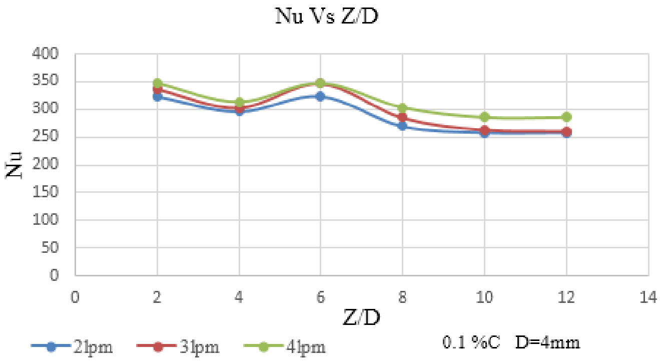

Figure 3: Stagnation Nu for different flow rates at various Z/D (0.1% Φ)

As shown in the fig 3 the variation of the Nusselt number in liquid jet impingement when Al_2O_3 nano-fluid has concentration 0.1% at varying Z/D ratios of 2,4,6,8,10,12 and flow rates of 2,3 and 4 lpm and diameter of nozzle 4 mm. The fig shows that Z/D ratio is not having much influence on the heat transfer coefficient or Nusselt number from 8 to 12.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. 4 lpm flow rate heat transfer coefficient has a maximum value than 2 and 3 lpm respectively.

1.2 0.2% ϕ

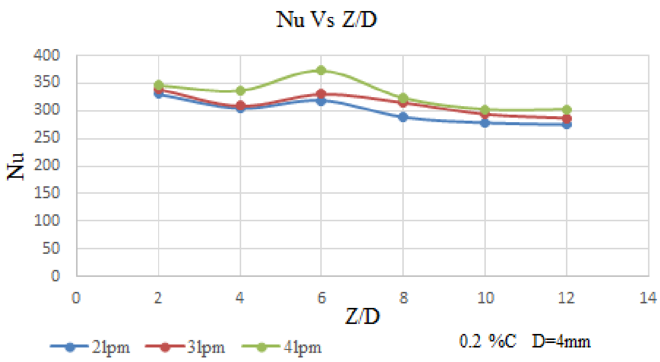

Figure 4: Stagnation Nu for different flow rates at various Z/D (0.2% Φ)

As shown in the figure four the variation of the Nusselt number in liquid jet impingement when Al_2O_3 nano-fluid has concentration 0.2% at the varying Z/D ratios of 2,4,6,8,10,12 and flow rates of 2,3 and 4 lpm and diameter of nozzle (D) 4 mm. This fig. Shows that Z/D ratio is not having an influence on the heat transfer coefficient or Nusselt number from 8 till 12. 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. Of the 4 lpm flow rate heat transfer coefficient is having maximum value than 2 and 3 lpm.

1.3 0.3% Φ

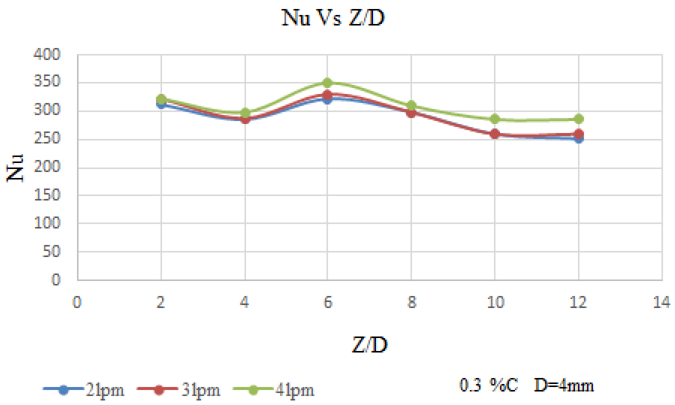

Figure 5. Stagnation Nu for different flow rates at various Z/D (0.3% Φ)

In fig 5 the variation of the Nusselt number in liquid jet impingement when Al_2O_3 nano-fluid has concentration 0.3% at varying Z/D ratios of 2,4,6,8,10,12 and flow rates of 2,3 and 4 lpm and diameter of nozzle (D) 4 mm. The figure shows that Z/D ratio is not having that much of an influence on the heat transfer coefficient or Nusselt number from 8 to 12.It is maximum in between Z/D 2 to 8.Influence of Z/D on Nusselt number is almost same forflow rates ranging from 2 lpm to 3 lpm. 4 lpm flow rate heat transfer coefficient has a maximum value than 2 and 3 lpm respectively.

1.4 Water

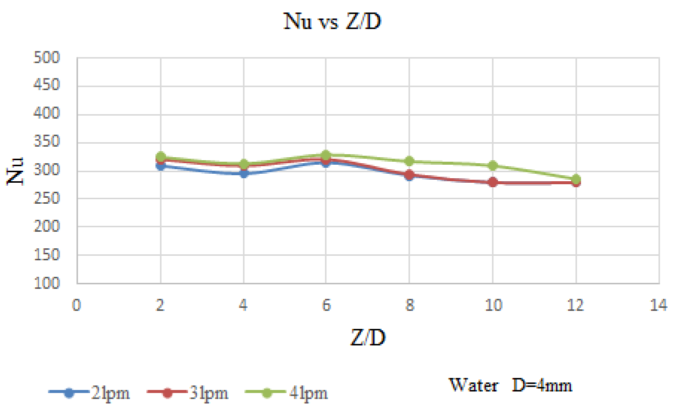

Figure 6. Stagnation Nu for different flow rates at various Z/D (Pure Water)

In fig 6 the variation of the Nusselt number in liquid jet impingement when Pure Water at varying Z/D ratios of 2,4,6,8,10,12 and flow rates of 2,3 and 4 lpm and diameter of nozzle (D) 4 mm. The figure indicates the heat transfer coefficient decreasing while moving outside from stagnation point. Variation in flow rates has more influence on the heat transfer coefficient. Heat transfer coefficient has the maximum value of all radial points for flow rate of 4lpmIt 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. Of the 4 lpm flow rate heat transfer coefficient is having maximum value than 2 and 3 lpm.

2 Effect of Radial Distance on Heat Transfer Coefficient

2.10.1% Φ

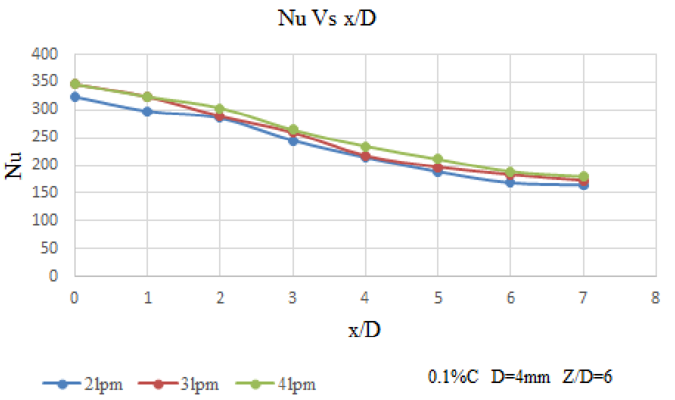

Figure 7 Local Nu at Free Jet, Impinging and Wall Jet Regions at Z/D = 6 (0.1% C)

In fig 7 the variation of the Nusselt number in liquid jet impingement when nano-fluid has concentration 0.1% at constant Z/D=6 and flow rates of 2,3 and 4 lpm and diameter of nozzle (D) 4 mm. The figure indicates the heat transfer coefficient decreasing while moving outside at stagnation point. Variation in flow rates has more influence on the heat transfer coefficient. Heat transfer coefficient has the maximum value of all radial points for flow rate of 4lpm.Heat transfer coefficient is found to be reduced by 50% at the end point than at the stagnation point for 2 lpm. Similar results were obtained for 3 and 4 lpm.

2.2 0.2% Φ

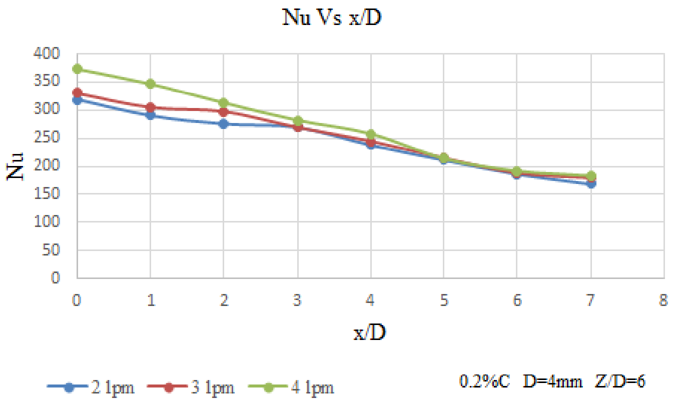

Figure 8 Local Nu at Free Jet, Impinging and Wall Jet Regions at Z/D = 6 (0.2% C)

In fig 8 the variation of the Nusselt number in liquid jet impingement when nano-fluid has concentration 0.2% at constant Z/D=6 and flow rates of 2,3 and 4 lpm and diameter of nozzle (D) 4 mm. The figure indicates heat transfer coefficient decreases while moving outside from stagnation point. Variation in flow rates has more influence on the heat transfer coefficient. Heat transfer coefficient has the maximum value of all radial points for flow rate of 4lpm.Heat transfer coefficient is found to be reduced by 50% at the end point than at the stagnation point for 2 lpm. Similar results were obtained for 3 and 4 lpm.

2.30.3% Φ

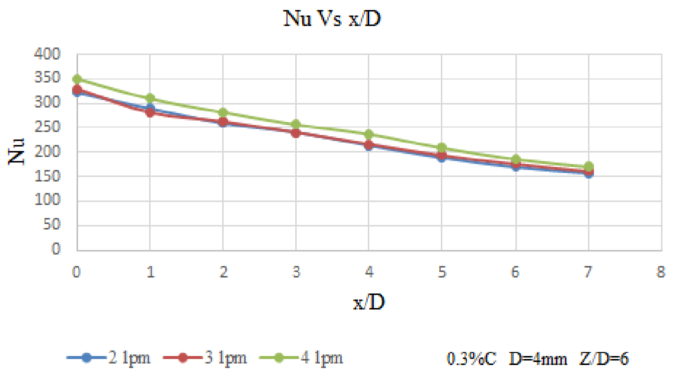

Figure 9 Local Nu at Free Jet, Impinging and Wall Jet Regions at Z/D = 6 (0.3% C)

In fig 9 the variation of the Nusselt number in liquid jet impingement when nano-fluid has concentration 0.3% at constant Z/D=6 and flow rates of 2,3 and 4 lpm and diameter of nozzle (D) 4 mm. The figure indicates heat transfer coefficient decreases while moving outside from stagnation point.. Variation in flow rates has more influence on the heat transfer coefficient. Heat transfer coefficient has the maximum value of all radial points for flow rate of 4lpm.Heat transfer coefficient is found to be reduced by 50% at the end point than at the stagnation point for 2 lpm. Similar results were obtained for 3 and 4 lpm.

2.4 Water

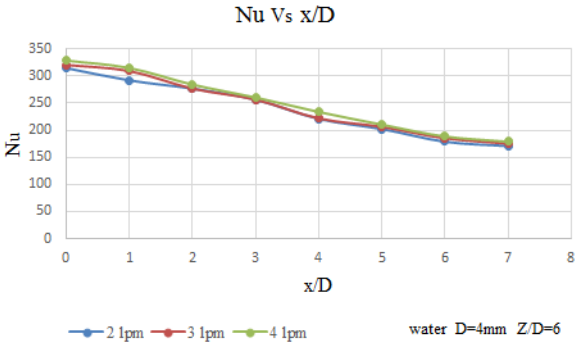

Figure 10 Local Nu at Free Jet, Impinging and Wall Jet Regions at Z/D = 6 (Pure Water)

In fig 10 the variation of the Nusselt number in liquid jet impingement when water is used as an impingement liquid at constant Z/D=6 and flow rates of 2,3 and 4 lpm and diameter of nozzle (D) 4 mm. The figure indicates heat transfer coefficient decreases while moving outside from stagnation point. Variation in flow rates has more influence on the heat transfer coefficient.Heat transfer coefficient has the maximum value of all radial points for flow rate of 4lpm.Heat transfer coefficient is found to be reduced by 50% at the end point than at the stagnation point for 2 lpm. Similar results are found for 3 and 4 lpm.

V. CONCLUSION

In the present work, experimental study for enhancement of heat transfer using nano-fluid jet impingement has been conducted. The experimental setup is fabricated at COEP's College of Engineering, Phaltan, Dist.-Satara. The experiments are conducted for various configurations of concentration of nano-fluid, flow rates, spacing between nozzle and target surface.

The temperatures are measured with K-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 are varied from 2, 4, 6, 8, 10 and 12. The result of variations in local heat transfer coefficient (*h)* are obtained by changing different parameters are presented.

1. For 0.1%, 0.2 % and 0.3 % concentrations h increases thanwaterrespectively at stagnation point. Thus, as nano-fluid concentration increases heat transfer coefficient increases.

2. Distance from stagnation point increases local convective heat transfer coefficient decreases.

3. The local heat transfer coefficient at stagnation point was moreby50 % as compared to heat transfer coefficient at outermostpoint. The heat transfer coefficient is found to be decreaseing from stagnation point to outer location of test surface.

4. The flow rate increasing from 2 lpm to 4 lpm, increase inheattransfer coefficient. Thus flow rate plays an important role onheat transfer enhancement.

5. 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.

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