HEAT TRANSFER ENHANCEMENT BY USING NANOFLUID JET IMPINGEMENT

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ABSTRACT

An experimental investigation was carried out for studying the heat transfer performance of the water-Al2O3 (28nm average particle size) nanofluid inside a liquid evacuated impinging jet system destined to the cooling of circular target surface. Results have shown that the surface heat transfer coefficient increases considerably when the mass flow rate is increased, but is relatively insensitive to the nozzle-to heated-surface distance. It was found that the use of a nanofluid can provide a heat transfer enhancement when compared to water. Thus most practical applications of jet impingement occur in industries where the heat transfer requirements have exceeded capacity of ordinary heating and cooling techniques. This work presents and discusses the results of an experimental investigation of heat transfer between the horizontal smooth plate of impinged jets.

INTRODUCTION

This work presents and discusses the results of an impinging circular jet working with a mixture of water and an Al2O3 nanoparticle is 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.

LITERATURE SURVEY

Obida Zeitoun and Mohamed Ali carried out heat transfer between a vertical round alumina-water nanofluid jet and a horizontal circular round surface. The parameters studied were different jet flow rates, jet nozzle diameters, various circular disk diameters and three nanoparticle concentrations of aluminium oxide (0, 6.6 and 10%, respectively). Their experimental results reinstated that using nanofluid as a heat transfer carrier can enhance the heat transfer process. They also found that the Nusselt number (upto 100 % in some higher concentrations) increases with increase in the nanoparticle concentration for the same Reynolds number. The Reynolds number at the respective impinging jet diameter is studied for the effects of the jet height and nozzle diameter. Presenting the data in terms of Peclet number, at fixed impingement nozzle diameter, makes the data less sensitive to the percentage change in the nanoparticle concentrations. Finally, general heat transfer correlation is obtained versus Peclet numbers using nanoparticle concentrations and the nozzle diameter ratio as parameters.

A numerical simulation on confined impinging circular jet working with a mixture of water and Al2O3 nanoparticles is investigated. The flow is turbulent and a constant heat flux is applied on the heated plate. A two-phase mixture model approach has been adopted. Different nozzle-to-plate distance, nanoparticle 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. The local Nusselt number profiles show that the highest values within the stagnation point region and the lowest at the end of the heated plate. It is observed that the average Nusselt number increases for increasing nanoparticle concentrations, moreover, the highest values are observed for H/D = 5 and a maximum increase of 10% is obtained at a concentration equal to 5%.

M. A. Teamah and S. Farahat carried out the heat transfer and fluid flow due to the impingement of vertical circular single jet on a horizontal heated surface is investigated numerically and experimentally. A mathematical model is driven and executed by a computer program, which is prepared for that purpose. The numerical results are presented for a range of Reynolds number between 1000 and 40000, showing the variation of segment and average segment Nusselt number as well as the velocity and temperature distribution in the film region. An experimental apparatus was designed to measure the film thickness distribution, wall temperature and mean temperature of flowing fluid, in order to calculate the segment and average segment Nusselt number. Six-volume flow rates were used 1, 2, 4, 5, 6, and 8 litre/minute. A comparison between experimental and numerical results was carried out; it was observed that there is a good agreement between them. From the data obtained either numerically or experimentally it was observed that for all Reynolds number that both segment and average segment Nusselt numbers are reduced with increasing radius ratio especially in the shooting flow region through which they are reduced sharply. The average segment Nusselt number was correlated for two ranges of Reynolds number.

EXPERIMENTAL SETUP

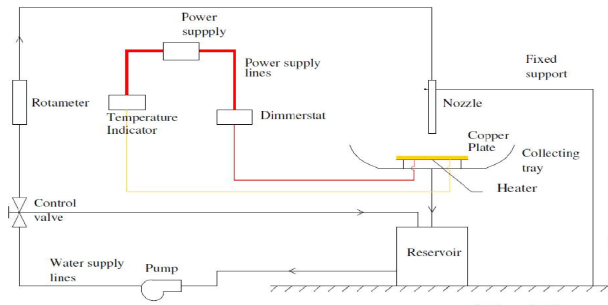

Figure 4.2 Schematic Diagram of Experimental Test Setup

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.

Experimental setup consists of following components and fluids
1. Cu plate
2. Nozzle
3. Motor
4. Heater
5. Thermocouple
6. Tank
7. Rota meter
8. Nanfluid

The present study is carried out to examine the effect of nanofluid flow rates and concentrations on cooling of horizontal circular disks. Water is used as liquid reference in the current investigation since it is the base fluid of the used nanofluid. Three nozzles are used to examine jet size effect on heat transfer from hot disks. At the beginning of the experiment, the control valve is used to establish the required flow rate through the nozzle. Then, the heater is turned on where the electric power is adjusted using the dimmer stat and recorded. The experiments are done first for pure water only, then for nanofluid. Water from collecting tank is passed through pump. From this pump through control valve it reaches to flow meter. From the flow meter it reaches to the nozzle and from that nozzle it impinges on a flat horizontal plate. This plate is heated by the heater plate. And mica is used here as an electrical insulator. Thus by using liquid jet impingement we can achieve cooling of the plate. Temperature of the plate is measured by a set of thermocouples which are connected to temperature indicator. By varying the above mentioned parameters and by using the nanofluid we can enhance the heat transfer. Thus different readings are taken and optimum parameters can be obtained for obtaining maximum heat transfer from plate.

Fill the water/nanofluid in the acrylic tank.

1. Attach the nozzle of required diameter. Adjust the distance between nozzle exit and plate surface. Readings are to be taken at Z/D= 2, 4, 8, 12, 16 and 18.
2. Switch on the pump and adjust the flow rate. Readings are to be taken at 2, 3 or 4 lpm.
3. Adjust flow rate by using control valves and knobs on rotameter. Now switch off the pump.
4. 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.
5. Now start the pump. Note down the readings from the digital indicator after 4 seconds at 8 different locations on plate.
6. Now switch off the pump and repeat same procedure for different flow rate and Z/D distance.
7. Same procedure is repeated for different concentrations of nanofluid.

RESULTS AND DISCUSSION

Effect of Z/D ratio on Heat Transfer Coefficient at Different Flow Rates

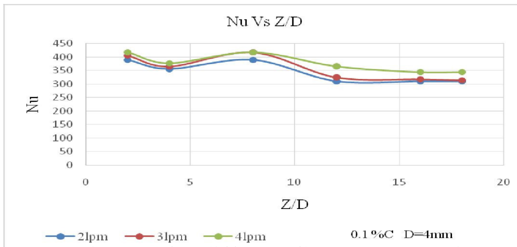

Figure 5.1 Stagnation Nu for different flow rates at various Z/D (0.1% **Φ**)

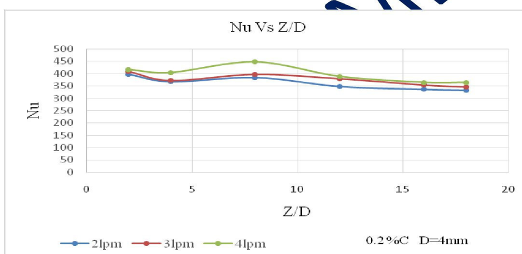

Figure 5.2 Stagnation Nu for different flow rates at various Z/D (0.2% **Φ**)

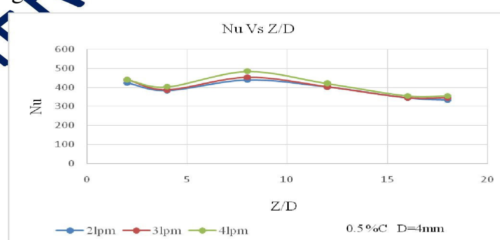

Figure 5.3 Stagnation Nu for different flow rates at various Z/D (0.5% **Φ**)

The variation of Nusselt number in liquid jet impingement when Al_2O_3 nanofluid has concentration of 0.1% is shown in figure 5.1,5.2 and 5.3 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 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.

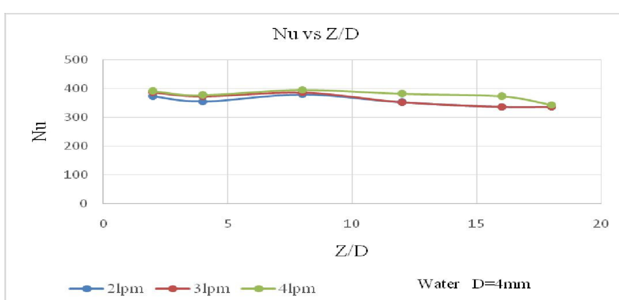

Figure 5.4 Stagnation Nu for different flow rates at various Z/D (Pure Water)

The variation of heat transfer coefficient in liquid jet impingement when water is used as impingement liquid is shown in figure 4.4 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 4.4 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.

CONCLUSION

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.

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