Heat Transfer Enhancement By Using Nanofluid Jet Impingement

Dr. V. B. Jaware¹ G. P. Bhagat²
1. Professor, Department of Mechanical Engineering, J.S.P.M.s Rajashree Shahu College of Engineering, Pune, Maharashtra, India.
2. ME Student, Department of Mechanical Engineering, J.S.P.M.s Rajashree Shahu College of Engineering, Pune, Maharashtra, India.

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.

Key words

1. INTRODUCTION
Impinging of liquid jet on a surface to remove heat from this surface is an effective method for high heat flux heat transfer. The use of jet impingement as a high performance technique for local heating or cooling a surface has become a well-established method because of its high heat transfer rates and its simplicity in application to a variety of industries. The impinging jets are classified in to the category of the active methods and they have been widely used in several industrial applications as means of providing high localized heat transfer coefficients. 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.

2. 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 2.1 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](image)

![Figure 2.2 Schematic of Experimental Test Setup](image)

**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. Readings are to be taken at $Z/D= 2, 4, 8, 12, 16$ and $18$.
3. 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.
4. Now switch off the pump.
5. Switch on the heater by adjusting voltage of dimmerstat. 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.
6. Now 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.
10. 3. RESULTS AND DISCUSSION

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

3.1.1 0.1% Φ

![Figure 3.1 Stagnation Nu for different flow rates at various Z/D (0.1% Φ)](image)

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

The variation of Nusselt number in liquid jet impingement when Al₂O₃ nanofluid 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 Al$_2$O$_3$ Al$_2$O$_3$ 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.

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 3.4 Stagnation Nu for different flow rates at various Z/D (Pure Water)](image)

3.2 Effect of Radial Distance on Heat Transfer Coefficient

3.2.1 0.1% \( \Phi \)
The variation of heat transfer coefficient in liquid jet impingement when \( \text{Al}_2\text{O}_3 \) \( \text{Al}_2\text{O}_3 \) 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 outside 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 3.5 Local Nu at Free Jet, Impinging and Wall Jet Regions at Z/D = 8 (0.1% \( \Phi \))](image)
3.2.2 0.2 % Φ

The variation of heat transfer coefficient in liquid jet impingement when Al₂O₃ 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 outside 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 3.6 Local Nu at Free Jet, Impinging and Wall Jet Regions at Z/D = 8 (0.2% Φ)](image)

3.2.3 0.5% Φ

The variation of heat transfer coefficient in liquid jet impingement when Al₂O₃ 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 outside 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 3.7 Local Nu at Free Jet, Impinging and Wall Jet Regions at Z/D = 8 (0.5% Φ)](image)
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 outside 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.

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% $\Phi$

![Figure 3.8 Local Nu at Free Jet, Impinging and Wall Jet Regions at $Z/D = 8$ (Water)](image)

![Figure 3.9 Local Nu at Free Jet, Impinging and Wall Jet Regions (0.1% $\Phi$)](image)
3.3.2 0.2% Φ

![Graph](image)

Figure 3.10 Local Nu at Free Jet, Impinging and Wall Jet Regions (0.2% Φ)

3.3.3 0.5% Φ

![Graph](image)

Figure 3.11 Local Nu at Free Jet, Impinging and Wall Jet Regions (0.5% Φ)
3.3.4 Water

Figure 3.12 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, Al$_2$O$_3$ nanofluid concentrations 0.1%, 0.2% and 0.5% is shown in figure 3.13 at constant $Z/D=8$, flowrate of 4lpm and $D=4$mm. 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 3.13 Effect of Different Liquid on Heat Transfer Coefficient

4. CONCLUSION

In the present work, experimental study for enhancement of heat transfer using nanofluid jet impingement has been conducted. The experimental setup is fabricated at HSBPVT’s College of Engineering, Kashti, Dist.-Ahmednagar. 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

National Journal of Engineering Technology, Management and Applied Sciences

www.ijetmas.com May 2015, Volume 3 Issue 5, ISSN 2349-4476


