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# EXPERIMENTAL STUDIES ON EFFECTS OF NOZZLE TO TARGET PLATE GAP DURING LIQUID JET IMPINGEMENT COOLING

Dr. Nirmal Kumar Kund
*Associate Professor, Department of Production Engineering*
*Veer Surendra Sai University of Technology, Burla 768018, India*

***Abstract— The current study includes the experimental examinations of the heat transfer behaviours of axisymmetric water jet impinging on a heated plate. Several parameters influencing the thermal performance of axisymmetric water jet are identified and their effects on heat transfer performance are also studied. The key parameters considered is nozzle to target plate gap (20-35 mm). Furthermore, all the examinations here are constrained to a uniform heat flux condition. Results show that the water jet performance can be optimized pertaining to this key parameter. Nevertheless, with the current experimental conditions, the nozzle to target plate gap of 25 mm offers reasonable heat transfer performance and is the optimum one.***

***Keywords— Water Jet, Nozzle, Plate, Gap.***

## I. INTRODUCTION

The continual increase in needs for faster and smaller electronic components in the electronic industry has resulted in the development of compact electronic equipments with high power densities. Conventional air cooling is insufficient in most cases to help sustain and safeguard the electronics components from the thermal failure. Garimella and Nenaydykh [1] have experimentally investigated the effect of nozzle geometry on the local heat transfer of FC-77 per-fluorinated dielectric liquid for normal jet impingement. Chakraborty and Dutta [2] found analytical solutions for heat transfer during cyclic melting and freezing of a phase change material used in electronic and electrical packaging. Nayak *et al*. [3] developed a numerical model for heat sinks with phase change materials and thermal conductivity enhancers. Pavlova and Amitay [4] studied on the heat transfer behaviour of electronics with synthetic normal jet impingement.

Additionally, Adoni *et al*. [5] developed a thermo-hydraulic model for capillary pumped loop and loop heat pipe used for cooling of electronics. Saha *et al*. [6] investigated on optimum distribution of fins in heat sinks filled with phase change materials. Sanyal *et al*. [7] numerically studied on heat transfer from pin-fin heat sink using steady and pulsated impinging air jets. Chaudhari *et al*. [8] examined heat transfer characteristics of synthetic air jet impingement cooling. Yu *et al*. [9] compared a series of double chamber model with various hole angles for enhancing cooling effectiveness by air jets. Besides, Cheng *et al*. [10] numerically studied air/mist impinging jets cooling effectiveness under several curvature models.

Thoughtful examination and consideration of the already stated relevant literature reveals no clear-cut and prior theoretical and experimental investigation on the local heat transfer under an obliquely impinging, axisymmetric free surface water jet flow. In addition, to the best of the authors' knowledge, there is not a single comprehensive experimental study pertaining to the effects of the nozzle to target plate gap on the heat transfer behaviour over the heated target plate previously maintained at a uniform heat flux of 6.25 W/cm$^2$ for investigating the relative importance of the key parameters involved. With this viewpoint, the current paper demonstrates experimental investigations relating to the influence and role of the nozzle to plate gap (20-35 mm) on the local heat transfer characteristics over a flat plate heated from the underneath and maintained at a uniform flux of 6.25 W/cm$^2$, for free surface axisymmetric water jet impingements. Additionally, the results thus obtained are analyzed and compared, so as to realize deeply, the heat transfer behaviour over the target plate for achieving better cooling effect.

## II. DESCRIPTION OF EXPERIMENTAL SETUP

Figure 1 represents the photograph of the complete assembly of the experimental setup consisting of a heater kept in a rectangular Plexiglas box, a nozzle connected to a rotameter via a flexible pipe and a copper target plate mounted on the heater. The heater consisting of tungsten filament (with heater wire diameter of 0.576 mm and heater element resistance of 4.3 Ω) is connected to a dual supply D.C. power source. For particular values of current and voltage the heat flux to the heater remains constant. A digital multimeter (Keithley 2700 model) is used to measure the voltage, whereas, current is directly measured from the display unit of power supply. The rotameter is connected to a water supply tap by means of a flexible pipe with brass ball valve arrangement for regulating water flow. The copper plate mounted on the heater have got grooves underside in order to accommodate thermocouples connected to data acquisition system. The surface of the copper plate is polished with sand paper and then is cleaned with acetone before conducting experiments. The nozzle is kept perpendicular or inclined to the target plate by means of a vertical stand with clamp arrangement. The test fluid (water) discharges out through the outlet of the test chamber after impinging on the target plate.

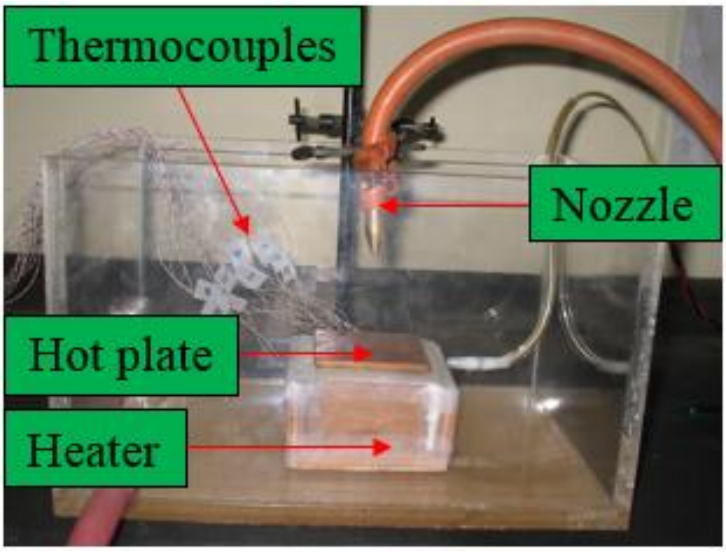


Fig 1. Photograph of experimental setup

## III. RESULTS AND DISCUSSIONS

Thorough experiments are performed to investigate the effects of nozzle to target plate gap on the heat transfer distribution over the heated target plate subjected to a uniform heat flux. To begin with, a nozzle of diameter 5 mm with the nozzle to target plate gap of 25 mm and a normal water jet of flow rate 30 lph. The heat flux of 6.25 $W/cm^2$ (corresponding to 30 V and 2 A of D. C. power source associated with copper target plate of size 31 mm × 31 mm) is applied in all investigations.

***Effect of nozzle to target plate gap***

Apart from the stated case involving nozzle to target plate gap of 25 mm, in this investigation three more nozzle to plate gaps of 20, 30 and 35 mm are taken into consideration with the said experimental conditions. The results so observed are compared to study the role and effect of the nozzle to target plate gap.

Figure 2 illustrates the variation of local Nusselt number with radial distance from the stagnation point for the said nozzle to plate gaps altogether for the comparative investigation. For the axisymmetric water jet with nozzle to plate gap of 35 mm, the local Nusselt number decreases from 37 at the centre to 20 at the edge of the target plate. Likewise, for the axisymmetric water jets with nozzle to plate gaps of 30, 25 and 20 mm, the local Nusselt numbers decrease from 43, 51 and 64 at the centre to 23, 26 and 33 at the edge of the target plate, respectively. It is observed that the local Nusselt number profile is relatively flat for the bigger nozzle to plate gap. This is because of slow cooling associated with the impinging jet.

 

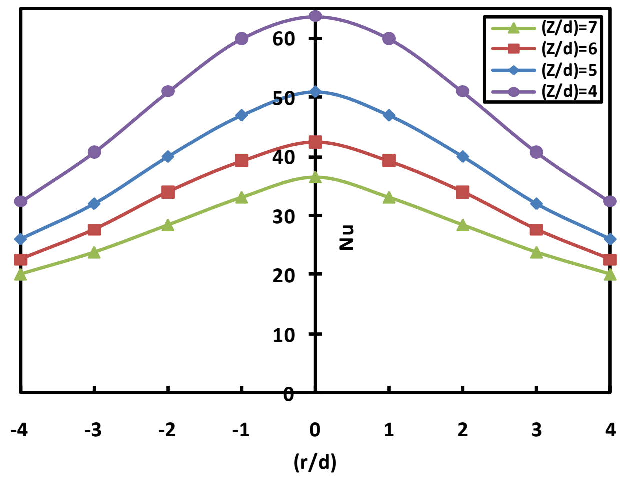


Fig 2. Variation of local Nusselt number with radial distance

Figure 3 depicts the variation of both stagnation and average Nusselt number with the nozzle to plate gap. The stagnation Nusselt numbers are 30, 43, 51 and 60 for the nozzle to plate gaps of 20, 25, 30 and 35 mm, respectively. Likewise, the average Nusselt numbers are 64, 51, 43 and 37 for the nozzle to plate gaps of 20, 25, 30 and 35 mm, respectively. From both the cited figures, it is clear that the local, stagnation and average Nusselt numbers decrease with nozzle to plate gap. This result as expected is on account of the higher nozzle to target plate gap causing the taking away of the heat from the target plate at relatively slower rate. From figure 4, it is also apparent that the variation of both stagnation and average Nusselt numbers with the nozzle to plate gap is approximately linear.

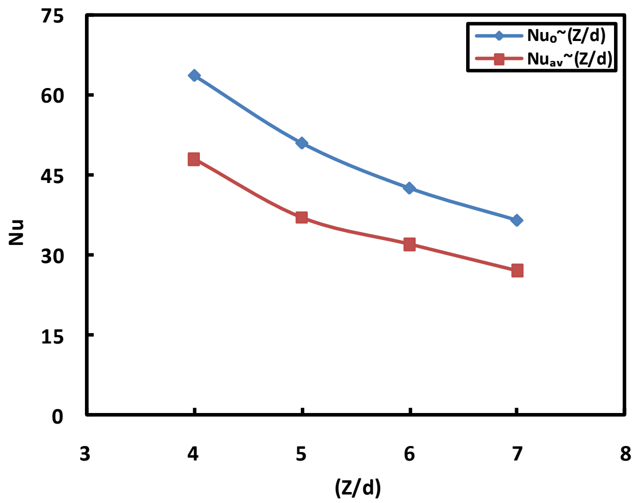


Fig 3. Variation of Nusselt number with nozzle to plate gap

## IV. CONCLUSIONS

Thorough experiments are performed for several combinations of interdependent and interrelated parameters involved with the water jet impingement on a heated plate to study the heat transfer characteristics. Complete experimental studies on the effects of the nozzle to plate gap are carried out as they greatly influence the thermal performance of the impinging water jets. Based on the measurements and the data derived, the trends of the results with regard to various parameters are observed to be along expected lines. In addition, the appropriate combinations of the key interdependent and interconnected parameters for which enhancement in the averaged heat transfer from the plate can be expected is also identified. Direct comparison with other experimental/numerical results is not possible due to non-availability of such experimental conditions in the literature. However, comparison with a numerical model pertaining to the present experimental conditions is planned for the future. In addition, the present study also neglects target plate side heat losses. Nonetheless, with the present experimental conditions the nozzle to plate gap of 25 mm offers reasonable heat transfer behaviour and is the optimum. Therefore, the present arrangement can be applied directly in production houses to augment heat transfer and for cooling of electronic items.

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## REFERENCES

[1] Garimella, S.V., Nenaydykh, B., Nozzle-geometry effects in liquid jet impingement heat transfer, Int. J. Heat Mass Transfer, 39 (1996), 14, pp. 2915–2923

[2] Chakraborty S., Dutta, P., Analytical solutions for heat transfer during cyclic melting and freezing of a phase change material used in electronic and electrical packaging, ASME Journal of Electronic Packaging, 125 (2003), 1, pp. 126-133

[3] Nayak, K.C., Saha, S. K., Srinivasan, K., Dutta, P., A numerical model for heat sinks with phase change materials and thermal conductivity enhancers, International Journal of Heat and Mass Transfer, 49 (2006), pp. 1833-1844

[4] Pavlova, A., Amitay, M., Electronic cooling using synthetic jet impingement, *J. Heat Transfer*, 128 (2006), 9, pp. 897-907

[5] Adoni, A., Ambirajan, A., Srinivasan, K., Dutta, P., Thermo-hydraulic modeling of capillary pumped loop and loop heat pipe, AIAA Journal of Thermophysics and Heat Transfer, 21 (2007), 2, pp. 410-421

[6] Saha, S. K., Srinivasan K., Dutta, P., Studies on optimum distribution of fins in heat sinks filled with phase change material, ASME Journal of Heat Transfer, 130 (2008), 3, ID 034505, pp. 1-4

[7] Sanyal, A., Srinivasan, K., Dutta, P., Numerical study of heat transfer from pin-fin heat sink using steady and pulsated impinging jets, IEEE Transactions on Components and Packaging Technology, 32 (2009), 4, pp. 859-867

[8] Chaudhari, M., Puranik, B., Agrawal, A., Heat transfer characteristics of synthetic jet impingement cooling, Int. J. Heat Mass Transfer, 53 (2010), 5-6, pp. 1057-1069

[9] Yu, Z. L., Xu, T., Li, J. L., Ma, L., Xu, T. S., Comparison of a series of double chamber model with various hole angles for enhancing cooling effectiveness, International Communications in Heat and Mass Transfer, 44 (2013), pp. 38–44

[10] Cheng, P., Yao, G., Chen, W., Li, B., Li, J., Xu, T., Yu, Z., Ma, L., Computational study of air/mist impinging jets cooling effectiveness under various curvature models, Advances in Mechanical Engineering, 2014 (2014), ID 569243, pp. 1-9