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Experimental Investigations on Impacts of Nozzle Diameter on Heat Transfer Behaviors with Water Jet Impingement

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***Abstract:** Rigorous experiments are done to study the impacts of nozzle size on heat spreading over flat plate exposed to uniform heat flux of 6.25 W.cm^{-2}. In lieu of that four nozzle diameters of 3, 4, 5 and 6 mm are chosen, besides, jet flow rate and Reynolds number of 30 lph and 2400, respectively. As expected, it is observed that the temperature increases in radial direction. Furthermore, the observed temperature distribution is axisymmetric. Additionally, it also reveals that the temperature increases with nozzle diameter. Besides, the observed temperature variation is almost linear. Likewise, it also shows that the Nusselt number decreases in radial direction. The observed Nusselt number distribution is axisymmetric as well. In addition, it also reveals that the Nusselt number decreases with nozzle diameter. The observed Nusselt number variation is almost linear on top. Nevertheless, the nozzle diameter of 5 mm offers average and optimum cooling characteristics.*

***Index Terms:** Water Jet, Flat Plate, Nozzle Diameter, Heat Transfer, Cooling.*

I. INTRODUCTION

Electronics cooling wants have risen at terrific speed since the establishment of ICT. Conventional cooling methods deployed previously, like free/forced convection of air are lacking for high thermal drives. Alternate cooling practice apprehending great focus is liquid jet impingement. It overwhelms the difficulty of high heat resistance related to the aforementioned methods.

Likewise, the nanofluid cooling is forthrightly vivacious as air cooling is poor to deliver the vitality. Experimental survey and theoretic review of thermal scattering on flat plate with striking air jet is pronounced in the works [1]. Computing model by simulated valuations are fully startling in genera [2-15]. Impacting jet on an outer annulus is superbly described [16].

Cautious assessment of the above-mentioned pertinent texts divulges no straightforward experimental research on heat transfer behavior relating to impinging water jet. No such broad experimental investigation about the influence of nozzle size on cooling behavior with water jet impingement.

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With this perspective, the present work establishes experimental studies about the impacts of nozzle diameter (3, 4, 5 and 6 mm) on thermal performances with water jet impingement over hot flat plate subjected to constant heat flux of 6.25 W.cm^{-2}. Furthermore, the observed results are assessed and compared for appreciating the importance of nozzle size in attaining desired cooling.

II. TEST APPARATUS

It elucidates comprehensively about the details of current physical model as well as experimental setup.

A. Illustration of Physical Problem

Fig. 1 shows the representation of physical model. It comprises a grooved copper plate (known as hot flat plate) of size 30×30×2 mm underneath which T-type thermocouples (with gaps 5 mm) are housed over the diagonal line. Hot plate is attached to a heater. Thermocouples are linked to data acquisition system for noting temperature data uninterruptedly throughout the experiments.

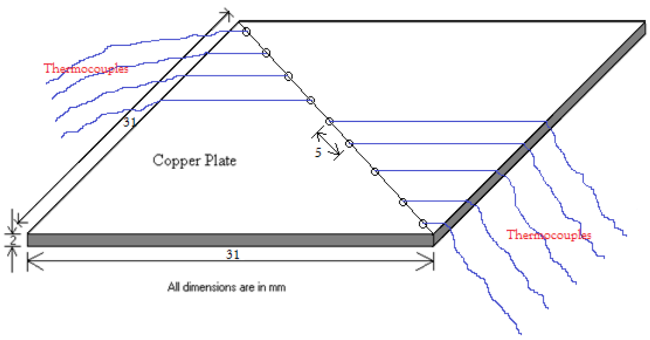

Figure 1. Representation of physical model

The hot plate is demarcated with various annuli concerning different thermocouples to determine heat transfer coefficient (h) and Nusselt number (Nu) for impinging water jet. The following equations 1-5, are used for calculating the same.

$$h_i = \frac{Q_{out}}{A_h (T_{si} - T_j)}; \; Q_{out} = VI \qquad (1)$$

$$\bar{h} = \frac{\sum h_i A_i}{\sum A_i} \qquad (2)$$

$$\bar{h} = \left[\frac{Q_{out}}{A_h^2}\right]\sum\left(\frac{A_i}{T_{si} - T_j}\right) \quad (3)$$

$$Nu_i = \frac{h_i d}{k} \quad (4)$$

$$\overline{Nu} = \frac{\bar{h} d}{k} \quad (5)$$

B. Demonstration of Experimental Setup

Fig. 2 illustrates the whole assembly of experimental arrangement. It involves heater residing in test chamber, nozzle with flexible pipe, hot plate and thermocouples. Heater with tungsten string is linked to D.C. energy font concerning both voltage and current. The rotameter is attached to flexible pipe. Hot plate is having grooves underneath for housing thermocouples linked to data acquisition system. The nozzle is held normal to hot plate using upright stand and clamp. Water releases out from exit of Plexiglas box once impinges on hot plate.

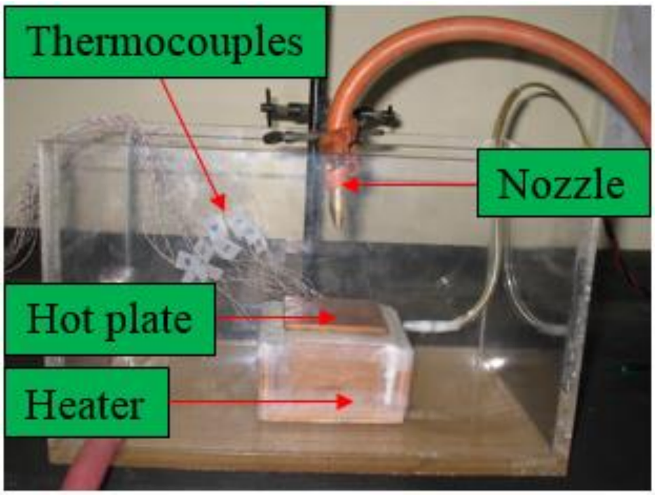

Figure 2. Snapshot of experimental setup

III. EXPERIMENTAL PROCEDURES

A. Water Flow Measurement

The flow rate of impinging water jet is measured using a rotameter with metering level up to 120 lph (and uncertainty of ±0.01lph). Besides, the fine-tuning of rotameter is done for avoiding fluctuations. The jet velocity is determined from flow rate. The associated jet Reynolds number is also determined from stated velocity.

B. Temperature Measurement

Polytetrafluoroethylene (PTFE) coated thermocouples (with response time of 0.8 sec) are deployed for measurement temperature at various points over hot flat plate throughout the water jet striking. Details about the specifications of thermocouples are declared in Table 1. Thermocouples are calibrated with Pt resistance thermometer. Julabo FH40-MH circulation bath is intended for present drive. The temperature data are noted from time to time using an interface PC with a data acquisition system. It involves a 40-channel thermocouple plug-in card to monitor temperature progress.

Table 1. Specifications of thermocouples

Material	Class	Size (mm)	Temperature range & uncertainty (°C)
Copper -Constantan	PTFE coated T-type	0.205	0-200°C & ±0.004T°C

IV. RESULTS AND DISCUSSIONS

Exhaustive experiments are accomplished to probe the paraphernalia of nozzle size on thermal spreading over the hot flat plate exposed to constant heat flux of 6.25 W.cm^{-2} (equivalent to 30 V and 2 A of energy font besides plate dimension of 30×30 mm). Initially chosen nozzle diameter, flow rate and Reynolds number are 5 mm, 30 lph and 2400, respectively.

Influence of Nozzle Diameter on Cooling Behavior

Besides, three additional nozzle diameters of 3, 4 and 6 mm are also considered for relative comparison of results.

A. Temperature Variation over Flat Plate for Different Nozzle Diameters

Fig. 3 exhibits the relative temperature variations in radial direction for different nozzle diameters. As expected, it also shows that the temperature increases in radial direction. Additionally, the observed temperature distribution is axisymmetric.

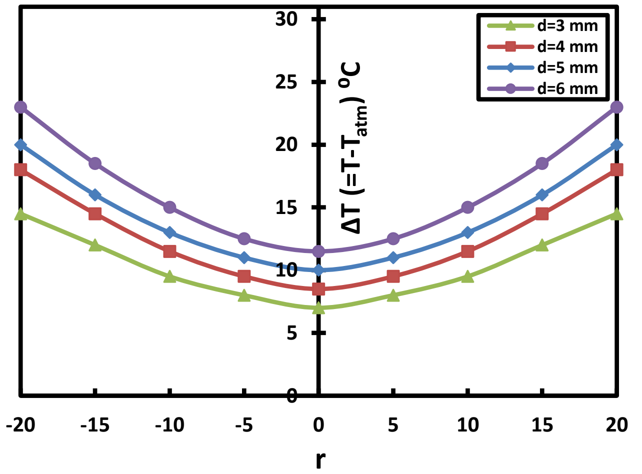

Figure 3. Variation of temperature with radial distance for different nozzle diameters

Fig. 4 elucidates the variation of temperature with nozzle diameter. As anticipated, it also reveals that the temperature increases with nozzle diameter. Furthermore, the observed temperature variation is almost linear.

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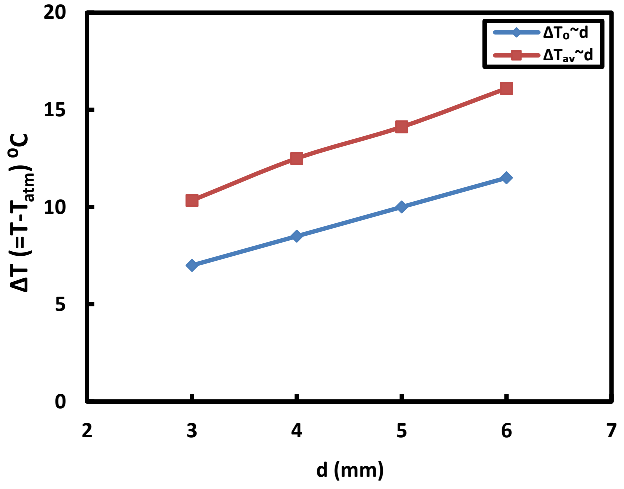

Figure 4. Variation of temperature with nozzle diameter

B. Nusselt Number Variation over Flat Plate for Different Nozzle Diameters

Fig. 5 exhibits the Nusselt number variations along radial direction for different nozzle diameters. As expected, it also shows that the Nusselt number decreases in radial direction. Additionally, the observed Nusselt number distribution is axisymmetric as well.

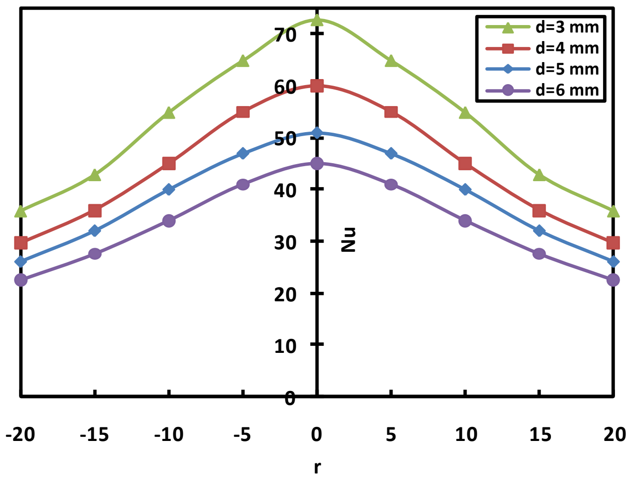

Figure 5. Variation of local Nusselt number with radial distance for different nozzle diameters

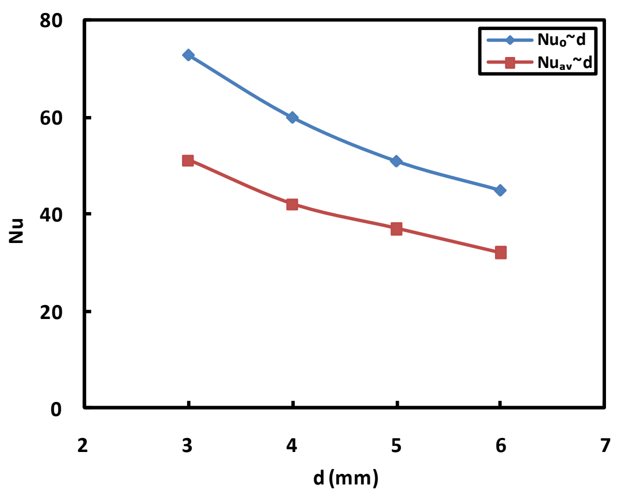

Figure 6. Variation of Nusselt number with nozzle diameter

Fig. 6 elucidates the variation of Nusselt number with nozzle diameter. As anticipated, it also reveals that the Nusselt number decreases with nozzle diameter. Furthermore, the observed Nusselt number variation is almost linear.

V. CONCLUSION

Comprehensive experiments are performed to examine the impacts of nozzle dimension on thermal spreading over the hot flat plate exposed to constant heat flux of 6.25 W.cm^{-2}. For that four nozzle diameters of 3, 4, 5 and 6 mm are considered, besides, jet flow rate and Reynolds number of 30 lph and 2400, respectively. As expected, it is observed that the temperature increases in radial direction. Furthermore, the observed temperature distribution is axisymmetric. Additionally, it also reveals that the temperature increases with nozzle diameter. Besides, the observed temperature variation is almost linear. Likewise, it also shows that the Nusselt number decreases in radial direction. The observed Nusselt number distribution is axisymmetric as well. In addition, it also reveals that the Nusselt number decreases with nozzle diameter. The observed Nusselt number variation is almost linear on top. However, the nozzle diameter of 5 mm renders moderate and optimal cooling performance.

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REFERENCES

1. V. Katti, S. V. Prabhu, 2008, Experimental study and theoretical analysis of local heat transfer distribution between smooth flat surface and impinging air jet from a circular straight pipe nozzle, International Journal of Heat and Mass Transfer, Vol. 51, pp. 4480–4495.
2. N. K. Kund, P. Dutta, 2010, Numerical simulation of solidification of liquid aluminium alloy flowing on cooling slope, Trans. Nonferrous Met. Soc. China, Vol. 20, pp. s898-s905.
3. N. K. Kund, P. Dutta, 2012, Scaling analysis of solidification of liquid aluminium alloy flowing on cooling slope, Trans. Indian Institute of Metals, Vol. 65, pp. 587-594.
4. N. K. Kund, 2014, Influence of melt pouring temperature and plate inclination on solidification and microstructure of A356 aluminum alloy produced using oblique plate, Trans. Nonferrous Met. Soc. China, Vol. 24, pp. 3465−3476.
5. N. K. Kund, 2015, Influence of plate length and plate cooling rate on solidification and microstructure of A356 alloy produced by oblique plate, Trans. Nonferrous Met. Soc. China, Vol. 25, pp. 61−71.
6. N. K. Kund, P. Dutta, 2015. Numerical study of solidification of A356 aluminum alloy flowing on an oblique plate with experimental validation, J Taiwan Inst. Chem. Ers., Vol. 51, pp. 159−170.
7. N. K. Kund, P. Dutta, 2016, Numerical study of influence of oblique plate length and cooling rate on solidification and macrosegregation of A356 aluminum alloy melt with experimental comparison, J. Alloys Compd., Vol. 678, pp. 343−354.
8. N. K. Kund, 2018, Effect of tilted plate vibration on solidification and microstructural and mechanical properties of semisolid cast and heat-treated A356 Al alloy, Int. J. Adv. Manufacturing Technol., Vol. 97, pp. 1617−1626.

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9. N. K. Kund, 2019, EMS route designed for SSM processing, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 382−384.
10. N. K. Kund, 2019, Cooling slope practice for SSF technology, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 410−413.
11. N. K. Kund, 2019, Comparative ways and means for production of nondendritic microstructures, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 534−537.
12. N. K. Kund, 2019, Simulation of electronics cooling deploying water-zinc oxide nanofluid, International Journal of Recent Technology and Engineering, Vol. 7, pp. 1076−1078.
13. N. K. Kund, 2019, Numerical studies on fuel cell cooling introducing water-copper nanofluid, International Journal of Recent Technology and Engineering, Vol. 7, pp. 1079−1081.
14. N. K. Kund, 2019, Computational modeling of fuel cell expending water-zinc oxide nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 424–426.
15. N. K. Kund, 2019, Investigations on modeling and simulation of electronics cooling exhausting water-aluminum nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 660−663.
16. A. Azimi, M. Ashjaee, P. Razi, 2015, Slot jet impingement cooling of a concave surface in an annulus," Experimental Thermal and Fluid Science, Vol. 68, pp. 300–309.

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Dr. N. K. Kund has obtained both M.Tech. & Ph.D. in Mechanical Engineering from Indian Institute of Science Bangalore. He has also obtained B.Tech.(Hons) in Mechanical Engineering from IGIT Sarang, Utkal University Bhubaneswar. He has published several research papers in international journals and also guided many research scholars, besides, wide teaching and research experience. He is presently working as Associate Professor in the Department of Production Engineering, VSSUT Burla (A Government Technical University).

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