International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-12, October 2019

Experimental Research on Effects of Nozzle Size Intended for Water Jet Impingement Cooling

N. K. Kund

***Abstract:** Rigorous experiments stay performed for examining influences of nozzle size on heat dispersal over flat plate concerning constant thermal value 6 W/cm^2. This paper presents the experimental studies on cooling behavior with water jet impingement. Several influencing parameters pertaining to cooling behaviors of striking jets got recognized for investigating impacts over heat transfer characteristics. The parameters taken into account are nozzle diameter (3, 4, 5 and 6 mm), Reynolds number (800, 1600, 2400 and 3200), nozzle to plate spacing (20, 25, 30 and 35 mm) and jet inclination (30º, 45º, 60º, 75º and 90º). Additionally, the studies are limited to a constant heat flux situation. The chary interpretations of results tell that performance remains boosted with regard to these key parameters. Nevertheless, for present experimental settings, nozzle diameter of 5 mm provides sufficient thermal features and is the finest one.*

***Index Terms:** Nozzle Diameter, Water Jet, Flat Plate, Thermal, Cooling Behavior.*

I. INTRODUCTION

The implication of smallness of electronic segments encompass exceedingly tall power densities. Accordingly, electronics cooling desires have grown at enormous rapidity from the development of ICT. Orthodox cooling means used before, like free/forced convection of air are deficient for huge heat energies. Alternating cooling exercise arresting boundless effort is fluid jet impingement. It engulfs strain of tall heat confrontation accompanying the aforesaid methods.

Equally, the nanofluid cooling is bluntly effervescent as air cooling is weak to convey the strength. Both numerical and experimental investigations of heat spreading on flat plate is prominent in the texts [1-10]. Computational enumerations as well as simulations are completely amazing in sorts [11-35].

Thoughtful valuation of the aforesaid relatable writings discloses no up-front experimental exploration on thermal characteristics about impacting water jet. No such experimentation on influences of nozzle size on cooling behaviors with striking water jet. With this outlook, the contemporaneous research institutes experimental studies for the influences of nozzle size (3, 4, 5 and 6 mm) on cooling behaviors of striking water jet over flat plate concerning constant thermal value 6 W/cm^2. Additionally, the witnessed results are evaluated/matched for escalating the prominence of nozzle size in accomplishing the sought after cooling.

Revised Manuscript Received on October 30, 2019.
* Correspondence Author
N. K. Kund*, Department of Production Engineering, Veer Surendra Sai University of Technology, Burla.

II. TEST ARRANGEMENT

It expounds expansively about the particulars of contemporary physical model along with experimental setup.

A. Demonstration of Physical Problem

Fig. 1 displays the depiction of physical model. It includes a channeled copper flat plate of dimension 30×30×2 mm beneath which T-type thermocouples (with spaces 5 mm) are accommodated along diagonal route. Flat plate is fixed to a heater. Thermocouples got joined with data recording device to store thermal data successively during the experiments.

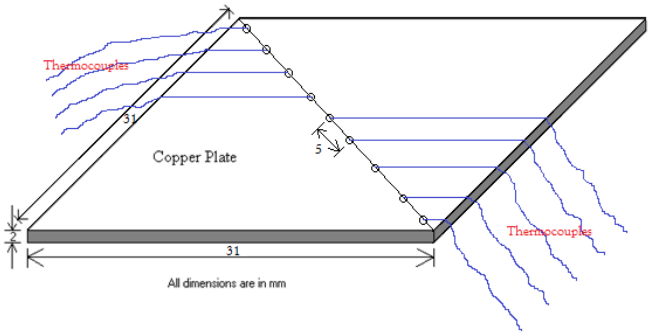

Figure 1. Schematic of physical model

The flat plate is delineated with several annuli vis-à-vis many thermocouples to estimate heat transfer coefficient (h) as well as Nusselt number (Nu) for impacting water jet. The under-mentioned equations 1-5, are used to figure the same.

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

$$\bar{h} = \frac{\sum h_i A_i}{\sum A_i} \tag{2}$$

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

$$Nu_i = \frac{h_i d}{k} \tag{4}$$

$$\overline{Nu} = \frac{\bar{h} d}{k} \tag{5}$$

B. Illustration of Experimental Setup

Fig. 2 elucidates the unabridged assembly of experimental preparation. It implicates heater housing inside trial compartment, nozzle with stretchy tube, flat plate in addition to thermocouples. Heater with tungsten thread is connected to D.C. drive vis-à-vis both voltage and current. The rotameter is fixed to stretchy tube. Flat plate is having channels beneath to hold thermocouples connected to data acquisition system. The nozzle stays normal to flat plate using upright stand plus lock. Water discharges from outlet of Plexiglas box when impinging on flat plate.

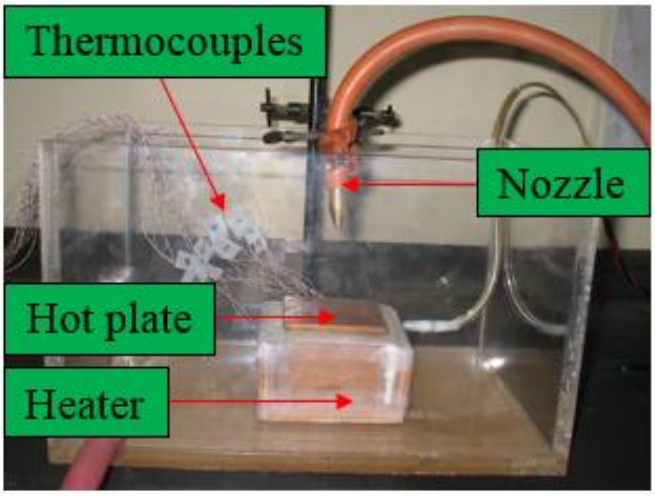

Figure 2. Photograph of experimental setup

III. EXPERIMENTAL TECHNIQUES

It embroils the measurements of under-mentioned vital variables.

A. Liquid Flow Measurement

The flow rate of impacting water jet is noted expending a rotameter having measuring limit up to 120 lph (with uncertainty of ±0.01lph). Above and beyond, the adjustment of rotameter is done for killing fluctuations. The jet velocity is calculated from flow rate. The related jet Reynolds number is calculated from said velocity as well.

B. Temperature Measurement

Polytetrafluoroethylene (PTFE) coated thermocouples (having response time of 0.8 sec) are used for measuring temperature at several plugs on flat plate during the water jet impinging. Particulars of the specifications of thermocouples are stated in Table 1. Thermocouples are calibrated using Pt opposition thermometer. Julabo FH40-MH flow path remains aimed at current effort. Thermal facts got chronicled unceasingly through a PC with storing device. It includes a 40-channel thermocouple plug-in card to observe temperature growth.

Table 1. Thermocouple information

Composition	Type	Dimension (mm)	Thermal limit (°C)
Cu -Constantan	T	0.2	0-200

IV. RESULTS AND DISCUSSION

Broad experimentations got effectuated to elucidate the appurtenances of Reynolds number on thermal diffusion on flat plate with constant thermal value 6 W/cm^2. Primarily picked nozzle size, stream rate and jet Reynolds number are 5 mm, 30 lph as well as 2400, one-to-one.

Effects of Nozzle Diameter on Cooling Behaviors

Furthermore, 3 supplementary nozzle diameters 3, 4 and 6 mm are picked for comparative appraisal of results as well.

A. Changes in Nusselt Number with Nozzle Diameter for Varying Reynolds Numbers

Fig. 3 unveils changes in average/stagnation Nusselt numbers with nozzle diameter for different Reynolds numbers of 800, 1600, 2400 and 3200. As anticipated, it displays, Nusselt number declines for increasing nozzle diameter. Furthermore, Nusselt number rises through Reynolds number.

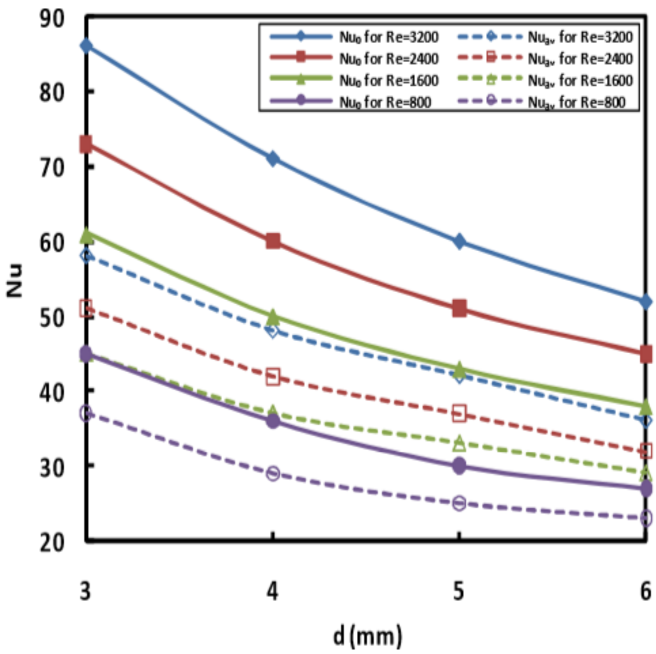

Figure 3. Changes in Nusselt number with nozzle diameter for varying Reynolds numbers

B. Changes in Nusselt Number with Nozzle Diameter for Varying Nozzle to Plate Spacings

Fig. 4 unveils changes in average/stagnation Nusselt numbers with nozzle diameter for different nozzle to plate spacings of 35, 30, 25 and 20 mm. As anticipated, it displays, Nusselt number declines for increasing nozzle diameter. Furthermore, Nusselt number declines for increasing nozzle to plate spacing.

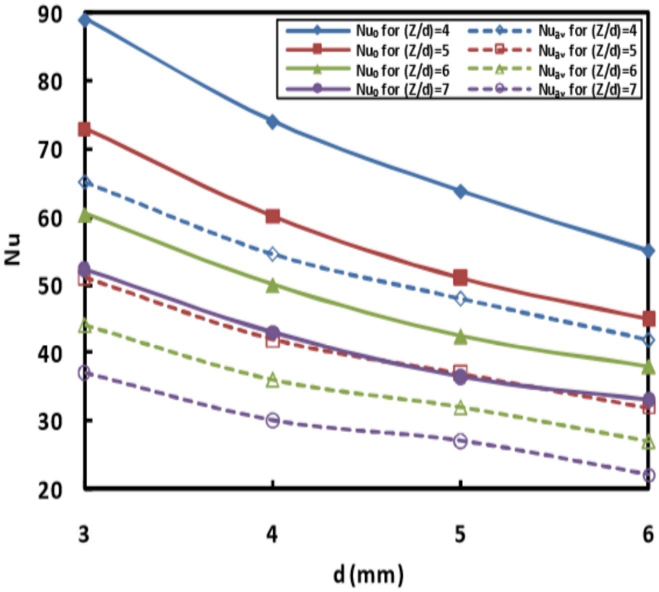

Figure 4. Changes in Nusselt number with nozzle diameter for varying nozzle to plate spacings

C. Changes in Nusselt Number with Nozzle Diameter for Varying Jet Inclinations

Fig. 5 unveils changes in average/stagnation Nusselt numbers with nozzle diameter for different jet inclinations of 30º, 45º, 60º, 75º and 90º. As anticipated, it displays, Nusselt number declines for increasing nozzle diameter. Furthermore, Nusselt number declines for increasing jet inclination.

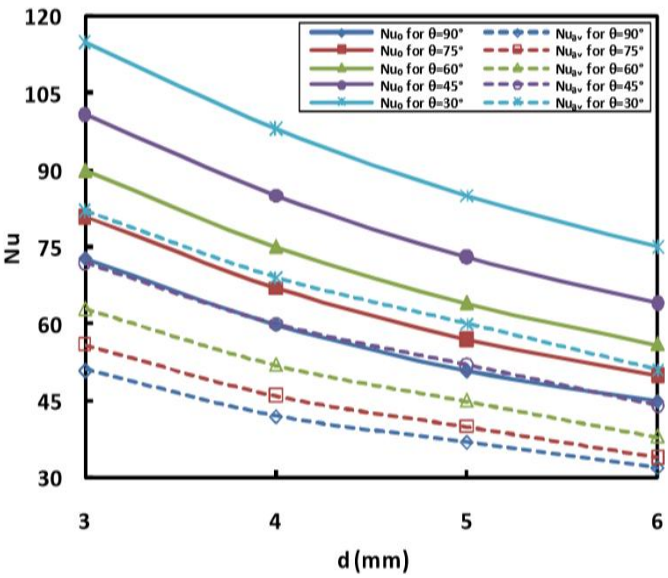

Figure 5. Changes in Nusselt number with nozzle diameter for varying jet inclinations

V. CONCLUSION

Sufficient experimentations stay prepared for investigating the effects of nozzle size on thermal dispersal over flat plate concerning constant thermal value 6 W/cm^2. For that four different nozzle diameters 3, 4, 5 and 6 mm are preferred, above and beyond, volume level and nozzle size of 30 lph and 5 mm, respectively. As anticipated, it is witnessed that the temperature rises in radial route. Additionally, the witnessed temperature distribution is axisymmetric. Furthermore, it also discloses that the temperature declines with Reynolds number. Further, the witnessed temperature variation is more or less linear. Similarly, it also displays that the Nusselt number drops along radial course. The witnessed Nusselt number distribution is axisymmetric on top. Besides, it also divulges, Nusselt number grows with Reynolds number. Nusselt number variation stays almost linear. However, the nozzle diameter of 5 mm gives pleasant and ultimate cooling performances.

ACKNOWLEDGMENT

The author gratefully acknowledge the support from VSSUT Burla for providing the essential resources to perform this research work. The author is also very much indebted to the referees besides journal editors for their painstaking efforts with perceptive thoughts for this manuscript.

REFERENCES

1. 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.
2. 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.
3. 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.
4. 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.
5. 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.
6. 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.
7. 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.
8. N. K. Kund, 2019, EMS route designed for SSM processing, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 382−384.
9. N. K. Kund, 2019, Cooling slope practice for SSF technology, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 410−413.
10. 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.
11. 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.
12. 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.
13. 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.
14. 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.
15. N. K. Kund, 2019, Numerical study on effect of nozzle size for jet impingement cooling with water-Al_2O_3 nanofluid, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 736−739.

16. N. K. Kund, 2019, Experimental investigations on impacts of nozzle diameter on heat transfer behaviors with water jet impingement, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 745−748.
17. N. K. Kund, 2019, Comparative CFD studies on jet impingement cooling using water and water-Al_2O_3 nanofluid as coolants, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 545−548.
18. N. K. Kund, 2019, Experimental studies on effects of jet Reynolds number on thermal performances with striking water jets, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2195−2198.
19. N. K. Kund, D. Singh, 2019, CFD studies on heat transfer and solidification progress of A356 al alloy matrix and Al2 O3 nanoparticles melt for engineering usages, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2043−2046.
20. N. K. Kund, S. Patra, 2019, Simulation of thermal and solidification evolution of molten aluminum alloy and SiC nanoparticles for engineering practices, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2047−2050.
21. N. K. Kund, 2019, Numerical modeling on heat dissipation from electronics through water-titanium carbide nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1772−1775.
22. N. K. Kund, 2019, CFD modeling on influence of impinging spout strength for device cooling with water-Al_2O_3 nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1776−1779.
23. N. K. Kund, 2019, Computational modeling on fuel cell cooling with water based copper oxide nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1967−1970.
24. N. K. Kund, 2019, Modeling and simulation on IC cooling using water centered SiO_2, TiC and MgO nanofluids, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1971−1975.
25. N. K. Kund, 2019, CFD simulation on IC thermal cooling through water involved TiO_2, AlN and CuO nanofluids, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1976−1980.
26. N. K. Kund, 2019, CFD simulation with modeling on fuel cell thermal management using water based SiO_2, TIC and SIC nanofluids, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 1291−1295.
27. N. K. Kund, 2019, CFD modeling on thermal management of IC using water based Fe, Cu and Al nanofluids, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 1666−1670.
28. N. K. Kund, 2019, Numerical simulation and modeling on thermal cooling of fuel cell using water based Al_2O_3, SiC and CuO nanofluids, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 2047−2051.
29. N. K. Kund, 2019, Computational modeling and simulation on thermal management of fuel cell with water based ZnO, TiC and AlN nanofluids, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 2052−2056.
30. N. K. Kund, 2019, Numerical modeling and simulation on fuel cell thermal cooling with water based TiO_2, AlN and CuO nanofluids, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 2272−2276.
31. N. K. Kund, 2019, Computational modeling on thermal control of electronics using water-silicon carbide nanofluid, International Journal of Recent Technology and Engineering, Vol. 8, pp. 644−647.
32. N. K. Kund, 2019, Numerical simulation on influence of nozzle to plate distance for spout impact cooling with water-Al_2O_3 nanofluid, International Journal of Recent Technology and Engineering, Vol. 8, pp. 1290−1293.
33. N. K. Kund, 2019, Numerical modeling on fuel cell cooling using water based aluminum nitride nanofluid, International Journal of Recent Technology and Engineering, Vol. 8, pp. 1294−1297.
34. N. K. Kund, 2019, Numerical simulation on IC cooling with water based TiN, TiC and SiC nanofluids, International Journal of Recent Technology and Engineering, Vol. 8, pp. 1351−1355.
35. N. K. Kund, 2019, Computational simulation on IC cooling using water based ZnO, AlN and Al_2O_3 nanofluids, International Journal of Recent Technology and Engineering, Vol. 8, pp. 2280−2283.

AUTHORS PROFILE

Dr. N. K. Kund completed Ph.D. & M.Tech. in Mechanical Engineering from IISc Bangalore. He completed B.Tech. (Hons) in Mechanical Engineering from IGIT Sarang (An Autonomous Government Technical Institute). He is having many international journal papers, besides, having years of research and teaching involvement. Presently, he serves as Associate Professor in VSSUT Burla (A Government Technical University).