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Experimental Work on Influences of Reynolds Number on Cooling Behaviors with Water Jet Impingement

N. K. Kund

Abstract: ***Vigorous experiments are conducted to investigate on effects of Reynolds number 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), jet 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. However, with the current experimental conditions, Reynolds number of 2400 offers adequate thermal characteristics and is the optimum.***

Index Terms: Reynolds Number, Water Jet, Flat Plate, Thermal, Cooling Behavior.

I. INTRODUCTION

The drift of miniaturization of electronic modules involve very high power fluxes. 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 aforementioned ways and means.

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 Reynolds number on cooling behaviors with striking water jet. With this outlook, the contemporaneous research institutes experimental studies for the influences of Reynolds number (800, 1600, 2400 and 3200) on cooling behaviors of striking water jet over flat plate concerning constant thermal value 6 W/cm^2. Additionally, the witnessed results are evaluated and matched for escalating the prominence of Reynolds number in accomplishing the sought after cooling.

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* 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.

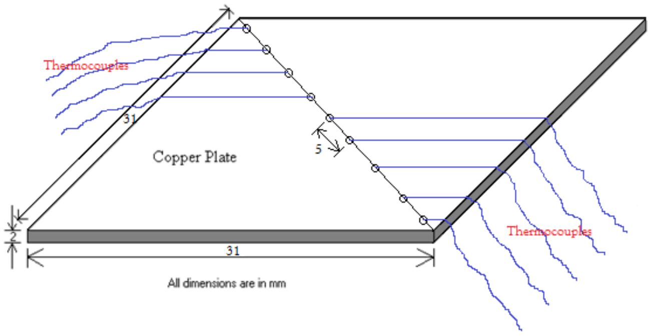

Figure 1. Schematic of physical model

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.

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

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

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

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

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

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.

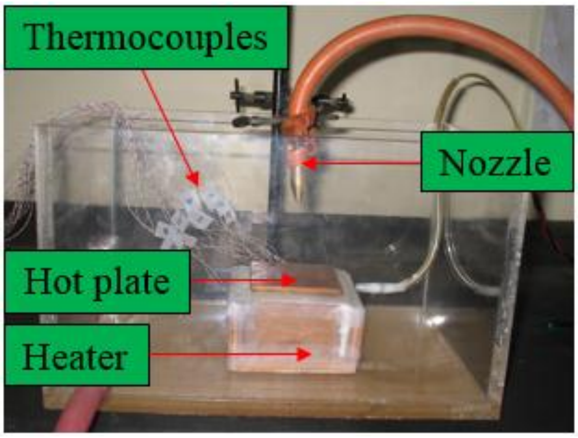

Figure 2. Photograph of experimental setup

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.

Influences of Reynolds Number on Cooling Behaviors

Furthermore, 3 supplementary Reynolds numbers 800, 1600 along with 3200 are picked for comparative appraisal of results as well.

A. Changes in Nusselt Number through Reynolds Number for Varying Nozzle Diameters

Fig. 3 unveils changes in average/stagnation Nusselt numbers with Reynolds number for different nozzle dimensions of 6, 5, 4 & 3 mm. As anticipated, it displays, Nusselt number increases with Reynolds number. Furthermore, Nusselt number declines for increasing nozzle diameter.

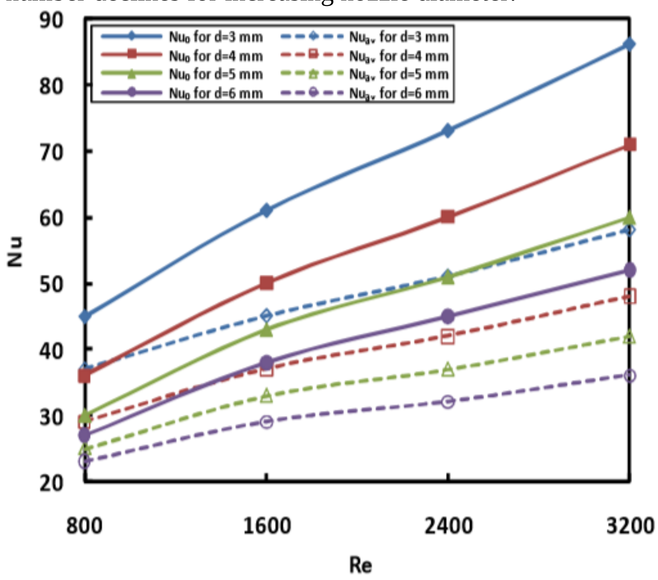

Figure 3. Changes in Nusselt number through Reynolds number for varying nozzle diameters

B. Changes in Nusselt Number through Reynolds Number for Varying Nozzle to Plate Spacings

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

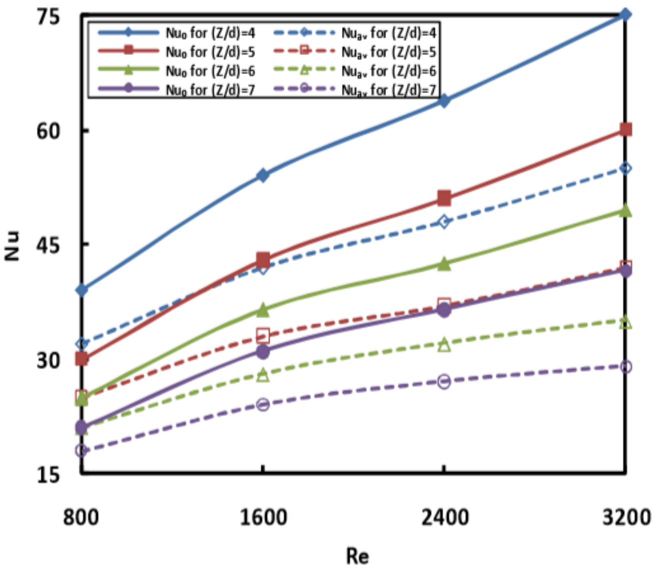

Figure 4. Changes in Nusselt number through Reynolds number for varying nozzle to plate spacings

C. Changes in Nusselt Number through Reynolds Number for Varying Jet Inclinations

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

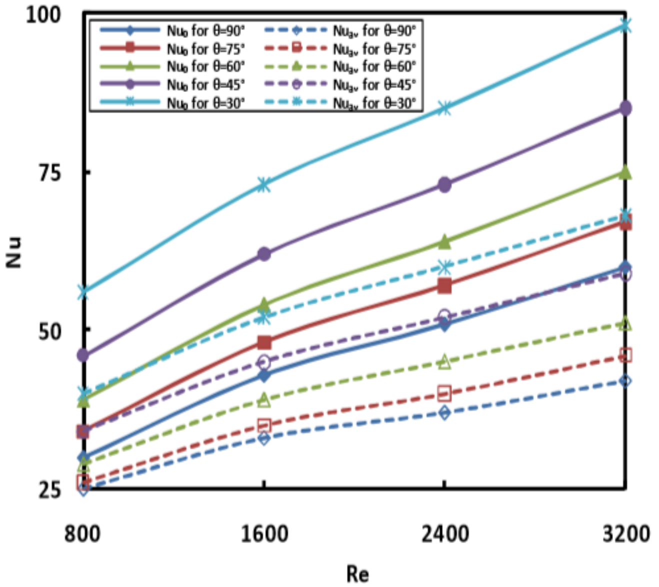

Figure 5. Changes in Nusselt number through Reynolds number for varying jet inclinations

V. CONCLUSION

Ample experiments are done to look at the influences of Reynolds number on thermal dispersal over flat plate concerning constant thermal value 6 W/cm^2. For that four different Reynolds numbers 800, 1600, 2400 and 3200 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 remains very nearly linear. Nevertheless, the jet Reynolds number of 2400 offers temperate and ideal cooling behavior.

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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).