Experimental Studies on Effects of Jet Reynolds Number on Thermal Performances with Striking Water Jets

N. K. Kund

Abstract: trenuous experiments are conducted to investigate the effects of jet Reynolds number on heat dispersal over flat plate concerning constant heat flux of 6.25 W.cm^{-2}. Aimed at that four different jet Reynolds numbers of 800, 1600, 2400 and 3200 are picked, above and beyond, jet flow rate and nozzle diameter of 30 lph and 5 mm, respectively. As anticipated, it is witnessed that the temperature upsurges in radial course. Additionally, the witnessed temperature distribution is axisymmetric. Furthermore, it discloses that the temperature decreases with jet Reynolds number. In addition, the witnessed temperature variation is more or less linear. Similarly, it also unveils that the Nusselt number declines along radial route. The witnessed Nusselt number distribution is axisymmetric on top. Additionally, it also divulges that the Nusselt number upsurges with jet Reynolds number. The witnessed Nusselt number variation is more or less linear as well. However, the jet Reynolds number of 2400 bids medium and ideal cooling performances.

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

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 liquid jet impingement. It engulfs the strain of tall thermal resistance associated with the above-mentioned ways and means.

Equally, the nanofluid cooling is bluntly effervescent as air cooling is weak to convey the strength. Experimental investigation of heat spreading on flat plate is prominent in the texts [1-2]. Computational enumerations as well as simulations are completely amazing in sorts [3-16].

Thoughtful valuation of the aforesaid relatable writings discloses no up-front experimental exploration on thermal characteristics about impacting water jet. No extensive experimental research for the effects of jet Reynolds number on cooling performances with water jet impingement. With this outlook, the contemporaneous research institutes experimental studies for the influences of jet Reynolds number (800, 1600, 2400 and 3200) on heat transfer behaviors with water jet impingement over flat plate concerning uniform heat flux of 6.25 W.cm^{-2}. Additionally, the witnessed results are evaluated and matched for escalating the prominence of jet Reynolds number in accomplishing the sought after cooling.

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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 the diagonal route. Flat plate is fixed to a heater. Thermocouples are connected to data acquisition system for storing temperature data successively during the experiments.

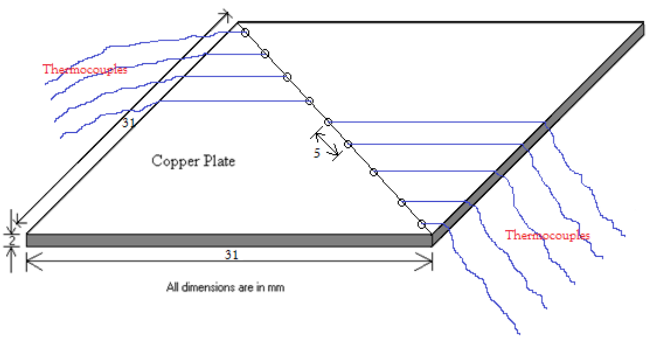

Figure 1. Schematic of physical model

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.

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

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

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

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

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

B. 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 for casing thermocouples connected to data acquisition system. The nozzle is kept perpendicular to flat plate by vertical stand and clamp. Water discharges from outlet of Plexiglas box when impingeing on flat plate.

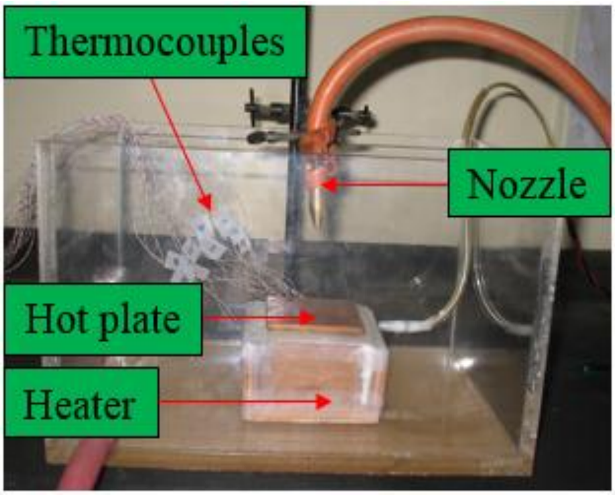

Figure 2. Photograph of experimental setup

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 resistance thermometer. Julabo FH40-MH circulation bath is aimed at current effort. The temperature data are recorded continuously by an interface PC having a data acquisition system. It includes a 40-channel thermocouple plug-in card to observe temperature growth.

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 DISCUSSION

Extensive experiments are consummated to explicate the accouterments of jet Reynolds number on thermal dispersal over flat plate with uniform heat flux of 6.25 W.cm^{-2} (concerning 30 V and 2 A of drive above and beyond plate measurement of 30×30 mm). Primarily picked nozzle size, stream rate and jet Reynolds number are 5 mm, 30 lph as well as 2400, one-to-one.

Influence of Jet Reynolds Number on Cooling Behavior

Furthermore, three more jet Reynolds numbers of 800, 1600 and 3200 are picked for comparative appraisal of results as well.

A. Temperature Variation over Flat Plate for Different Jet Reynolds Numbers

Fig. 3 unveils the comparative temperature distinctions along radial route for various jet Reynolds numbers. As anticipated, it displays that the temperature rises in radial course. Furthermore, the witnessed temperature distribution is axisymmetric.

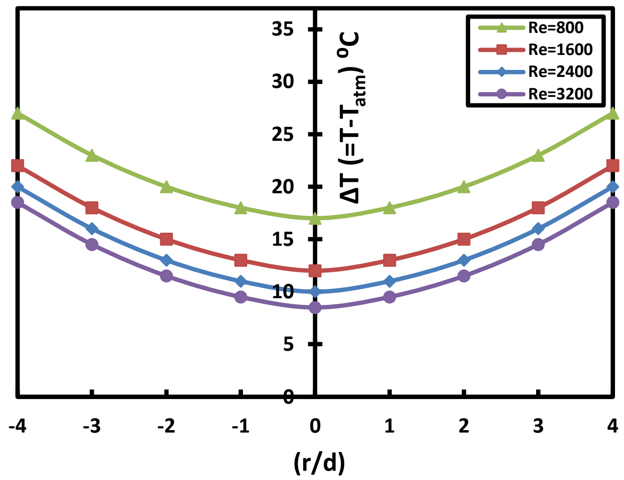

Figure 3. Variation of temperature with radial distance for different jet Reynolds numbers

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Fig. 4 explicates the variation of temperature with jet Reynolds number. As foreseen, it divulges that the temperature decreases with jet Reynolds numbers. Additionally, the witnessed temperature variation is nearly linear.

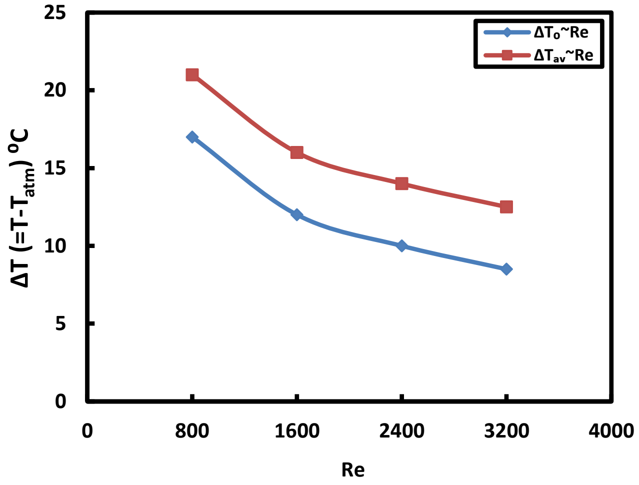

Figure 4. Variation of temperature with jet Reynolds number

B. Nusselt Number Variation over Flat Plate for Different Jet Reynolds Numbers

Fig. 5 displays the Nusselt number deviations in radial course for different jet Reynolds numbers. As anticipated, it reveals that the Nusselt number declines along radial route. Furthermore, the witnessed Nusselt number distribution is axisymmetric on top.

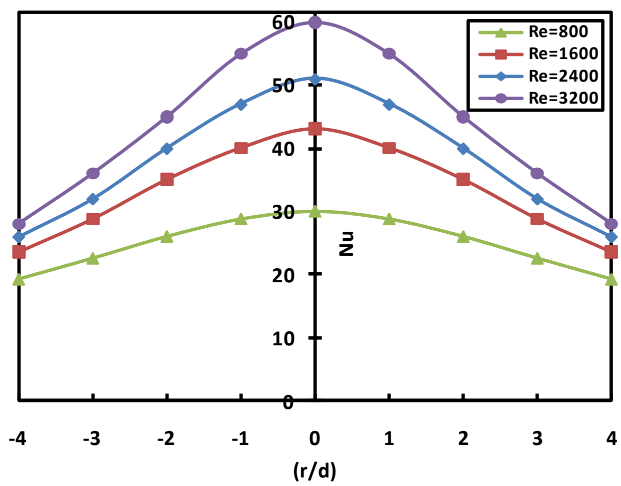

Figure 5. Variation of local Nusselt number with radial distance for different jet Reynolds numbers

Fig. 6 expounds the variation of Nusselt number with jet Reynolds number. As predicted, it discloses that the Nusselt number rises with jet Reynolds number. Additionally, the witnessed Nusselt number variation is more or less linear.

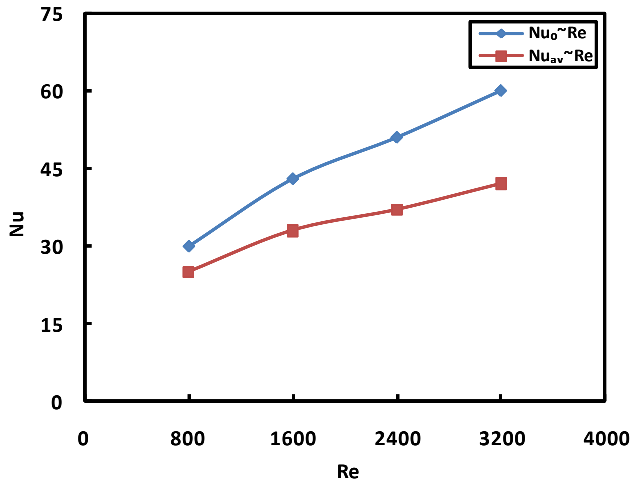

Figure 6. Variation of Nusselt number with jet Reynolds number

V. CONCLUSION

Ample experiments are done to look at the effects of jet Reynolds number on thermal dispersal over flat plate concerning uniform heat flux of 6.25 W.cm^{-2}. For that four different jet Reynolds numbers of 800, 1600, 2400 and 3200 are preferred, above and beyond, jet flow rate and nozzle diameter 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 jet 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 that the Nusselt number rises with jet Reynolds number. The witnessed Nusselt number variation is very nearly linear. Nevertheless, the jet Reynolds number of 2400 offers temperate and ideal cooling behavior.

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Dr. N. K. Kund has completed both M.Tech. & Ph.D. in Mechanical Engineering from Indian Institute of Science Bangalore. Furthermore, he has 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, having years of teaching and research experience. He is currently working as Associate Professor in the Department of Production Engineering, VSS University of Technology Burla (A Government Technical University).