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Experimental Exploration on Influences of Nozzle to Plate Spacing on Cooling Performances using Impinging Water Jets

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Abstract: ***Arduous experimentations remain accomplished for exploring effects of nozzle to plate spacing 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. However, for current experimental settings, nozzle to plate spacing of 25 mm delivers enough thermal credentials and is the exceptionally supreme.***

Index Terms: Nozzle to Plate Spacing, Water Jet, Flat Plate, Thermal, Cooling Behavior.

I. INTRODUCTION

The insinuation of compactness of electronic parts involve remarkably tall 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 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 to plate spacing on cooling behaviors with striking water jet.

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With this outlook, the contemporaneous research institutes experimental studies for the influences of nozzle to plate spacing (35, 30, 25 and 20 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.

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 31×2×31 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.

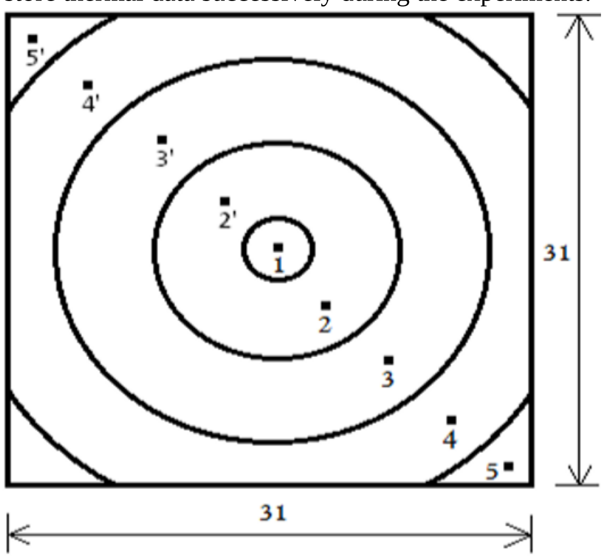

Figure 1. Schematic of physical model divided into annuli

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.

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

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

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

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

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

B. 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.

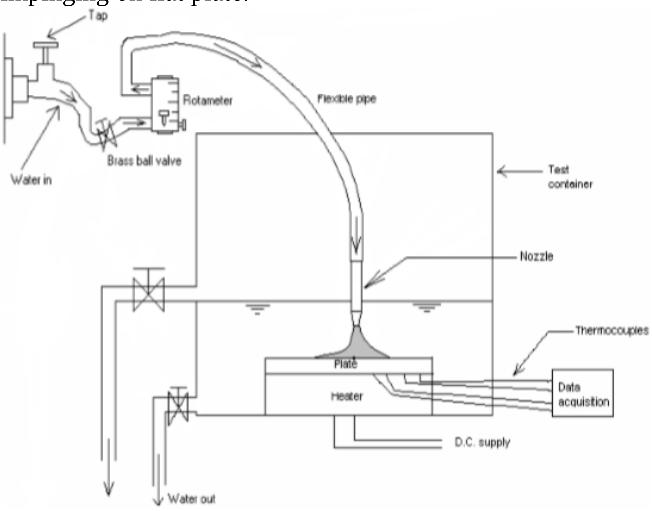

Figure 2. Schematic of experimental setup

III. EXPERIMENTAL TECHNIQUES

It embroils the measurements of below mentioned 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 Nozzle to Plate Spacing on Cooling Behaviors

Furthermore, 4 additional nozzle to plate spacings 35, 30, 25 and 20 mm are picked for comparative appraisal of results as well.

A. Changes in Nusselt Number with Nozzle to Plate Spacing for Varying Reynolds Numbers

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

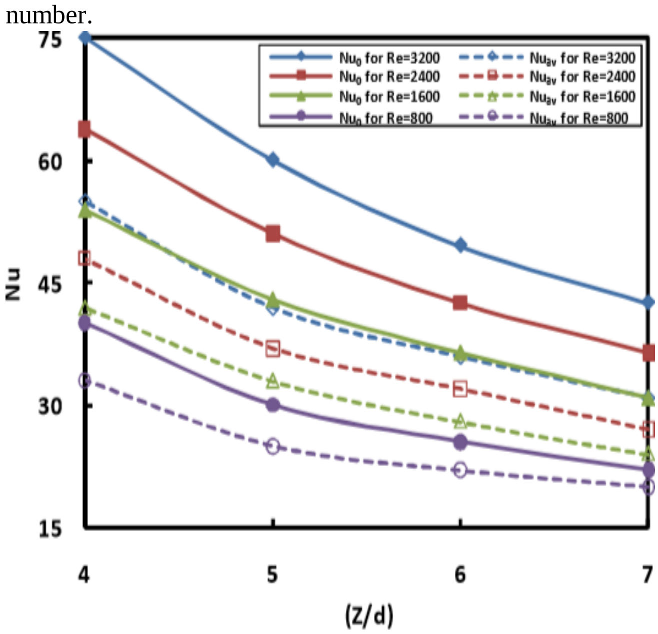

Figure 3. Changes in Nusselt number with nozzle to plate spacing for varying Reynolds numbers

B. Changes in Nusselt Number with Nozzle to Plate Spacing for Varying Nozzle Diameters

Fig. 4 unveils changes in average/stagnation Nusselt numbers with nozzle to plate spacing for different nozzle diameters of 6, 5, 4 and 3 mm. As anticipated, it displays, Nusselt number declines for increasing nozzle to plate spacing. Furthermore, Nusselt number declines for increasing nozzle diameter.

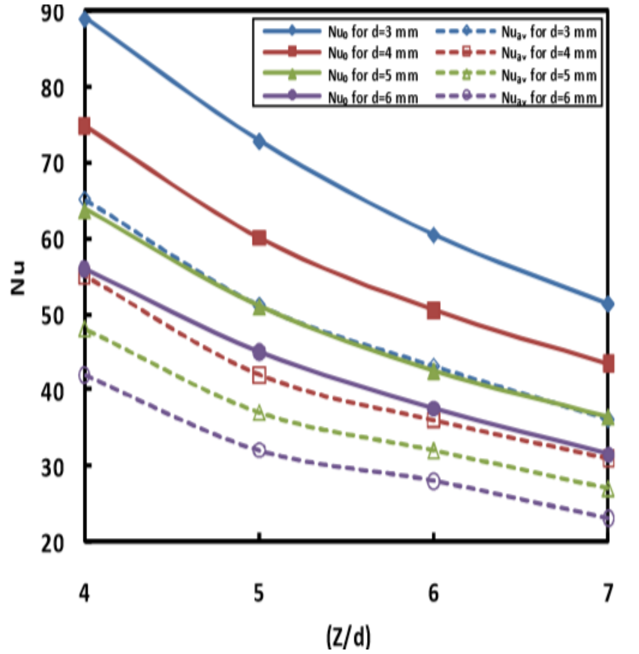

Figure 4. Changes in Nusselt number with nozzle to plate spacing for varying nozzle diameters

C. Changes in Nusselt Number with Nozzle to Plate Spacing for Varying Jet Inclinations

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

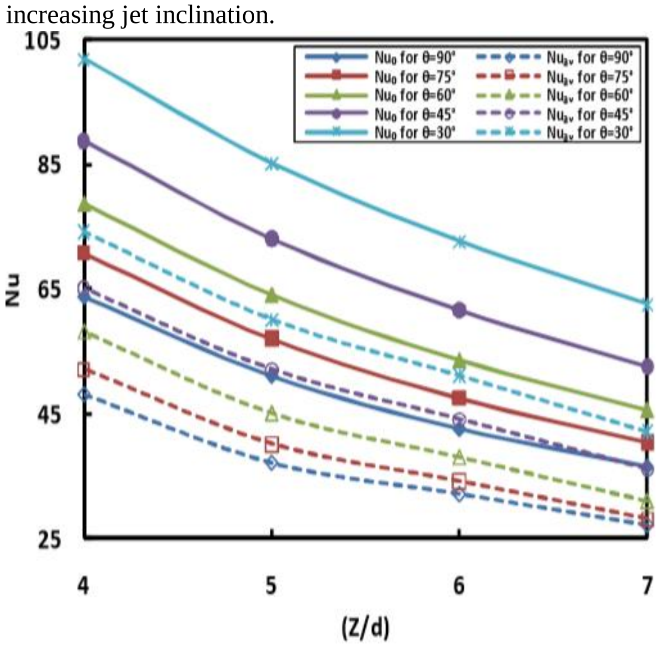

Figure 5. Changes in Nusselt number with nozzle to plate spacing for varying jet inclinations

V. CONCLUSION

Necessary experiments stand equipped for exploring the influences of nozzle to plate spacing on thermal dispersal over flat plate concerning constant thermal value 6 W/cm^2. For that four different nozzle to plate spacings 35, 30, 25 and 20 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 to plate spacing of 25 mm provides agreeable and decisive thermal behaviors.

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