Experimental Investigation of Twin Water Jet Impingement on Flat Surface

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Abstract: Hydraulic jumps are a sudden drop in water level caused by a decrease in speed while flowing over a surface or channel. The hydraulic jump is the most inexplicable flow phenomenon in nature and has attracted the attention of various researches over the last many years. In this study, attempts were made to analyze the effect of twin water jets impinging on flat surfaces, which may have different flow rates on the hydraulic jump profile. The flow field caused by twin jets is different from the flow field associated with a single jet. Depending on the relative position of the jets and their relative strength, different types of hydraulic jump profiles can be determined. The area of the circular hydraulic jump strongly depends on the adjacent hydraulic jump and leads to the upwash fountain flow.

***Keywords* – Hydraulic jump, jet impingement, twin jet.**

I. Introduction

Hydraulic vertical jumps can be easily observed in kitchen and bathroom sinks when vertical water flows against horizontal surfaces. When a vertical jet impinges on a horizontal plate, it first diffuses racially into a thin layer. However, at a certain distance from the jet, the height of the liquid suddenly jumps to a higher value [1]. The location of this jump depends primarily on the water flow rate of the faucet. Examples of hydraulic jumps can be seen downstream of the hydraulic structure, such as spillways, gates, and venturi sinks. twin impingement jets have been widely used in practice, such as (a) obtaining uniform cooling, and (b) coating purposes for use in the coatings industry. , (c) concentrated solution by evaporation, [2]

Hydraulic jumping is a phenomenon in hydraulic science that is often observed in open channels such as rivers and spillways. When the high velocity liquid is discharged to a lower velocity region, the liquid surface undergoes a rather abrupt rise. [1] Typically, hydraulic jumping is a region of rapidly changing hydrodynamic properties that connects supercritical and subcritical free surfaces or interfacial flows. Hydraulic jumping is a typical feature of rivers, rivers, natural flows in the ocean, and the spread of impinging jets. The fast flowing liquid suddenly slows down and increases in height, converting some of the initial kinetic energy of the flow into an increase in potential energy, some of which irreversibly loses heat through turbulence. Hydraulic jumps quickly convert the energy of the flow into potential energy.

In the open channel, when the fast flowing flow suddenly becomes a slow flowing flow, the height of the liquid surface rises or jumps significantly, this is called hydraulic jumping. [1] The hydraulic jump is caused by a sudden drop in water level due to a decrease in speed. In running water, the water before jumping moves much faster than the water after jumping. When the speed of the water drops to a critical flow rate, a jump occurs. Above this speed, the water moves too fast and does not allow gravity waves to move upstream. At the point where the water reaches the critical flow rate, the gravity wave cannot move upstream and accumulates at the jump, forming a sudden increase in the water level, called a hydraulic jump. [3] This phenomenon depends on the initial fluid velocity. If the initial velocity of the fluid is below the critical speed, it is impossible to jump. For an initial flow rate that is not significantly above the critical speed, the transition appears as an undulating wave. As the initial flow rate increases further, the transition becomes more abrupt, until a sufficiently high speed, the transition leading edge will break and curl itself. When this happens, the jump can be accompanied by severe turbulence, eddy currents, entrained air, surface undulations or waves. Kate et al. (2007) experimentally studied different cases of inclined and twin jet, the jump-jump interactions formed in this case, the different jet spacing values and the different intensities of the individual jets. A similar flow field associated with the interaction between a single impinging jet and a fence was also investigated to allow for convenient experimental flow visualization [5, 6 and 8].

The flow field caused by the two normally impinging liquid jets is different from the flow field associated with a single normal impinging liquid jet [7], even different from the flow field surrounding the two normally impinging compressible fluid jets. Depending on the spacing between the twin liquid jets and their relative strength, different types of hydraulic jump interactions can be performed to create various flow patterns.

II. Experimental Facility

2.1 Constructional Details

A schematic diagram of the experimental setup is shown in fig. 1 The setup consists of closed-loop water jet system. The experimental setup implemented with the suitable instrument, to control and measure the different variable affecting the phenomena. A centrifugal pump is used for delivering water in the form of a jet at the required flow rate. The flow rate is measured using two flowmeters (0-10 lpm). The flowmeter is connected to a nozzle arrangement through the piping. Circular tubes of copper and aluminum with internal diameter of 5 mm, 6 mm, 8 mm, 10 mm are used as nozzles. These tubes have length to diameter ratio of 50–120, so as to ensure a fully developed flow condition at the exit. The jet issuing from the nozzle is made to fall on a square glass plate of dimension 600 mm × 600 mm, and a thickness of 10 mm, mounted on four leveling screws.

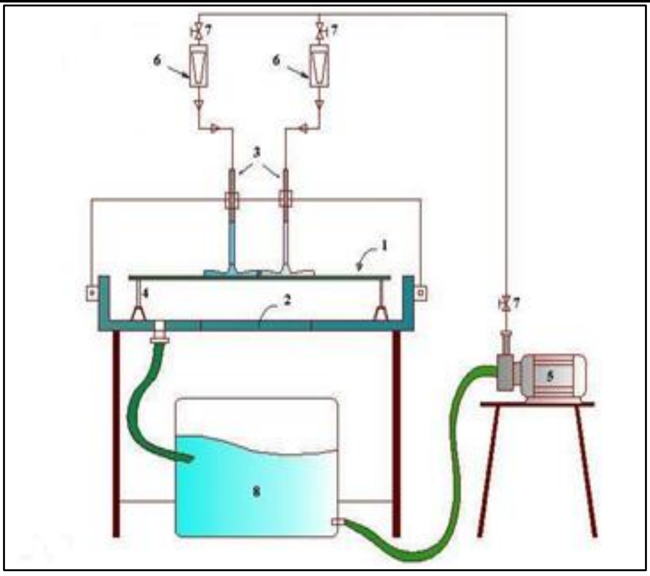


Fig. 1: The Schematic view of Experimental setup for multiple hydraulic jumps on a stationary plate. (1 – glass plate, 2 - water collecting tray, 3 - nozzle, 4 - leveling screw, 5 -centrifugal pump, 6 - flowmeter, 7 - flow control valves, and 8 - storage tank)

2.2 Experimental Procedure

Water is used as a working medium in the experiment. The tray not only contains the water but also acts as a reservoir as shown in fig. 1. Open the outlet valve of the tray and switch on the pump. Thus pump sucks the water from the tank through flexible pipe connected to the inlet of the pump. The outlet of the pump divided into two parts, discharges water as per requirement to flowmeter through flow control valves, and excess water through the bypass pipe. Nozzles made up of stainless steel of diameter 5mm, 6mm, 8mm and 10mm are used. To ensure fully developed flow at outlet of nozzle length of nozzle is selected as 1:100 to 1: 150 diameters to length ratio. Jet of water hits the transparent glass plate. Graph paper is pasted on bottom side of glass plate for note down radius of hydraulic jump on its upstream flow. Twin jet hydraulic jump interaction is traced on graph paper from lower side of glass plate. Location of each nozzle can be adjusted separately by using special arrangement in 3D ways.

2.3 Observations

Though very high heat transfer rates can be achieved in the vicinity of the stagnation point (or impingement point region) with a single jet impingement cooling, the heat transfer rate decreases sharply as the distance from the stagnation point increases. As a result, the net heat flux distribution is highly non-uniform around the stagnation point. To overcome this limitation, in many industrial applications, multiple impinging jets are used.

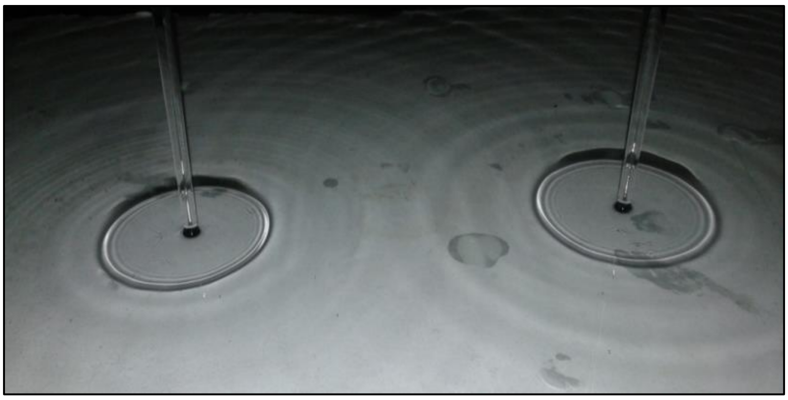
From our flow visualization experiments, it has been observed that the flow field due to multiple impinging jets, for a given volume flow rate of liquid, mainly depends on the spacing (S) between the twin jets and strength of jet. When twin jets are spaced at too large distance, the radial symmetry of the circular hydraulic jump remains unaffected, indicating no perceptible interaction between the hydraulic jumps, as can be seen in fig. 2 Below an inter-jet critical spacing (Sc), the hydraulic jumps of individual jets start interacting with each other, disturbing of the radial symmetry of the individual jump profiles [5]. This critical spacing (Sc) is observed to be a function of the volume flow rate of liquid (Q) through each jet, as evident from fig. 2, In general, the system of multiple impinging jets can be broadly grouped into two categories: (a) Distant impinging jets, and (b) Adjacent impinging jets.

III. Twin Impinging Liquid Jets

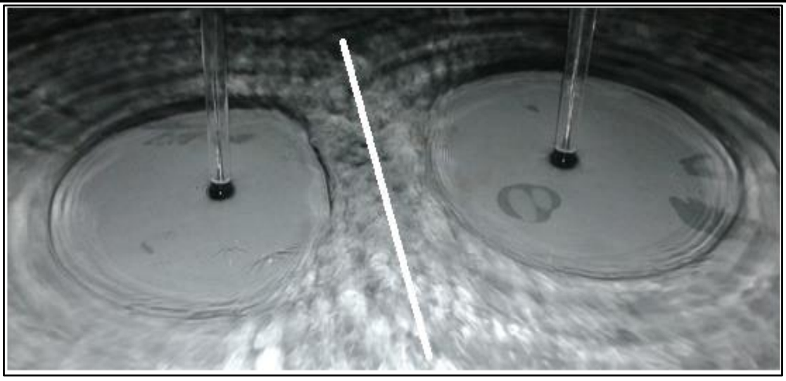
Depending on the spacing between the water jet and its relative strength, various flow patterns can be obtained.

3.1 Far distant and distant impinging jets:

Two far-distant impinging jets are depicted in fig. 2 (a). The circular hydraulic jump profiles remain more or less intact in such cases.



(a)



(b)

Fig. 2: (a) Two far-distant impinging jets indicating no jump interactions. (b) Two jets spaced at a critical distance, volume flow rate Q = 2 lpm, S = 75 mm, H = 50 mm, and d = 6 mm, Interaction is visible at the stagnation line.

However, for distant impinging jets, a region of stagnation line is clearly visible, as can be seen in fig. 2(b). In such cases, the hydraulic jumps interact to form thick films. Theses interactions are relatively weak and do not have significant effects on the radial symmetry of the circular hydraulic jumps.

- Effect of number of jets on jump area:

An experiment was performed to check the effect of area of jets on for different flow rates and is shown in fig. 3. For performing the experiment we use nozzle diameter ranging from 6 mm diameter, spacing between two jets is 75 mm and drop height is 75 mm.

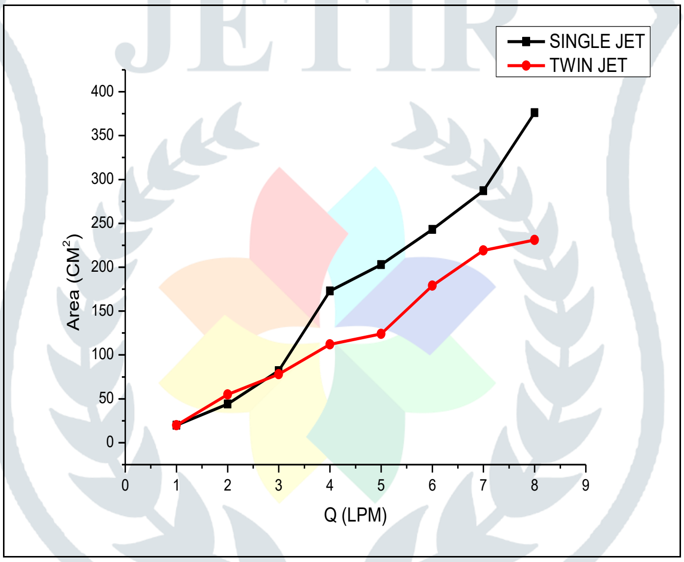
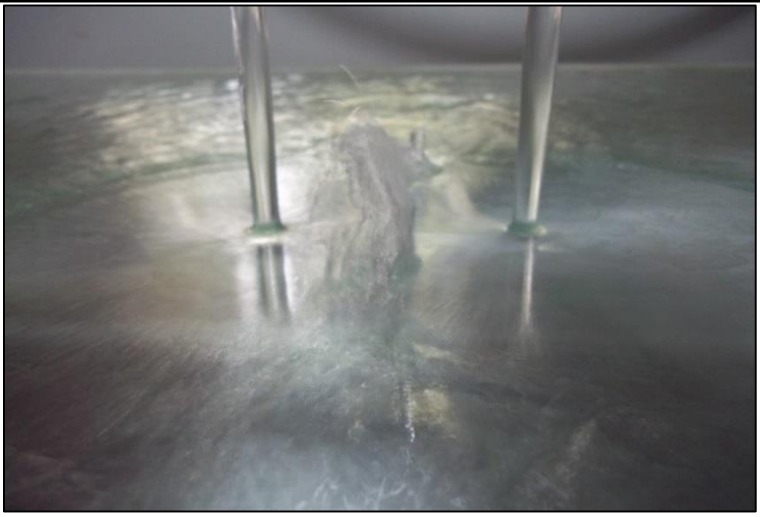


Fig. 3: Effect of number of jets on area of twin jet.

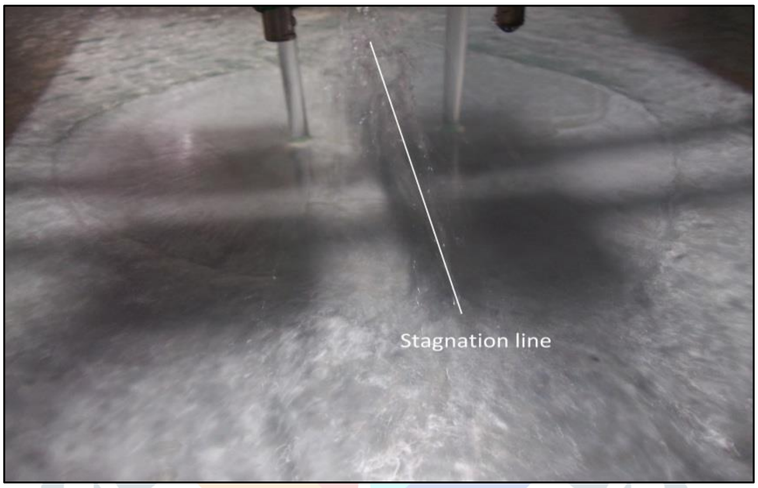
It was noticed that as increases the volume flow rate, radius of hydraulic jump also increases gradually. It was also noticed that the radius of hydraulic jump is increases with increase in flow rate. While during experimentation, transitions of hydraulic jump from circular to non-circular were observed above certain flow rate. Since radius of hydraulic jump is a function of volume flow rate only. From that we have to calculate area of two jets separately and comparing with each other, we found that as increases the volume flow rate (Q), area of jet also increases gradually.

3.2 Adjacent impinging jets:

The upwash liquid fountain has the shape of an arch or an approximate segment of a circle formed on a chord which coincides with the stagnation line as shown in fig. 4, 5 and 6. The maximum height of this arch lies on the point where line joining the center of the jet intersects the stagnation line. The vertical liquid sheet is considerably thicker for higher values of spacing, and to be thinner with progressive decreases in spacing.



(a)



(b)

Fig. 4: (a) Beginning of upwash formation (b) upwash fountain flow.

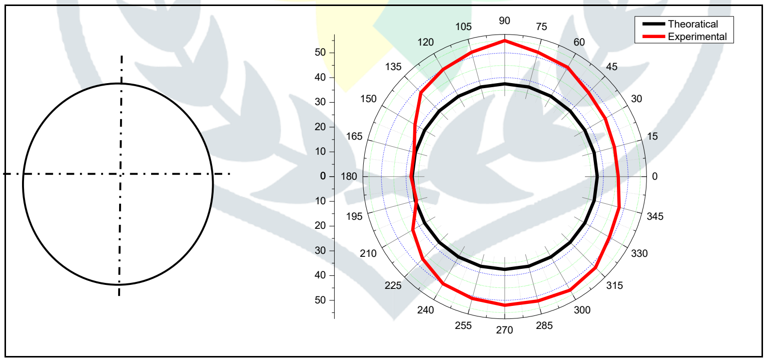


Fig. 5: Radial plot for jump due to two impinging jet when (Q=3 lpm, spacing S=75 mm, dia. of nozzle = 6mm)

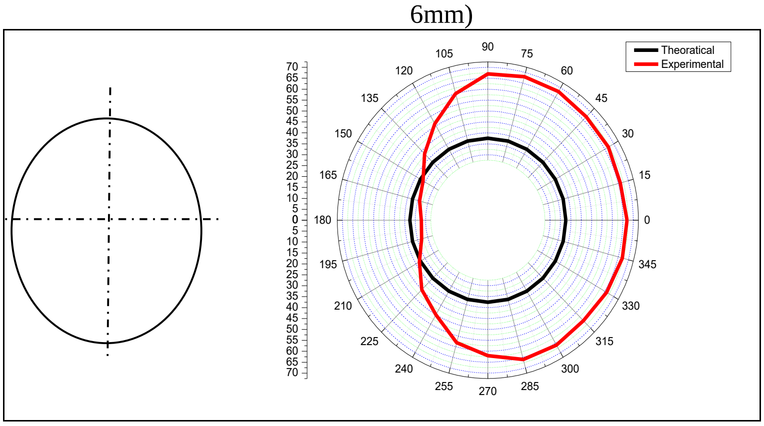


Fig 6: Radial plot for jump due to two impinging jet when (Q=4 lpm, spacing S=75 mm, dia. of nozzle=6mm)

IV. CONCLUSION

The flow pattern due to two normal jets of collision is characterized by hydraulic jumping interactions on the stagnation line. Depending on the types of the two jets, various hydraulic jumping interactions are possible. The flow pattern due to more than one water jet is characterized not only by abrupt interactions along the stagnation line, but also by the stagnation line interactions leading to the appearance of an additional dome-shaped flow area, called the stagnation zone. This stagnation zone is formed by using more than one falling jet. This complex region of flow is characterized by a maximum film thickness at the point of intersection of the stagnation lines. Area of hydraulic jump is less for twin jet than single jet for same liquid flow rate.

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