Indian Institute of Technology Gandhinagar

Measurement of force due to Jet Impingement

ME 351: Mechanical Engineering Lab-I

Experiment Report

AUTHORS

Anutosh Jaishwal 20110020

Harshil Safi 20110073

Krish Raj 20110160

Shail Prajapati 20110188

Suhani Mittal 20110204

Under The Guidance Of:

Prof. Uddipta Ghosh

Prof. Jaichander Swaminathan

NOMENCLATURE:

Q = actual discharge in m^3/s
ρ = density of water, kg/m^3
v = volume of water in collecting tank, m^3
R = rise of water level in measuring tank, cm
t = time for R, sec
A = area of cross section of nozzle in m^2

Diameter of nozzle = 10 mm = 0.01 m
Area of cross section nozzle, $A = \pi \frac{d^2}{4} = 7.85 * 10^{-5}\ m^2$
Density of water at ambient conditions = 1000 kg/m^3

Formula used

$F_{th} = \rho * A * V^2$
$V = \frac{Q}{A}$
$\rho =$ specific weight of water, where A is inlet area.
$F_{th} = \rho * A * \frac{Q^2}{A^2}$
$F_{th} = \rho * \frac{Q^2}{A}$
F_{act} = (weight of pan + weight on pan) * 981
% error = $\frac{F_{act} - F_{th}}{F_{th}} * 100$

According to the last point, the hemispherical cup is more efficient for using in a turbine than the flat plat.

Objectives:

- This experiment aims to:
- Determine the force produced by a water jet when it strikes a flat vane and a hemispherical cup.
- By adjusting a balancing weight, study the force a liquid jet impinging on a surface generates.
- Observe the variations in the force for different jet speeds.

- Compare the results measured with the theoretical values calculated from the force in the jet.
- Interpret the results using the Reynolds transport theorem.

The Essential background:

1. Why are liquid jets important? Briefly discuss any 3 applications of liquid jets.

We frequently see liquid jets in our day-to-day lives. A liquid jet that is projected or released from a nozzle has a velocity, which means it contains kinetic energy. Additionally, the liquid jet exerts a force consistent with the conservation of linear momentum when colliding with any surface. Long-distance liquid jets are also capable of doing so without losing energy. These characteristics of liquid jets make it extremely valuable and significant.

- Electricity production is one of the uses for jet impact. The generator's Pelton wheel, or turbine, is rotated by the impact of the jet. The wheel is being forced tangentially by the water jet. The maximal moment or torque is produced on the wheel by the tangential forces of the water jet, which also increases the mechanical energy of the Pelton wheel. Then, the wheel's rotational energy is transformed into electrical energy.
- Vaccine/syringe
- Water jet cutting

2. Read up on the Reynolds transport theorem (RTT). How is momentum conservation expressed in this theorem?

According to the Reynolds transport theorem, the rate of change of an extensive property of a system concerning time is equal to the product of the property's efflux rate and the rate at which the property changes per unit of time for a control volume.

The Reynolds transport theorem is a key concept that aids in the derivation of conservation laws, including the conservation of mass, momentum, linear momentum, etc.

For the linear momentum,

B = m$\vec{V}$ and $b = \frac{B}{m} = \frac{m\vec{V}}{m} = \vec{V}$

Now put these values in the Reynolds transport theorem,

$$\frac{d}{dt}\left[m\vec{V}\right]_{System} = \frac{\partial}{\partial t}\iiint_{CV}\rho\vec{V}d\forall + \iint_{CS}\rho\vec{V}\left(\vec{V}.\hat{n}\right).dA$$

As per the Newtons second law,

$$\frac{d}{dt}\left[m.\vec{V}\right] = m.a = F$$

Therefore the equation becomes,

$$\frac{\partial}{\partial t}\int\int\int_{CV} \rho V d\forall + \int\int_{CV} \rho V\left(V \cdot \hat{n}\right) \cdot dA = F$$

3. The force exerted by a liquid jet impinging on a flat surface.

The momentum equation can be used to determine the force a jet of fluid exerts on a flat or curved surface. So according to the Reynolds Transport Theorem, we get to the final equation to calculate force as below:

$$F = \rho V^2 A$$

$$\Rightarrow F = \frac{\rho Q^2}{A}$$

Experimental setup:

1. Schematic:

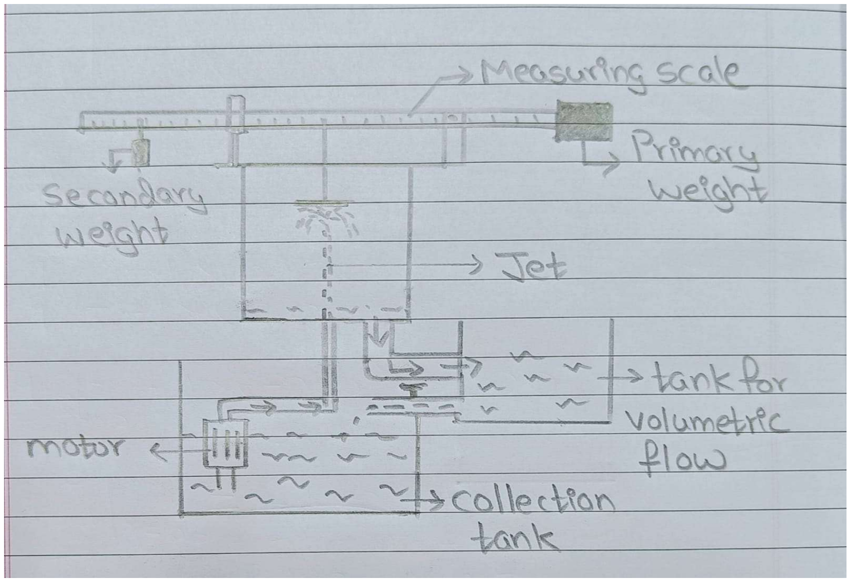

Figure 1: Schematic diagram of the apparatus

2. Experimental Procedure

Figure 2 : Complete Experimental Setup

This experiment is performed to find the hydraulic force of water. The exploratory arrangement fundamentally comprises a nozzle through which a water fly arises upward so that it might be advantageously seen through the straightforward sheet. It strikes the objective vane situated above it. The power applied on the vane by the fly can be estimated by applying loads to balance as a response force for the effect of the fly. Vanes are exchangeable, for example, level plate and hemispherical.

The plan is made for the development of the plate under the activity of the fly and because of the weight put on the stacking container. A scale is accommodated, conveying the vanes to their unique position, for example, before the fly strikes the vane. The arrangement is associated with Hydraulic Bench with an adaptable line.

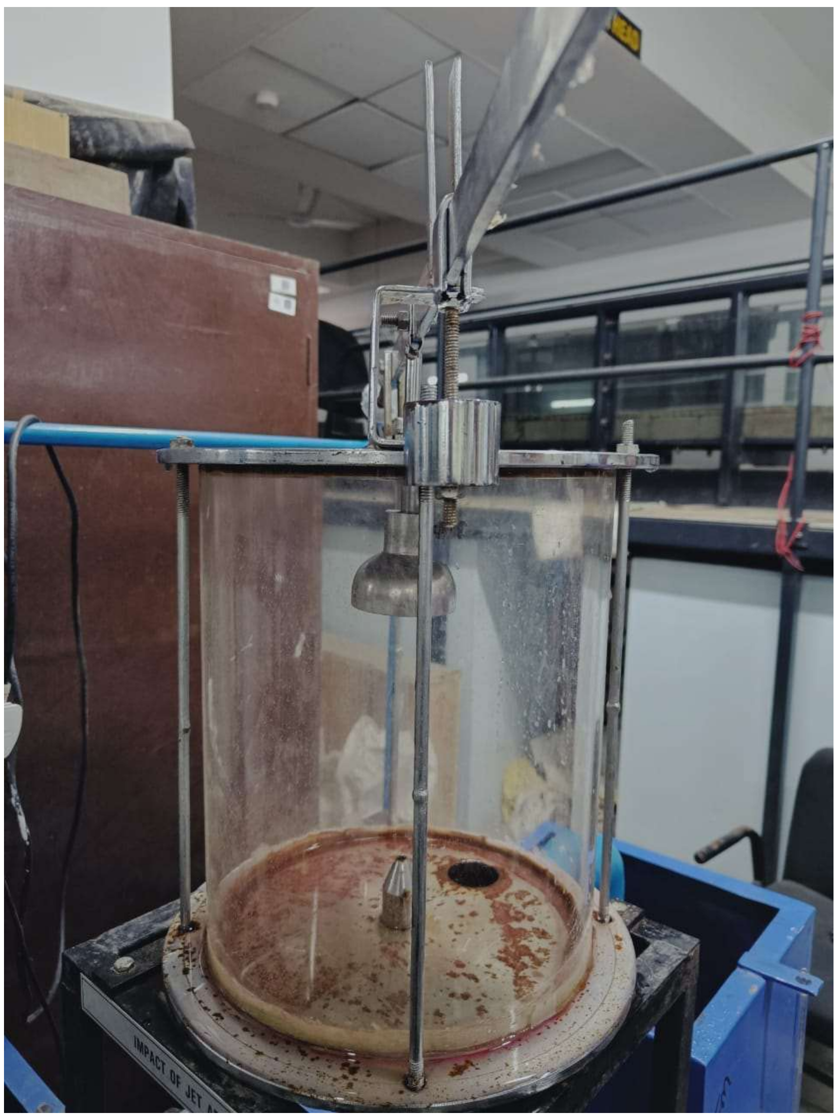

Figure 3 : Cylindrical Chamber

Liquid jet force measurement: The valve is opened to apply a constant force when the liquid jet from the nozzle impacts the vane. In order to balance the moment caused by the liquid jet, the primary weight's distance is changed.
Measuring the Flow rate
The secondary tank is filled with water from the nozzle after it has struck the vane.
This secondary tank's outflow is sealed, and the water level and time needed to reach it are computed.

(a) Measure the balancing weight and its position for different flow rates. From this calculate the force exerted on the vane by the liquid jet.

Flat plane vane
Mass = 220 g

Weight (g)	R1 (cm)	R2 (cm)	Actual Force F1
150	37.5	25	3.882136364
150	37.5	25	3.882136364
150	38.5	25	3.948954545

Weight (g)	R1 (cm)	R2 (cm)	Actual Force F1
250	38.5	25	5.663954545
250	38.7	25	5.686227273
250	38.4	25	5.652818182

Weight (g)	R1 (cm)	R2 (cm)	Actual Force F1
150	41.2	25	4.129363636
150	41.0	25	4.116
150	41.4	25	4.142727273

Hemispherical vane

Mass = 320 g

Weight (g)	R1 (cm)	R2 (cm)	Actual Force F1
150g	42	25	5.162818182
150g	41.8	25	5.149454545
150g	42	25	5.162818182

Weight (g)	R1 (cm)	R2 (cm)	Actual Force F1
180g	39	25	5.483545455
180g	38.7	25	5.459490909
180g	38.6	25	5.451472727

Calculations for Volumetric Flow Rate:

For Flat Plate Vane:

S. No.	Weight	l*b	h	t	Q	Avg. Q
1	150g	0.0885	0.02	11.29	0.0001567759079	0.0001677795614
		0.0885	0.02	10.75	0.0001646511628	
		0.0885	0.02	9.73	0.0001819116136	
2	250g	0.0885	0.02	5.9	0.0003	0.0003024871595
		0.0885	0.02	5.95	0.0002974789916	
		0.0885	0.02	5.71	0.0003099824869	
3	150g	0.0885	0.02	5.39	0.0003283858998	0.0003287958527
		0.0885	0.02	5.36	0.0003302238806	
		0.0885	0.02	5.4	0.0003277777778	

For Hemispherical Vane:

S. No.	Weight	l*b	h	t	Q	Avg. Q
1	150g	0.0885	0.02	5.5	0.0003218181818	0.0003214542041
		0.0885	0.02	5.45	0.0003247706422	
		0.0885	0.02	5.57	0.0003177737882	
2	180g	0.0885	0.02	5.56	0.0003183453237	0.0003194973608
		0.0885	0.02	5.54	0.0003194945848	
		0.0885	0.02	5.52	0.0003206521739	

(b) Compute the theoretical force using the RTT. Compare the measured force and the theoretically calculated force. Report experimental uncertainties and quantify errors by running the experiments multiple times.

S. No.	W (kg)	Actual Force F1 (N)	Actual discharge Q	Theoretical Force F2 (N)	Deviation from theory (%)
1	0.15	3.904409091	0.0001677795614	0.358598487	988.7968669
2	0.25	5.667666667	0.0003024871595	1.165585754	386.2505096
3	0.15	4.129363636	0.0003287958527	1.377155577	199.8472871

S. No.	W (kg)	Actual Force F1 (N)	Actual discharge Q	Theoretical Force F2 (N)	Standard Deviation (%)
1	0.15	5.158363636	0.0003214542041	2.632682938	95.93561999
2	0.18	5.464836364	0.0003194973608	2.600727734	110.1271998

(c) Reasons for Mismatches:

- Errors in taking the reading.
- Losses in the experimental apparatus.
- Outflow of water falling directly on the pump.
- Irregularities in the pump, pressure not constant.

Conclusion:

As the volumetric flow rate increases, the force that resulted from the impact of the jet on the flare and the hemispherical cup increases for the predicted F1 and the measured F2 values of the force. This relation can be seen clearly from the four plots accompanied by this report. The liquid comes out in the form of a jet from the outlet of a nozzle, which is fitted to a pipe through which the liquid is flowing under pressure

Some measured values of the Jet force showed **larger** values than the predicted one.