Experiment - 3
Force due to Jet impact

Arka Pramanick, AE21B007
Department of Aerospace Engineering
IIT Madras

Instructor:
Professor Dr. R. Sriram

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1. Aim :

To calculate reaction forces due to change in momentum of a fluid flow as jet of water strikes the plate.

2. Apparatus :

Required apparatus for performing this experiment are:

- Plates of different angles(90°, 120° and 180°)
- Weights
- Stopwatch
- Jet Apparatus(Having nozzle of diameter 0.008m)

3. Theory :

Volume flow rate(Q) =

$$Q = Au \tag{1}$$

Au
Mass flow rate =

$$Q_m = \rho Au \tag{2}$$

Applying conservation of momentum in figure :
X axis : Net momentum = 0
$Yaxis$: Outflux = -$Q_m u$ $(\sin\theta)$ Influx = $Q_m u$
Rate of change in momentum = -$Q_m u \sin\theta$- $Q_m u$ = $-Q_m u(1+\sin\theta)$

Using equation(1) :

$$F_y = \rho A u^2 (1 + \sin\theta) \tag{3}$$

ρ : Density of fluid.
A : Cross section area of the nozzle.
u : Velocity of water leaving nozzle.
$\theta = \alpha - \frac{\pi}{2}$; α is the deflection angle.

4. Procedure :

1. Mass of fixed mass is first placed on a weight pan.
2. It is checked whether the datum line is on weight panel is on the same level of gauge.
3. Valve is opened slowly and stopwatch is started.
4. Flow rate is measured by stopping timer after measuring time it take to accumulate a particular volume of water.
5. Process is repeated on adding additional mass.
6. Whole test is repeated for three different deflection angle.

5. Observation :

5.1 Force due to jet impact on a deflector of turn angle 120°

Test No.	Angle deflector = 120°							
	Mass(g)	Weight(N)	Volume(L)	Time(s)	Q($\times 10^{-3}$)	Velocity(u)	u^2	Force(N)
1	50	0.49	3	21.5	0.140	2.776	7.706	0.583
2	100	0.98	3	16	0.188	3.730	13.914	1.052
3	150	1.47	3	12.92	0.232	4.619	21.339	1.607
4	200	1.96	4	16.37	0.244	4.854	23.564	1.678
5	250	2.45	4	15.035	0.266	5.292	28.004	2.112
6	300	2.94	4	13.14	0.304	6.056	36.677	2.762
7	350	3.43	4	12.295	0.325	6.466	41.805	3.152
8	400	3.92	4	10.665	0.375	7.460	55.657	4.196

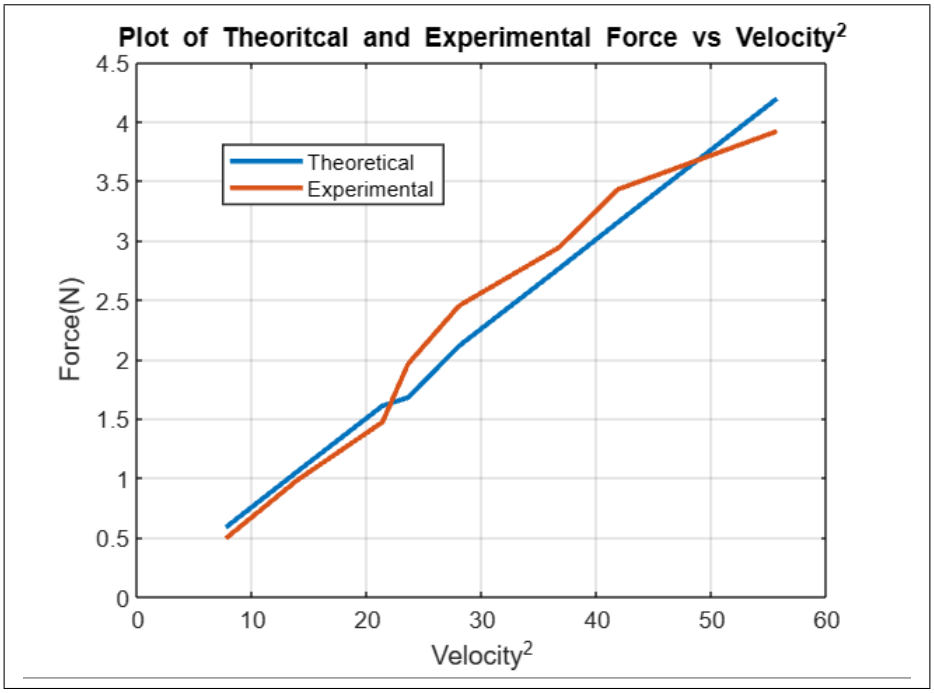

Figure 1: Theoretical and Experimental Pressure vs $Velocity^2$ for Angle delector = 90°

5.2 Force due to jet impact on a deflector of turn angle 90°

Test No.	Angle deflector = 90°							
	Mass(g)	Weight(N)	Volume(L)	Time(s)	Q($\times 10^{-3}$)	Velocity(u)	u^2	Force(N)
1	50	0.49	1	6.38	0.157	2.785	7.757	0.437
2	100	0.98	1	4.59	0.218	4.334	18.786	0.945
3	150	1.47	1	3.56	0.280	5.570	31.030	1.560
4	200	1.96	1	3.25	0.308	6.121	37.471	1.885
5	250	2.45	6	17.46	0.344	6.837	46.738	2.352
6	300	2.94	6	15.95	0.376	7.480	55.955	2.812
7	350	3.43	6	14.57	0.412	8.193	67.119	3.376
8	400	3.92	6	13.88	0.432	8.600	73.958	3.715

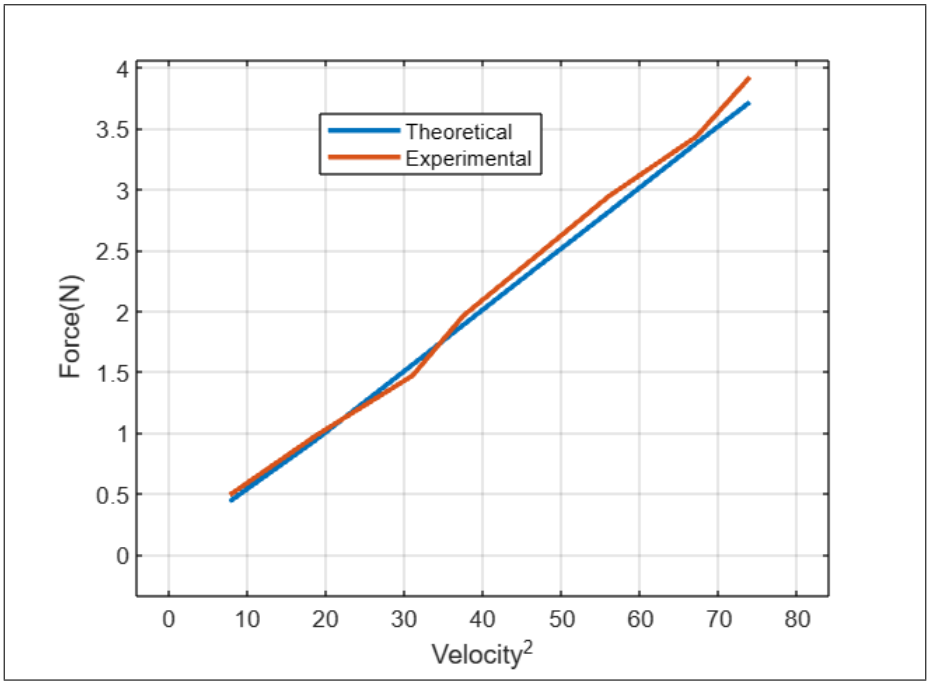

Figure 2: Theoretical and Experimental Pressure vs $Velocity^2$ for Angle delector = 90°

5.3 Force due to jet impact on a deflector of turn angle 180°

Test No.	Angle deflector = 180°							
	Mass(g)	Weight(N)	Volume(L)	Time(s)	Q($\times 10^{-3}$)	Velocity(u)	u^2	Force(N)
1	50	0.49	3	25.47	0.118	2.348	5.513	0.554
2	100	0.98	3	18.33	0.164	3.263	10.645	1.070
3	150	1.47	4	18.57	0.215	4.277	18.295	1.839
4	200	1.96	5	20.56	0.243	4.834	23.370	2.349
5	250	2.45	5	18.69	0.268	5.322	28.326	2.853
6	300	2.94	3	11.01	0.272	5.411	29.282	2.944
7	350	3.43	3	10.69	0.281	5.583	31.171	3.138
8	400	3.92	3	9.93	0.302	6.010	36.125	3.630

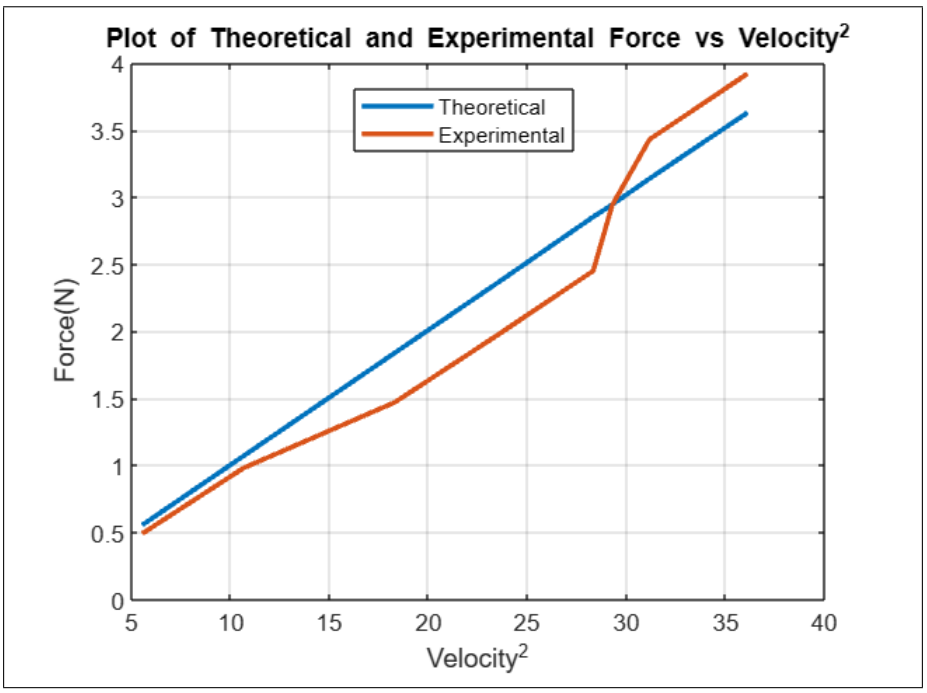

Figure 3: Theoretical and Experimental Pressure vs $Velocity^2$ for Angle delector = 180°

6. Calculations :

Calculations are shown for angle deflector = 120° and Test No. 1 :
From experimental set up we know :
Area of nozzle(A) = $\frac{\pi \times (0.008)^2}{4}$; Mass = 50g ; Volume of fluid(We took water as fluid for the experiment.) = 3L ; Time taken(t)=21.5s ;
$\alpha = 120° \implies \theta = 30°$
Volume flow rate(Q) = $\frac{3 \times 10^{-3}}{21.5} = 0.140 \times 10^{-3}\ \frac{m^3}{s}$
From equation (1) : Velocity = $\frac{Q}{A} = 2.776\ \frac{m}{s}$
Force = $\rho Qu(1 + sin\theta) = 1000 \times 0.140 \times 10^{-3} \times 2.776 \times 1.5 = 0.554$ N Theoretical force = 0.554N
Experimental force = 0.49 N
% error in force = 11.55 %

7. Sources of Error:

- Error in measuring flow rate.
- Parallex error in checking datum line on weight pan is on the same level of gauge.
- Error due to environmental effect like temperature,pressure change.
- Instrumental error.

8. Conclusion :

- Force due to jet impact is almost directly proportional to Velocity^2

- Experimental pressure somewhat deflects from Theoretical pressure.
- Reaction force is developed as jet of water strikes the plate.
- For a particular angle deflector flow rate and velocity increases as weight increases.