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ME224-Lab 2

Experiment 2- Impact of Jets

Name- Manav Doshi

Roll Number- 200100094

Aim- To study the impact of jets on stationary surfaces

Working and Calculations

For table 1 ⇒ Using reading 4 (Flat plate)

Given- Nozzle diameter - 6 mm

Weight added $m = 0.1$ kg

Distance of weight $L = 37.2$ cm

Time taken $t = 18.8$ s

Amount of water $V = 5$ litres

Discharge $= V/t = \frac{5\times10^{-3}}{18.8} = 2.66\times10^{-4}$ m³/s

Velocity $v = Q/\frac{\pi d^2}{4} = \frac{2.66\times10^{-4}}{\frac{\pi}{4}\times(6\times10^{-3})^2} = 9.40$ m/s

$F_{th} = \rho A v^2 = 1000\times\frac{\pi}{4}(6\times10^{-3})^2\times(9.40)^2$

$= 2.50$ N

$F_{expt} = \frac{mgL}{0.135} = \frac{0.1\times9.8\times37.2\times10^{-2}}{0.135} = 2.70$ N

Error $= \frac{F_{th}-F_{expt}}{F_{th}}\times100 = \frac{2.50-2.70}{2.50}\times100 = -7.94\%$

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For table 2: (Using reading 4, Hemispherical Plate)

Given nozzle diameter = 6mm
weight added m = 0.2 kg
Distance of weight L = 39.3 cm
Time taken = 15.23 s
Amount of water = $V = 5\times10^{-3}\ m^3$

$$\text{Discharge} = \frac{5\times10^{-3}}{15.23} = 3.283\times10^{-4}\ m^3/s$$

$$\text{Velocity} = \frac{Q}{\frac{\pi d^2}{4}} = \frac{3.283\times10^{-4}\ m^3/s}{\frac{\pi}{4}\times(6\times10^{-3})^2} = 11.61\ m/s$$

$$F_{th} = 2\rho A v^2 = 2\times1000\times\frac{\pi}{4}\times(6\times10^{-3})^2\times(11.61)^2 = 7.62\ N$$

$$F_{expt} = \frac{mgL}{0.135} = \frac{0.1\times9.8\times39.3}{0.135} = 5.71\ N$$

$$\text{Error} = \frac{F_{th}-F_{expt}}{F_{th}}\times100 = \frac{7.62-5.71}{7.62}\times100 = \boxed{25.16\%}$$

Sources of error

a) we have neglected the frictional force in the calculation of theoretical force giving an error
b) We have considered the collision to be elastic, which is not the case.
c) Volume flux from the jet may not be uniform.
d) Parallax error while measuring the length

Conclusion

a) The graph of F vs v is almost parabolic - in accordance with the formula $\boxed{F = \rho A V^2}$

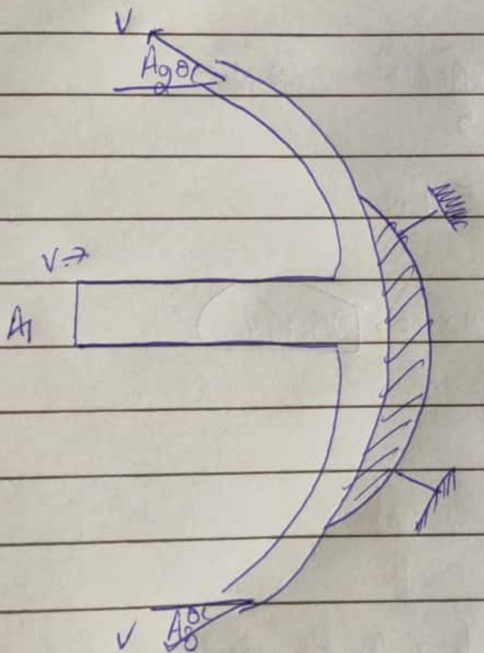
b) For the flat plate, error is negative i.e. $F_{ex} > F_{th}$ ⇒ This suggest that jet might not flow exactly horizontal but collides downwards, adding to the change in momentum.

For the hemispherical plate, error is positive i.e. $F_{th} > F_{ex}$. This may be due to the effect of friction which reduces the vertical velocity of rebounded water. Also we assume a complete 180° which might not be case, This results in a lower F_{expt}

c) The magnitude of error for hemispherical plate is much more than for the flat plate. This is mainly due to the fact that a factor of 2 is involved for calculation of the force. Also for the hemispherical plate, friction acts in both directions while it only acts in the horizontal direction for the latter case.

Questions

Q1)



From continuity $\frac{\partial}{\partial t}\int_{CV} \rho \, d\forall + \int_{CV} \rho \vec{V} \cdot d\vec{A} = 0$

$$\boxed{\frac{A_1}{2} = A_2 = A_3}$$

Momentum equation in the horizontal ~~eq~~ direction

$$\Sigma \vec{F_x} = \frac{\partial}{\partial t}\int_{CV} \rho \vec{V}\, dV + \int \rho (\vec{V}\cdot d\vec{A})\vec{V}$$

$$F_x = -\rho A_1 v^2 - \rho\left(v^2 A_2 \cos\theta + v_3^2 A_1 \cos\theta\right)$$
$$= -\rho_1 A_1 v^2 (1+\cos\theta)$$

Momentum equation in vertical direction

$$\Sigma F_y = \cancel{\frac{\partial}{\partial t}\int_{CV} \rho \vec{V}\cdot dV} + \int \rho(\vec{V}\cdot d\vec{A})\vec{V}$$

$$\rho v_2 (A_2 \sin\theta - A_3 \sin\theta) = 0$$

Q2) We know due to friction $v_f = Kv$

From continuity eq^n

$$\frac{\partial}{\partial t}\int_{CV} \rho\, dV + \int \rho(\vec{V}\cdot d\vec{A}) = 0$$

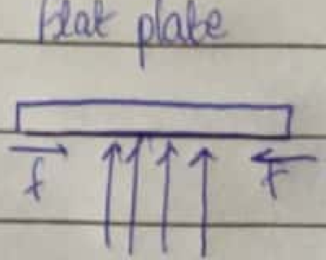
$$-\rho A_1 v - (\rho A_2 K v + \rho A_3 K v) = 0$$

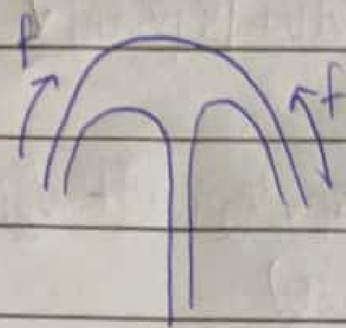
$$\boxed{\frac{A_1}{2K} = A_2 = A_3}$$

From momentum equation in horizontal direction and vertical direction

$$\boxed{\begin{aligned} F_x &= -\rho A_1 v^2 (1+K\cos\theta) \\ F_y &= 0 \end{aligned}}$$

Q3) If we include friction, the result will change only in case of hemispherical plate.
Friction in the case of the flat plate will cancel out.





Hemispheric plate

In hemespheric plate, friction will have a vertical component as well.

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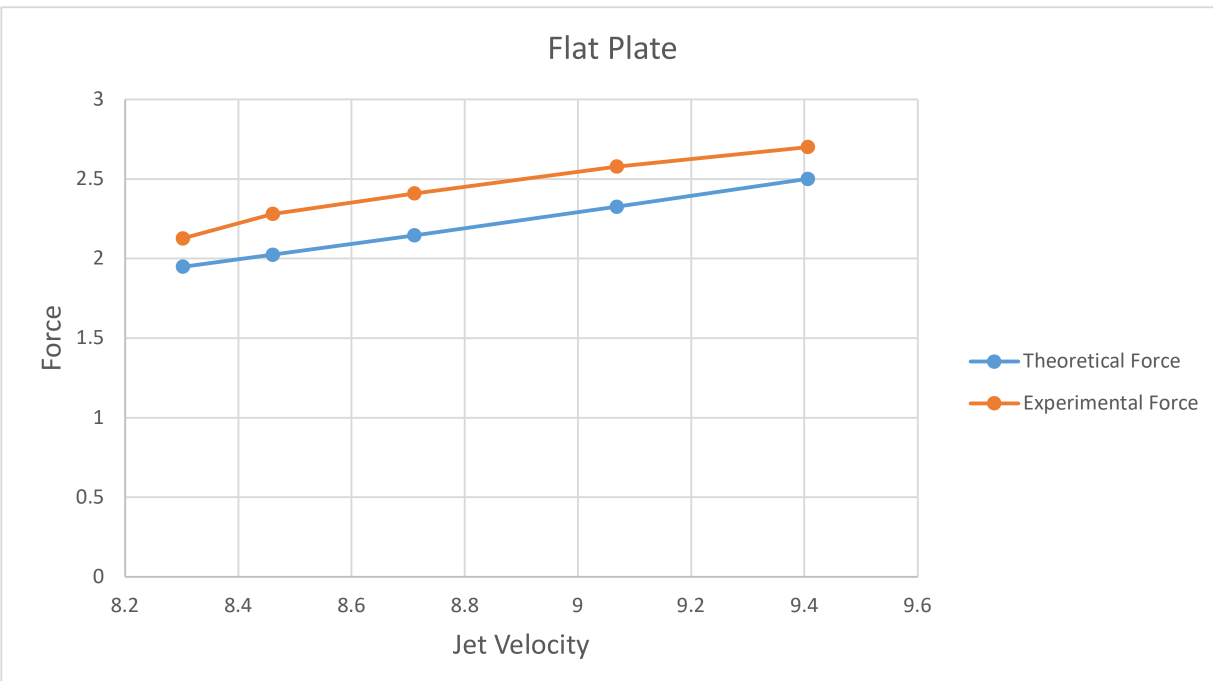
g=9.81m/s^2

Sr. No.	Nozzle diameter, d (mm)	Type of vane	Weight added, m (kg)	Distance of sliding weight, L cm	Time for 5 litres rise in measuring tank, t (sec)	Discharge, Q (m^3/s)	Velocity, v (m/s)	Theoretical force, F_{th} (N)	Experimental force, F_{expt} (N)	Error (%)
0	6	Flat vanes	0.1	29.3	21.3	0.000234742	8.302292284	1.948894902	2.126962963	-9.13687343
1	6		0.1	31.4	20.9	0.000239234	8.461187831	2.024207615	2.279407407	-12.60739217
2	6		0.1	33.2	20.3	0.000246305	8.7112722	2.145633547	2.410074074	-12.32458952
3	6		0.1	35.5	19.5	0.00025641	9.068657726	2.325296853	2.577037037	-10.82615254
4	6		0.1	37.2	18.8	0.000265957	9.406320514	2.501680988	2.700444444	-7.94519596



g=9.81m/s^2

Sr. No.	Nozzle diameter, d (mm)	Type of vane	Weight added, m (kg)	Distance of sliding weight, L (cm)	Time for 5 litres rise in measuring tank, t (sec)	Discharge, Q (m^3/s)	Velocity, v (m/s)	Theoretical force, F_{th} (N)	Experimental force, F_{expt} (N)	Error (%)
0	6	Hemi-spherical vanes	0.2	31.8	16.9	0.000295858	10.46383584	6.191618839	4.616888889	25.43325083
1	6		0.2	33.8	16.4	0.000304878	10.78285522	6.574911721	4.907259259	25.36387609
2	6		0.2	36.2	16.1	0.000310559	10.98377799	6.822222355	5.255703704	22.96199933
3	6		0.2	37.7	15.8	0.000316456	11.19233074	7.083753632	5.473481481	22.73190506
4	6		0.2	39.3	15.23	0.000328299	11.61121639	7.62391096	5.705777778	25.15943841