OBJECTIVES

1. To measure the force generated by impact of the jet on 2 type of vanes:
   i) Flat plate
   ii) Hemispherical cup
2. To compare the result from the experiment with theory calculation.

LEARNING OUTCOME

At the end of the lab session, student should be able to

1. Apply the momentum equation to a different shape of vanes
2. Determine the force generated by the jet on different type of vanes

THEORY

One way of producing mechanical work from fluid under pressure is to accelerate the fluid to a high velocity in a jet. The jet is directed to the vanes of a turbine wheel, which is rotated by the force generated on the vanes due to the momentum change or impulse that takes place as the jet strikes the vanes.

Consider a vane symmetrical about the x-axis as shown in Figure 1. A jet of fluid flowing at the rate of $\dot{m}$ (kg/s) along the x- axis with the velocity u_0 (m/s) strikes the vane and is deflected by it through angle β, so that the fluid leaves the vane with the velocity u_1 (m/s) inclined at an angle β to the x-axis. Changes in elevation and in piezometric pressure in the jet from striking the vane to leaving it are neglected.

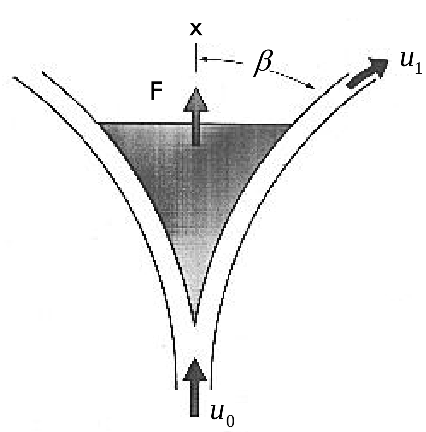

Figure 1 Vane Symmetry about the X-Axis

Momentum enters the system in the x direction at a rate of:

$$\dot{m}u_0 \tag{1}$$

Momentum leaves the system in the same direction at the rate of:

$$\dot{m}u_1 \cos\beta \tag{2}$$

The force on the vane in the x direction is equal to the rate of change of momentum change. Therefore:

$$F = \dot{m}(u_0 - u_1 \cos\beta) \tag{3}$$

Ideally, jets are ' isotachtic', or constant velocity so that $u_0 = u_1$. Therefore:

$$F = \dot{m}u_0(1 - \cos\beta) \tag{4}$$

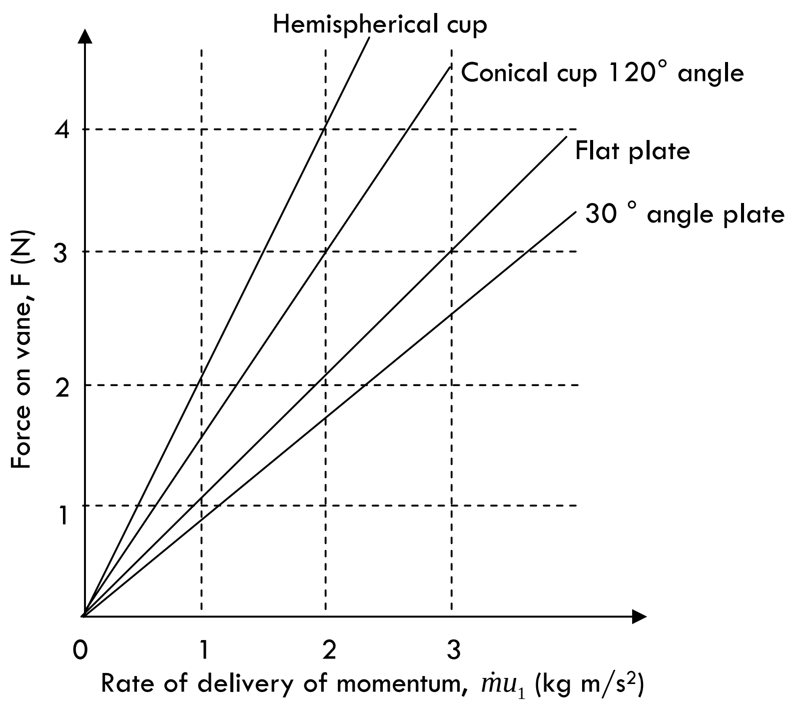

Figure 2 Force Developed (Theoretical) on Vane of Various Shapes

APPARATUS

H8 Impact of a Jet, Hydraulic bench (gravimetric) & stop watch.

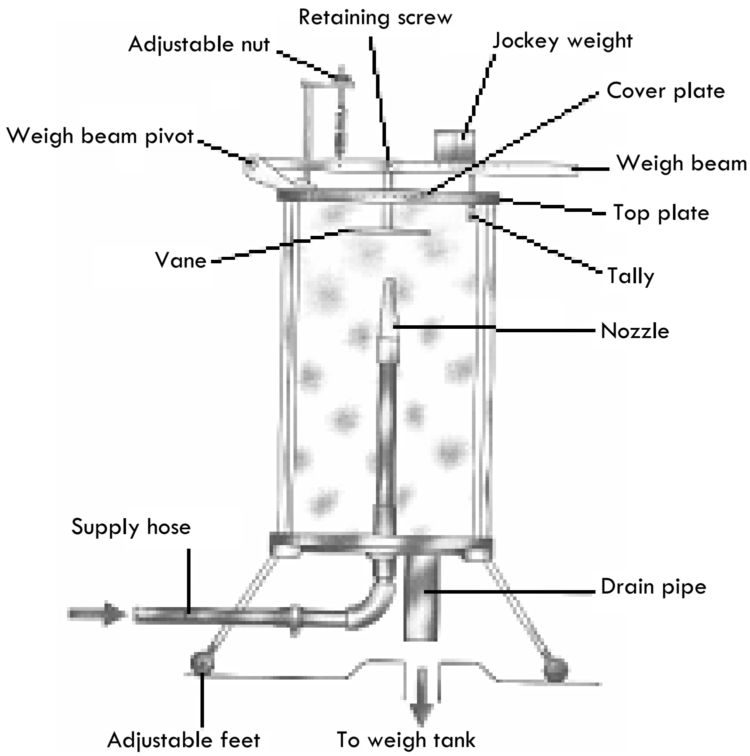

Figure 3 Impacts of Jet Apparatus

PROCEDURES

1. Set the weigh beam lever (of Figure 3) to the balance position with the jockey weight at zero position by adjusting the nut (Impact of a Jet Apparatus). The beam lever is balance once it is in a horizontal position when the tally indicator is in line with the top plate.
2. Slide the weigh beam stop (of Figure 4) out of line of the beam and lift the beam for 10 – 15 seconds to ensure the weigh tank is empty (Hydraulic bench).
3. Slide the weigh beam stop above the weigh beam (of Figure 4).

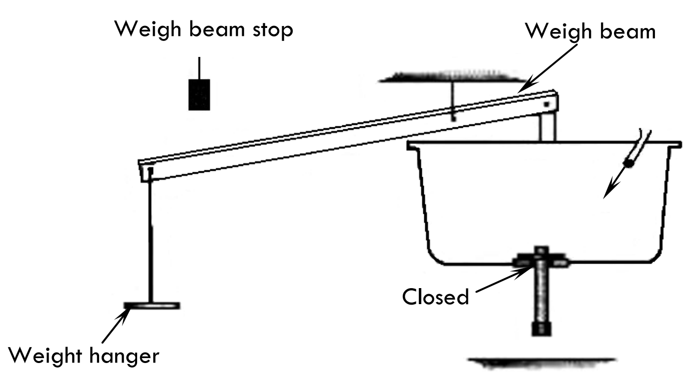

Figure 4

4. Switch on the pump and open the bench supply valve to maximum.

5. Start timing when the weigh beam touching the weigh beam stop and place selected mass immediately on the weight hanger (8 kg).

6. When the mass of water collected balances the mass of the weight hanger, the beam will rise again to the horizontal position and touching the weigh beam stop, immediately stop the timer and record the time interval.

7. Adjust the jockey weight (Figure 3) position to set the weigh beam lever at balance position (refer to tally indicator) in line with the top plate.

8. Record the time and jockey weight distance into Table 1 for flat plate or Table 2 for hemispherical plate.

9. Switch off the pump.

10. To drain the weigh tank, depress weigh beam above weight hanger and slide weigh beam stop away. Gently let weigh beam rise until it stops against the sump tank. Remove the weights and the tank will continue draining. (Lift it for 10 - 15 seconds to drain completely).

11. Repeat the procedures 2 to 7 with decreasing the water flow rate by closing the supply valve three-quarter turn each time.
    Note:
    (a) The mass of water collected is three times the mass used on the weight hanger.
    (b) Repeat the above experiment with at least six readings of flow rate.
    (c) Change the vane to different type and repeat again the above procedures

Information and equations for calculation:

Density of water $\rho = 10^3$ kg/m^3
Diameter of nozzle = 10 mm
Cross-section area of nozzle, A = 78.5 mm^2
Mass of jockey weight = 0.6 kg
Distance from centre of vane to pivot of lever = 0.15 m

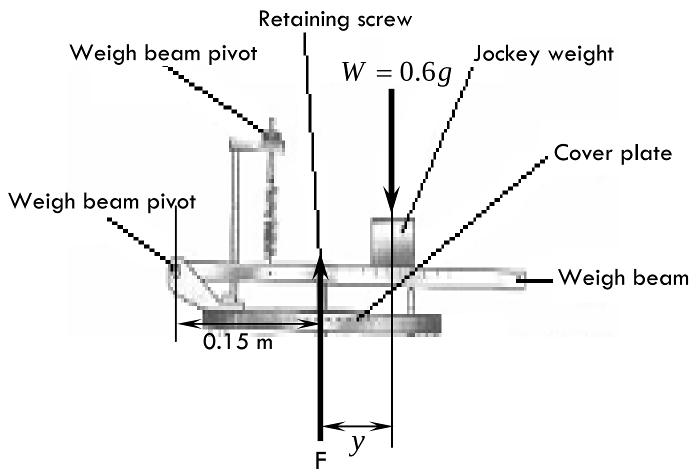

Figure 5

From Figure 5, the jockey weight weighs ($0.6g$) Newtons. When it is moved a distance y metres from weigh beam pivot, the corresponding force F Newtons on the vane is obtained, by taking moments about the pivot, as:

$$0.15F = 0.6gy$$
$$F = 4gy \tag{5}$$

Height of vane above tip of nozzle, s = 35 mm
The flow is measured as $\dot{m}$ (kg/s)
Since $\dot{m} = \rho A u$, the speed if the jet at exit from the nozzle is equal to:

$$\begin{aligned} u &= m/\rho A \\ &= \dot{m}/10^3 \times 78.5 \times 10^{-6} \\ &= 12.75\dot{m} \end{aligned} \tag{6}$$

The velocity u_0 of the jet as it is deflected by the vane is less than the velocity u at exit from the nozzle because of the deceleration due to gravity and may be calculated from the expression:

$$\begin{aligned} u_0^{\,2} &= u^2 - 2gs \\ u_0^{\,2} &= u^2 - 2 \times 9.81 \times 0.035 \\ u_0^{\,2} &= u^2 - 0.687 \end{aligned} \tag{7}$$

Record the readings into Table 1 and 2. Use the above equations to calculate F, u and u_0.

IMPACT OF A JET

Name: ___________________________________ **Metric Number:** __________________

Section / Group: ___________________________ **Date of experiment:** _______________

EXPERIMENTAL DATA

Table 1 Flat plate

Water mass (kg)	Time, t (s)	Distance, y (m)	Mass Flow Rate, $\dot{m}$ (kg/s)	Velocity, u (m/s)	Initial velocity, u_0 (m/s)	Momentum, $\dot{m}\, u_o$ (N)	Force on vane, F (N)
24							
24							
24							
24							
24							
24							

Table 2 Hemispherical cup

Water mass (kg)	Time, t (s)	Distance, y (m)	Mass Flow Rate, $\dot{m}$ (kg/s)	Velocity, u (m/s)	Initial velocity, u_0 (m/s)	Momentum, $\dot{m}\, u_o$ (N)	Force on vane, F (N)
24							
24							
24							
24							
24							
24							

Note: Attach samples of calculation in different sheet.

Plot a graph for F versus $\dot{m}\, u_o$ for both cases. Calculate the slope of the graph. Compare with theoretical slope and describe.

DISCUSSION

1. By referring to the graph, the relationship between F and $\dot{m}\, u_o$ for flat plate and hemispherical cup are ____
____
____
____
____
____
____
____
____
____

2. The percentage of error of the experimental result: -

Vane Type	Percentage of Error	Factor
Flat plate		
Hemispherical cup		

QUESTION (FOR FORMAL REPORT ONLY)

3. Suggest two ways to improve the accuracy of the results. Provide explanations in details.

CONCLUSION (Please attach more pages if necessary):

SHORT REPORT

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