MPMUNRO

MANCHESTER POLYTECHNIC
JOHN DALTON FACULTY OF TECHNOLOGY
DEPARTMENT OF MECHANICAL PRODUCTION & CHEMICAL ENGINEERING

AERODYNAMICS AND FLUID MECHANICS LABORATORY

Experiment No
ME/AF/2/5

IMPACT OF JETS

OBJECT

The object of the experiment is to verify the momentum equation.

APPARATUS

TecquipmentImpact of Jets Apparatus. This consists of a force balance and a tapered nozzle through which a measurable flow of water impinges on

(a) a flat plate

(b) a hemispherical cup

ROTATION

Force exerted by jockey weight = W(N)
Force exerted by water = F(N)
Distance of jockey weight from zero position = y(mm)
Distance of centre line of plate or cup to fulcrum = d(mm)
Density of water = $\rho(kg/m^3)$
Quantity (volume) of water per second = $Q(m^3/s)$
Mass of water per second = $\dot{m}$ (kg/s)
Area of nozzle = $A(m^2)$
Velocity of water from nozzle = V
Velocity coefficient of cup = $\frac{\text{Outlet velocity}}{\text{Inlet velocity}} = C_V = 0.85$ (assumed)
Angle through which flow is deflected = 90° (flat plate)
= 165° (hemispherical cup)

THEORY

Force = Rate of change of momentum
$F = \dot{m}\, V$ (flat plate)
$F = \dot{m}\,(V + C_V V \cos 15^\circ)$
$= \dot{m}\, V(1 + C_V \cos 15^\circ)$ (hemispherical cup)

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From these formulae can be obtained these equations:-

$$F = \frac{\rho Q^2}{A} = \frac{\dot{m}^2}{\rho A} \text{ (flat plate)}$$

$$F = \frac{\rho Q^2}{A}(1 + C_V \cos 15^\circ) = \frac{\dot{m}^2}{\rho A}(1 + C_V \cos 15^\circ) \text{ (hemispherical cup)}$$

If the force balance is set correctly :-

$$Wy = Fd$$

$$\therefore \quad F = \frac{Wy}{d}$$

If you are writing a full report the various equations given must be proved.

PROCEDURE

Carefully level the balance arm with the jockey weight in the zero position by adjusting the tension in the balance spring, having positioned the flat plate. Set the water flowing through the nozzle at the maximum rate and balance with the jockey weight.

Measure y and the time (t sec) to collect a suitable mass (M lb mass) of water in the collecting tank. Repeat for about seven reducing flow rates. Repeat for the hemispherical cup using a different jockey weight as necessary.

Note: The balance masses labelled 15 mean 15 lb mass of water collected.

RESULTS

Sketch and describe the apparatus. Plot theoretical and experimental values F against Q^2 as abscissa.

CONCLUSIONS

Comment on the accuracy of the experiment and discuss whether the theory has been verified.

A G READ
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IMPACT OF JETS LOG SHEET Experiment No ES/AF/2/CL

OBJECT

The object of the experiment is to verify the momentum equation.

APPARATUS

"Tecquipment" Impact of Jet Apparatus.

THEORY

Theoretical Force = $F = \frac{\dot{m}^2}{\rho a}$ (flat plate)

$= F = \frac{\dot{m}^2}{\rho a}(1 + C_v \cos 15^0)$ (hemispherical cup)

Experimental Force = $F = \frac{Wy}{d}$

RESULTS

Sketch the apparatus, and plot experimental and theoretical graphs of F against $\dot{m}^2$ as abscissa.

(a) Flat Plate

W(lb wt)	W(Kg)	t(s)	$\frac{M}{t} = \dot{m}$	$F = \frac{\dot{m}^2}{\rho a}$	y(mm)	$F = \frac{Wy}{d}$	$(\dot{m})^2$
15	6.8	16.6	0.41	214	9.5	208	0.168
"	"	17.57	0.39	194	9	197	0.152
"	"	19.1	0.36	166	7	154	0.130
"	"	21.4	0.32	129	5	110	0.102
"	"	26.25	0.26	85.3	3	66	0.067

(b) Hemispherical Cup K = $1 + C_v \cos 15^0$ "

W(lb wt)	W(Kg)	t(s)	$\frac{M}{t} = \dot{m}$	$F = \frac{\dot{m}^2 K}{\rho a}$	y(mm)	$F = \frac{Wy}{d}$	$(\dot{m})^2$
15	6.8	18.45	0.37	318	15	329	0.137
"	"	20.15	0.34	269	12	263	0.115
"	"	22.4	0.30	209	9	197	0.090
"	"	27.25	0.25	144	6	132	0.062
"	"	36.5	0.19	83	3	66	0.036

CONCLUSIONS

SEE NOTES.

NAME OF STUDENT: MICHAEL P. MUNRO

DATE OF EXPERIMENT: 23rd MAY 1983

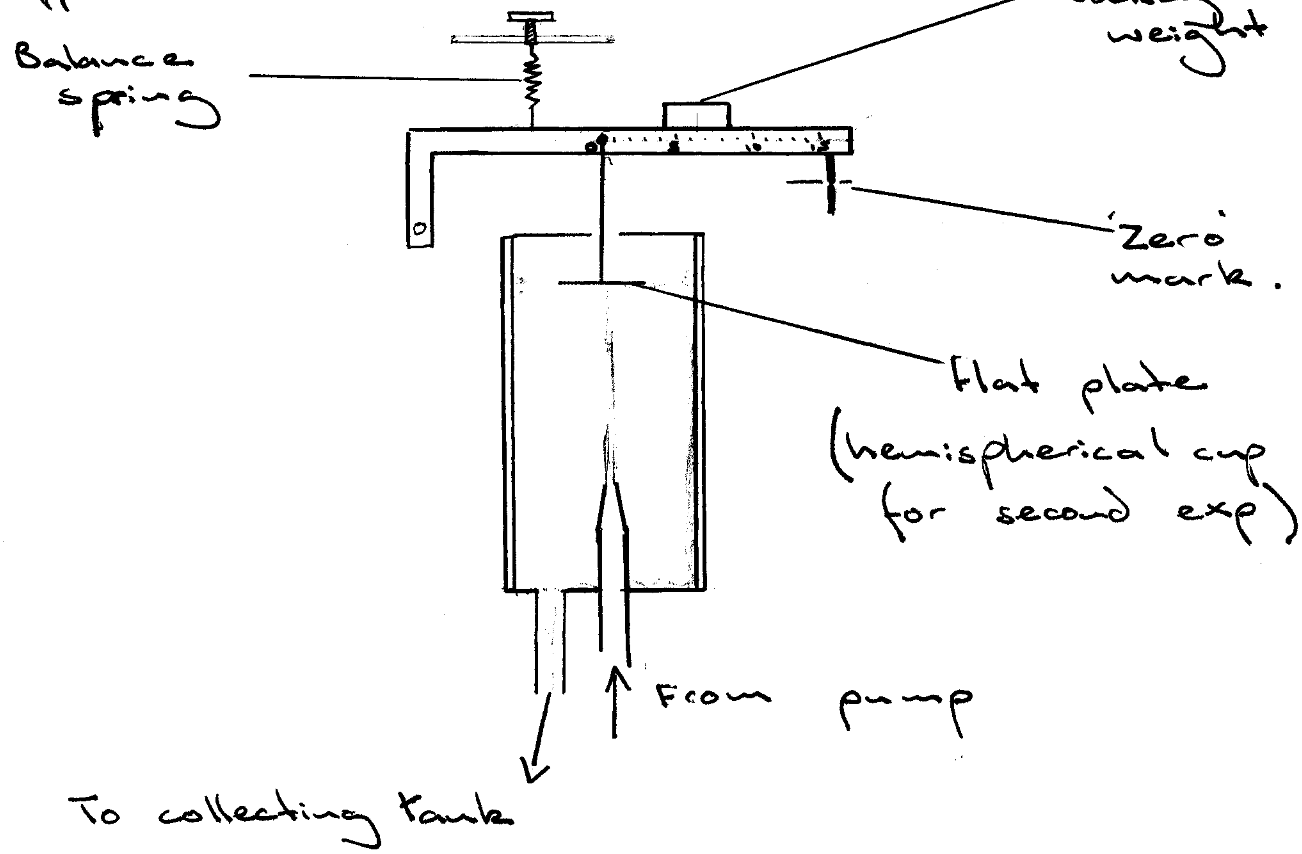
GROUP: ....

M.P. Munro

23.5.83

Impact of Jets

Apparatus



Collecting tank is used to measure the mass flow rate of water, by measuring the time it takes to increase its content of water by a known weight. As the tank is pivoted, on 'tipping' a balance mass can be placed on a counter balancing arm so as to reset the tanks position and the time taken for the tank to 'tip' itself again.

Results

$d = 152$ mm

mass of jockey = 339.835 grams

force exerted by jockey = 339.83 × ·81 N

$W = 3.334$ N

Diameter of nozzel = 10mm
∴ Area of nozzel = $\pi \times 5^2$
$A = 78.54 \, mm^2$
$= 78.54 \times 10^{-6} \, m^2$

Density of water = 1000 kg/m^3

$(1 + C_v \cos 15°) = 1 + 0.85 \times \cos 15$
$= 1.82$

Discussion/Conclusion

The graphs show that the force f applied to the cup/plate is proportional to the mass flow rate of the water jet squared ✓

The values obtained for the force, theoretical and experimental have a slight discrepency. The theoretical values are higher than the experimental ones. This is due to factors:

The water does not always deflect through 90° on hitting the flat plate, but at high water flow rates tends to deflect slightly upwards after contact with the plate. ✓

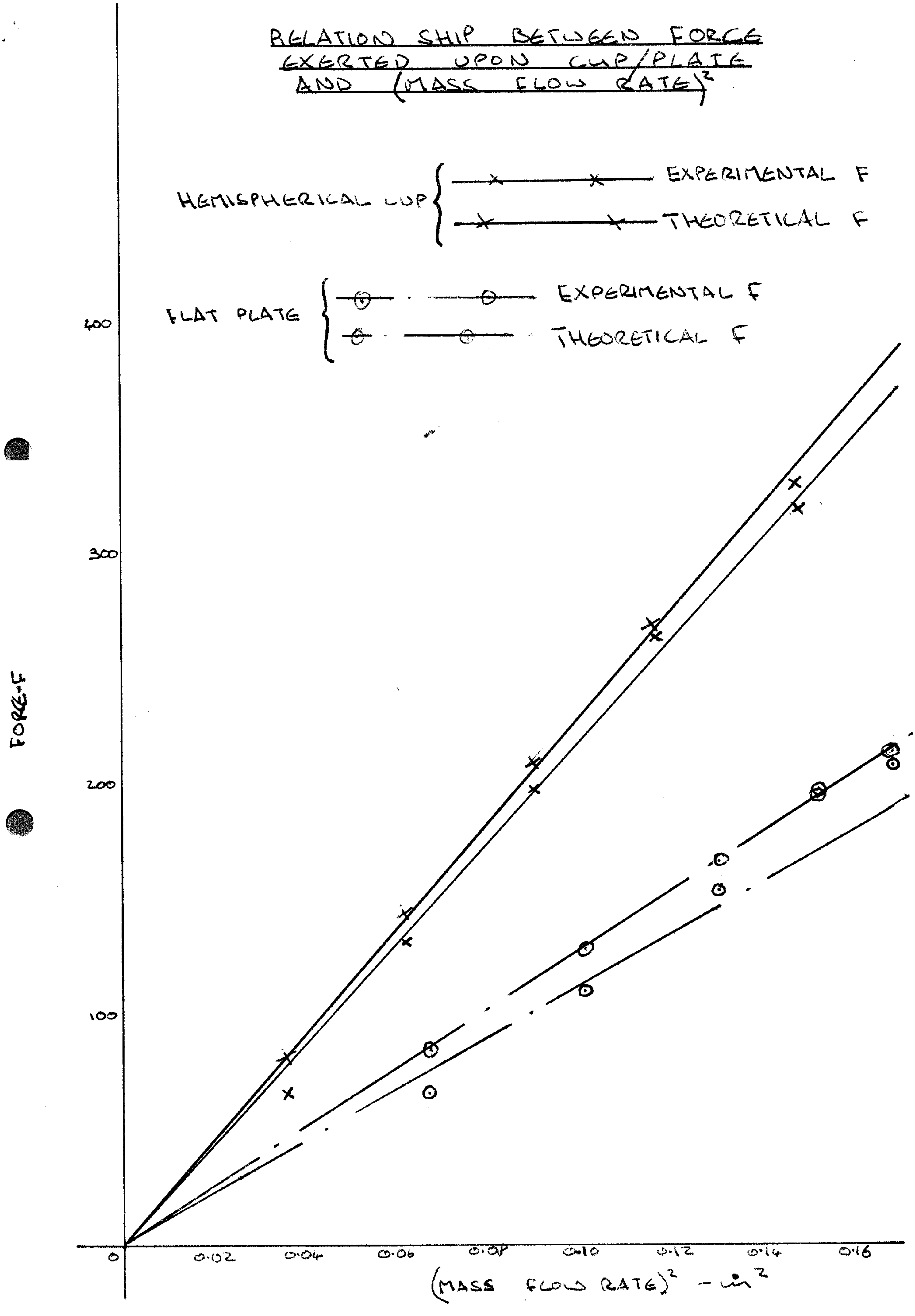
The experimental values donot take into account, the fact that energy is lost in the water rising from the nozzle to the plate. ✓

Energy is lost in the bearings

of the balance arm on which the jockey weight rests. This gives the experimental results slightly lower values than the theoretical ones.

Taking all the above losses into account the experiment shows that energy is conserved, i.e. the momentum equation is verified.

Good


RELATION SHIP BETWEEN FORCE
EXERTED UPON CUP/PLATE
AND (MASS FLOW RATE)²
HEMISPHERICAL CUP
EXPERIMENTAL F
THEORETICAL F
FLAT PLATE
EXPERIMENTAL F
THEORETICAL F
400
300
200
100
0
FORCE-F
0·02
0·04
0·06
0·08
0·10
0·12
0·14
0·16
(MASS FLOW RATE)² - in²