Faculty of Engineering and Technology

Mechanical Engineering Department

Fluid mechanics Lab

ENME 312

Section 2

Experiment #5 report

Impact of a Jet

Done by: Nada Abu Alteen

1200663

Group 3

Partner: Lara Abu Zir 1190345

Instructor: Dr. Adel Dweik

Teaching Assistant: Eng. Ahmad Abu Baker

Date of experiment: 15-10-2024

Data of submission: 25-10-2024

Table of Contents

Abstract

The purpose of this experiment is to compare between two shapes of vanes which are the flat plate and the hemispherical cup in mass flow rate, velocity at inlet, velocity at nozzle, force and efficiency. This experiment is done by taking different values of displacement for the jockey weight and then balance the lever to take a correct time reading needed to raise the weigh arm for both flat plate and hemispherical cup. It depends on three principles which are newton second law, symmetry about x-axis and newton third law which leads us to know that the force on the jet in the x direction opposes the force on the vane from the jet in the x direction.

The most significant results are the experimental mass flow rate, velocity at inlet and at nozzle, theoretical and experimental forces where the relation between them is plotted to find the efficiency value from the slope, so for the flat plate the efficiency from the equation is 0.675, and for the hemispherical cup it equals 0.937 from the linear equation.

From the results it is found that the hemispherical cup has larger force and efficiency also the efficiency values must not be larger than 100% and the relation between the experimental and theoretical force is approximately linear.

Objectives and measurement methods

The aim of this experiment is to compare between two shapes of vanes which are the flat plate and the hemispherical cup, and this comparison is by notice the difference in mass flow rate, velocity at inlet, velocity at nozzle, force and efficiency.

To make this comparison we started by fixing the first shape on the lever and be sure that it is balanced by placing the jockey weight on the zero position after that many displacement values were taken for the jockey weight with changing the flow rate to achieve balance at the end, we need to record the time needed to rise the weight arm and these actions were repeated 8 times for each shape.

For both the flat plate and hemispherical cup shapes, the measuring instruments are a graduated scale lever in mm carrying a jockey weight and restrained by spring to measure the displacement of the weight in millimeters to find the experimental force in newton, also a stopwatch or phone timer needed to record the time needed to raise the weight arm in seconds and this time and the weight used which is 4 kgs on 3:1 arm ratio to got an 12 kgs weight are both used to calculate the mass flow rate. There are some given constants like jockey weight mass, the nozzle cross sectional area, distance from center vane to pivot of lever and the height of vane above tip of the nozzle and all these used to calculate velocity and force.

Sample calculations

Calculations done for run one

- $\dot{m}$= mass (12 kg) /time (s)

Where:

$\dot{m}$: the experimental mass flow rate (kg/s)

$\dot{m}$=12kg/26 sec= 0.462 kg/s

and the same for all runs in both hemispherical and flat plate

- Newton's second law: F= $\dot{m}$*u

Where:

F: the theoretical force (N)

ṁ: the mass flow rate (kg/s)

u: velocity (m/s)

- Fp= ṁ*u0

Where:

Fp: theoretical force for flat plate (N)

U0: velocity at the vane inlet (m/s)

Fp= 0.462*5.855=2.703 N

- Fc=2* ṁ*u0

Where:

Fc: theoretical force for hemispherical cup (N)

Fc=2*0.444*5.634=5.008 N

- ṁ= ρ*a0*u

where:

ρ: water density (1000kg/m^3)

a0: cross sectional area of the nozzle (78*10^-6 m)

u: water velocity at the nozzle exit (m/s)

u=ṁ/a0*ρ

u=0.462/1000*78*10^-6=5.917 m/s

and the same for all runs in both hemispherical and flat plate

- u0^2=u^2-2*g*s

where:

g: the gravity acceleration (9.81 m/s^2)

s: height of vane above the tip of the nozzle (0.037 m)

u0= (5.917^2-(2*9.81*0.037))^0.5=5.855 m/s

and the same for all runs in both hemispherical and flat plate

- w*g*y= b*F

where:

w: jockey weight mass (0.61 kg)

b: the distance from center to vane to pivot of the lever (0.1525 m)

y: the distance which jockey weight moved (m)

F: the experimental force (N)

F=w*g*y/b

F=0.61*9.81*0.055/0.1525=2.165 N

and the same for all runs in both hemispherical and flat plate

- efficiency= F excremental (N)/F theoretical (N)= slope

efficiency= 2.703/2.156=0.798

and the same for all runs in both hemispherical and flat plate

Presentation and results

Table 1: Results and calculations for the flat plate (run, time (sec.), distance (mm), exp. Mass flow rate (kg/s), velocity at nozzle (m/s), velocity at inlet (m/s), theoretical force (N), experimental force (N), efficiency).

for the flat plate								
Run	Time (sec)	Y (mm)	exp. Mass flow rate (kg/s)	velocity at nozzel (m/s)	velocity at inlet (m/s)	theoretical force (N)	experimental force (N)	effeciency
1	26	55	0.462	5.917	5.855	2.703	2.156	0.798
2	30	50	0.400	5.128	5.057	2.023	1.960	0.969
3	33	45	0.364	4.662	4.583	1.667	1.764	1.058
4	37	40	0.324	4.158	4.070	1.320	1.568	1.188
5	41	35	0.293	3.752	3.654	1.070	1.372	1.283
6	43	30	0.279	3.578	3.475	0.970	1.176	1.213
7	46	25	0.261	3.344	3.234	0.844	0.980	1.162
8	48	20	0.250	3.205	3.090	0.772	0.784	1.015

Table 2: Results and calculations for the hemispherical cup (run, time (sec.), distance (mm), experimental mass flow rate (kg/s), velocity at nozzle (m/s), velocity at inlet (m/s), theoretical force (N), experimental force (N), efficiency).

for the Hemispherical cup								
Run	Time (sec)	Y (mm)	exp. Mass flow rate (kg/s)	velocity at nozzel (m/s)	velocity at inlet (m/s)	theoretical force (N)	experimental force (N)	effeciency
1	27	120	0.444	5.698	5.634	5.008	4.704	0.939
2	30	110	0.400	5.128	5.057	4.046	4.312	1.066
3	34	90	0.353	4.525	4.444	3.137	3.528	1.125
4	35	80	0.343	4.396	4.312	2.957	3.136	1.061
5	42	60	0.286	3.663	3.563	2.036	2.352	1.155
6	50	40	0.240	3.077	2.957	1.419	1.568	1.105
7	60	30	0.200	2.564	2.418	0.967	1.176	1.216
8	130	10	0.092	1.183	0.821	0.152	0.392	2.585

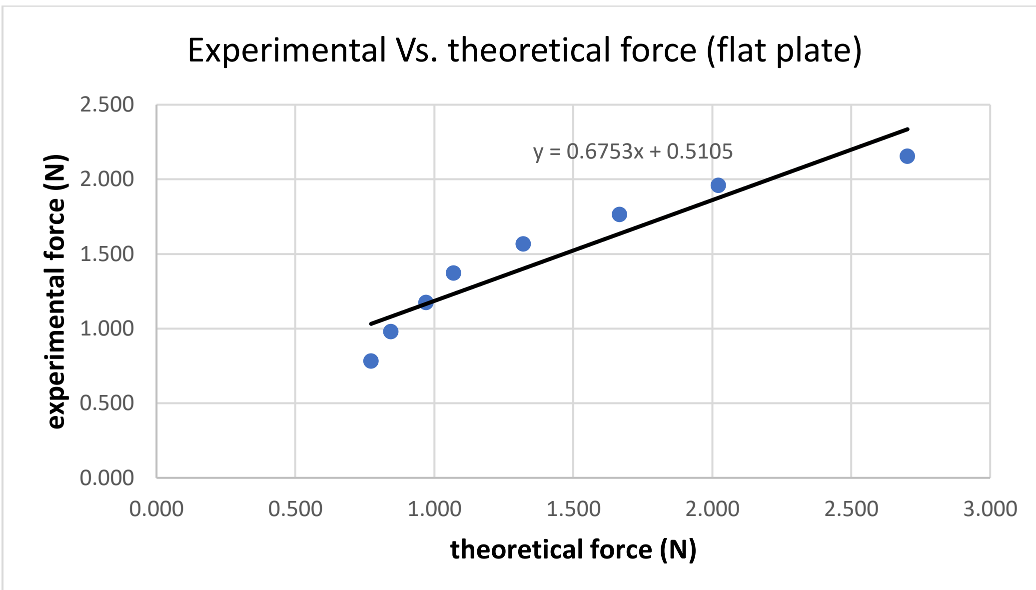


Figure 1: Experimental Vs. theoretical force (flat plate)

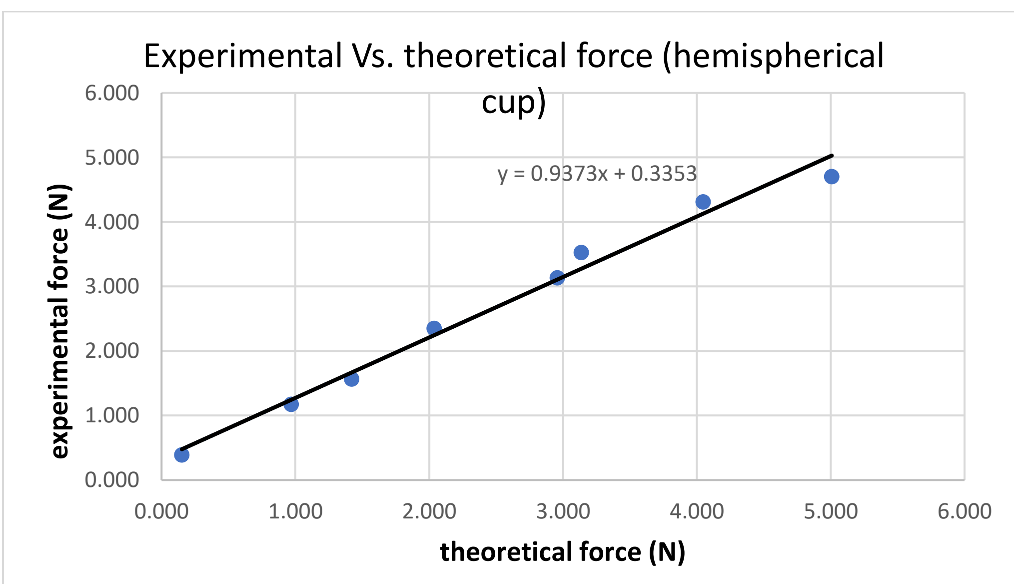


Figure 2: Experimental Vs. theoretical force (hemispherical cup)

Discussion of results

The results I got after doing all calculations like velocity, force and mass flow rate have a strong relationship with measurements recorded from the experiment which are time and distance because all these parameters are related together by direct or indirect relations (equations).

It is observable from tables 1 and 2 that the theoretical and experimental forces from the hemispherical cup are larger than the theoretical and experimental forces from the flat plate (approximately 2 times) also the velocities at nozzle and at inlet for both shapes are near to each other, lastly the efficiency of hemispherical cup is larger than the flat plate.

From graph 1 which shows the experimental vs. theoretical force for flat plate the relation between them is not exactly linear and the slope of the line indicates the efficiency which from the equation equals 0.675. For graph 2 which shows the experimental vs. theoretical force for hemispherical cup the relation between them is approximately linear and better than graph 1, the slope of the line indicates the efficiency which from the equation equals 0.937.

The independent variables are the given and measured variables like displacement, time, Jockey weight mass, the nozzle cross sectional area, distance from center vane to pivot of lever and the height of vane above tip of the nozzle. The dependent variables are the calculated ones like velocity, force and mass flow rate which effected by changing the measured variables, for example when the time increases the mass flow rate decreases and then the velocity decreases consequently the theoretical force decreases also when the distance increases the experimental force increases.

In general, most experimental results agree with the theory instead of the efficiency which must be less than or equals 1, this means that there are some error sources and uncertainty like error in balancing the lever, uncertainty about jockey weight, error in time recording, error while reading the distance of the jockey weight and uncertainty in the nozzle diameter. To decrease the amount of uncertainty we need to be more accurate while doing the experiment and recording the data by more than one trial done and to be read by different students and then taking the average.

If there is an error in jockey weight by additional 0.001 kg the efficiency will increase because the experimental force will increase while if the distance from center of the vane to pivot is increased by 1mm the efficiency will decrease due to inverse relation between the experimental force and the distance also it will decrease if the diameter of the nozzle increased by 0.1mm because the mass flow rate increases and then the theoretical force increase.

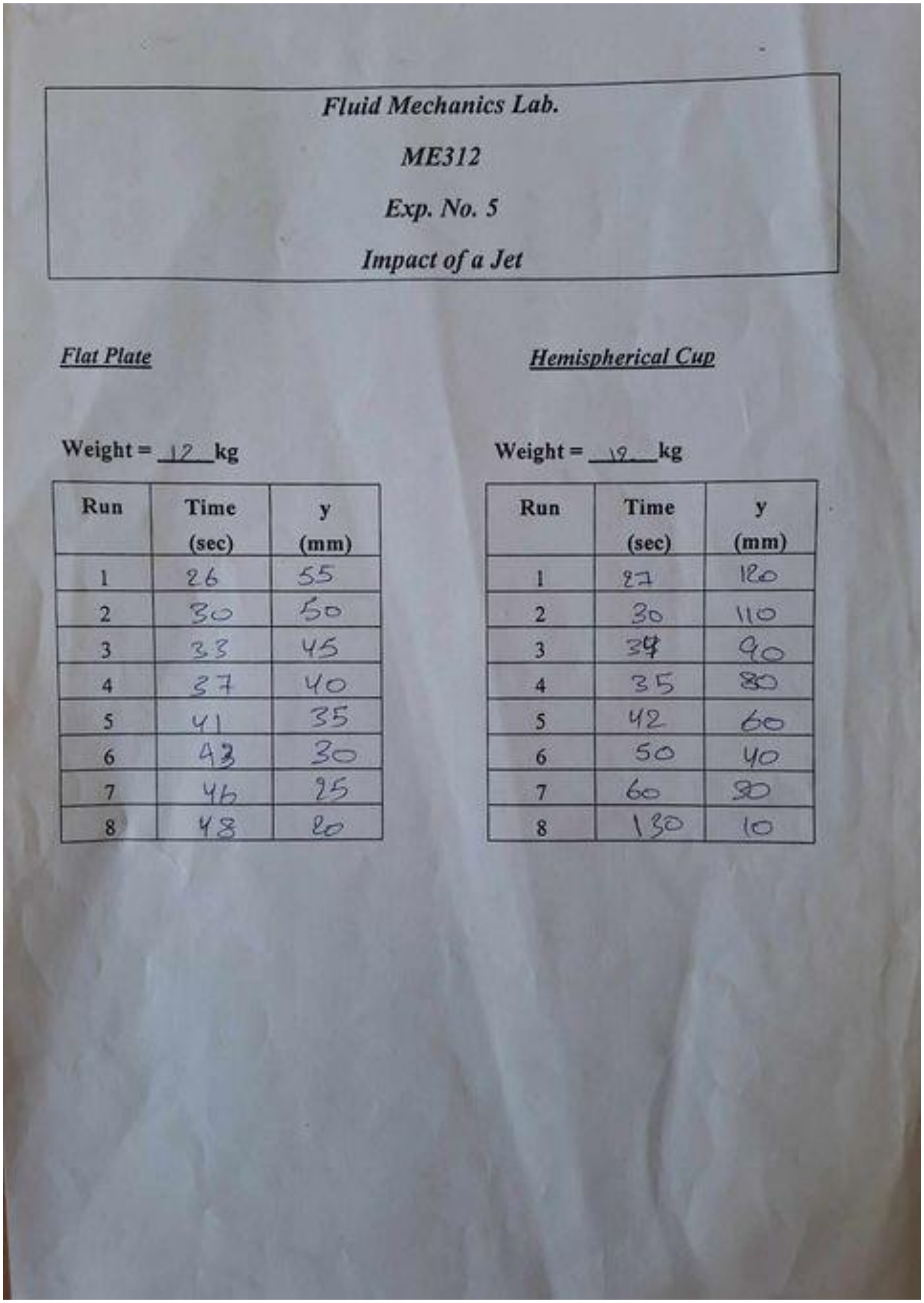
Conclusions

The experiment results are acceptable and logical according to theory with some exceptions like efficiency because it can't be more than 1 or 100% due to losses while in my results there is some values are more than 1. In my opinion the experiment was successful and I conclude that the hemispherical cup has larger force and less losses than the flat plate.

There are many examples and applications from real life on the water vane jet like power generation to generate electricity, in treatment process for distributing chemicals, in marine applications like ships or controlling movement and to direct or distribute the fluids in pipelines.

Appendices

- Fluid mechanics laboratory manual-ENME 312, march 2022.



Fluid Mechanics Lab.

ME312

Exp. No. 5

Impact of a Jet

Flat Plate

Weight = 12 **kg**

Run	Time (sec)	y (mm)
1	26	55
2	30	50
3	33	45
4	37	40
5	41	35
6	43	30
7	46	25
8	48	20

Hemispherical Cup

Weight = 12 **kg**

Run	Time (sec)	y (mm)
1	27	120
2	30	110
3	34	90
4	35	80
5	42	60
6	50	40
7	60	20
8	130	10

Figure 3: original data sheet