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| **CIVE 340 Fluid Mechanics and Laboratory** |
| Experiment 4: Force on Plate |
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# Introduction

This experiment aims to determine the force acting on a plate through experimental work based on the momentum equation and compare the findings with those obtained by directly measuring the force acting on the plate.

# Equipment

The following equipments were used to carry out this experiment:

* Hydraulic bench
* Jet impact apparatus (nozzle diameter 7 mm)
* Three plates: Flat (0 o), 120o and 180o (horizontal).
* Stop watch

# Procedure

To carry out this experiment we followed the following procedure:

1. Mount the plate on the jet impact apparatus.
2. Install the flat plate.
3. Level the apparatus by adjusting the legs to get the bubble centered in the spirit level.
4. Adjust the level gauge to point to the datum on the weight pan.
5. Place a nominal mass (say 100 g) on the weight pan.
6. Open the supply valve and adjust the flow until the weight pan is back to its initial level.
7. Take readings of volume and time to find the flow rate and note the mass on the weight pan.
8. Add additional mass on the weight pan and repeat steps 3 to 6 for two additional settings.
9. Repeat the experiment for the 120o and 180o plates.



Masses,

100g each

Flat plate

1800 plate

# Detailed Derivation of Equations 1, 2 & 3

Assumptions made in the derivation:

1. Z1 and Z2 are very close to each other, and therefore, there difference is considered to be null. This yields (using Bernoulli) that V1=V2.
2. Neglect the weight of water.

Momentum equation: -Fx = ρQ(V2.cos(α) – V1.cos(β)) where α is the angle of projection of V2 leaving the plate, and β is the angle of projection of V1 entering the plate. β is always = 0.

## C:\Users\Hagop\Downloads\photo 3.JPGFlat Plate

α= 90 therefore,

-Fx = ρQ(Vx2.cos(90) – Vx1)

V=Q/A, and V1=V2 (explained above)

 Fx= (ρQ2/A) [EQN 1]

## 120o Plate

α= 60 therefore,

-Fx = ρQ( -Vx2.cos(60) – Vx1)

Fx= ρQ(V1 + V2.cos(60))

V=Q/A, and V1=V2 (explained above)

Fx= ρQV1 (1+cos (60)) = 3/2(ρQV1)

Fx= (3/2) (ρQ2/A) [EQN 2]

## 180o Plate

α= 0 therefore,

-Fx= ρQ( -Vx2.cos(0) – Vx1)

Fx= ρQ(V1 + V2.cos(0))

V=Q/A, and V1=V2 (explained above)

FX =ρQV1 (1+cos (0)) = 2(ρQV1)

FX =2(ρQ2/A) [EQN 3]

# Collected Data

## Flat Plate

|  |  |  |  |
| --- | --- | --- | --- |
| Mass (g) | Volume (m3) | Time (s) | Flow rate (m3/s) |
| 100 | 0.005 | 25.2 | 0.000198 |
| 200 | 0.005 | 18.48 | 0.000271 |
| 300 | 0.005 | 17.95 | 0.000279 |

## 120o Plate

|  |  |  |  |
| --- | --- | --- | --- |
| Mass (g) | Volume (m3) | Time (s) | Flow rate (m3/s) |
| 100 | 0.005 | 31.31 | 0.00016 |
| 200 | 0.005 | 23.14 | 0.000216 |
| 300 | 0.005 | 22.35 | 0.000224 |

## 180o Plate

|  |  |  |  |
| --- | --- | --- | --- |
| Mass (g) | Volume (m3) | Time (s) | Flow rate (m3/s) |
| 100 | 0.005 | 33.82 | 0.000148 |
| 200 | 0.005 | 24.55 | 0.000204 |
| 300 | 0.005 | 19.48 | 0.000257 |

# Calculations:

In order to calculate the experimental force, we only need to substitute the density, flow rate, and the area in the equations found above. On the other hand, the theoretical force on the plate must be equal to the weight placed on the apparatus 🡺 F=Mg.

These results are summed up in the table below.

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| --- | --- | --- | --- |
| Flat PlateUsing Eq. 1 | Experimental | Theoretical | Percent error |
| 100g | 1.022946606 | 0.981 | 4.275902744 |
| 200g | 1.908326233 | 1.962 | -2.735666017 |
| 300g | 2.022657947 | 2.943 | -31.27224101 |
|  |  |  |  |
| 120 oUsing Eq. 2 | **Experimental** | **Theoretical** | **Percent** **error** |
| 100g | 0.997804051 | 0.981 | 1.712951211 |
| 200g | 1.818497884 | 1.962 | -7.314073209 |
| 300g | 1.955695941 | 2.943 | -33.54753854 |
|  |  |  |  |
| 180 oUsing Eq. 3 | **Experimental** | **Theoretical** | **Percent error** |
| 100g | 1.138328122 | 0.981 | 16.03752517 |
| 200g | 2.162740281 | 1.962 | 10.23141088 |
| 300g | 3.432497906 | 2.943 | 16.63261657 |

# Conclusion

There are slight errors in the experiment which may result from one of the following reasons:

* Human errors (errors in recording time for example)
* Neglecting the weight of water (which leads to the negative percent error)
* Experimental and apparatus errors (when using a mass of 300g, the jet was not strong enough to lift the weight to its initial position, and we used the maximum that the apparatus can handle. This is why we see a large percent error for the mass 300g.