

Faculty of engineering

Mechanical engineering department

Fluid mechanics Laboratory

ENME312

Section NO.1

Experiment NO.5

**"Impact of a Jet"**

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**Abstract:**

The impact of a jet experiment shows that the water turbine can be operated by the momentum exchange between the high velocity jet and the turbine vane. Or shows the force produced by a jet of water as it strikes a flat plate or hemispherical cup or cone cup, then they can compare this to the momentum flow rate in the jet.

The apparatus which are used in the experiment are the hydraulic bench, which supply water to the vertical nozzle, and a jet of water that is generated and directed vertically towards the vane. The vane is supported by a lever carrying a jockey weight and restrained by a light spring.

The experiment is divided into three parts; the difference of the three parts is the shape of the vane. The first part a flat plate is used, and in the second part a hemispherical cup is used, and in the third part a cone cup is used.

The principle of this experiment: adjust the bench valve on the hydraulic bench into maximum and move the jockey weight until the initial balance position is restored. Then the jockey weight displacement (y) and the mass flow rate are measured. The mass flow rate is measured by adding weights on the hanger and measuring the time to raise the weigh arm. The jockey was moved several times and the time was recorded. In our experiment, these steps were done for each plate.

**OBJECTIVES:**

1. To study the flow over the three vanes, the flat plate, the hemispherical plate and the cone plate.
2. To calculate the velocity at the vane inlet and the velocity at the nozzle exit.
3. To find the efficiency of the vanes and compare with them to decide which one is more efficient than others.

**CALCULATIONS:**

 Sample calculation for the **flat plate** from run #1:

The following equation was used to determine the experimental mass flow rate:

$$ \dot{m}=\frac{m}{t} \left(1\right)$$

Where:

$\dot{m}$: The mass flow rate of water (kg/s).
$m$ : Mass of water in kilograms (kg).
t : The time needed to discharge the water from tank in seconds (s).

 Substitute $m=12kg $ and $t=20.81 s$ in equation (1) to find the mass flow rate:

$$\dot{m}=\frac{12}{22.97}$$

$\dot{m}=0.522kg/s$

The next equation was used to find the velocity at the nozzle exit:

$$ \dot{m}=a\_{0} ρ u (2)$$

Where:

$a\_{0}$= the cross-sectional area of the nozzle ($m^{2}$).

$ρ$=the density of water equals to 1000 kg/$m^{3}$.

 $u$ = the velocity of water at the nozzle exit m/s.

Substitute $\dot{m}$= 0.522kg/s, $a\_{0}=78.5\*10^{-6} m^{2}$ in equation (2) to find the velocity of water at the exit of nozzle $\left(u\right):$

$$0.522=78.5\*10^{-6}\*1000\*u$$

*u=6.655m/s*

 Then substitute the velocity at the exit in the next equation to find the velocity at the inlet:

$$ u\_{0}^{2}=u^{2}-2gs (3) $$

Where:

$u\_{0}$: The velocity of water at the inlet of the nozzle (m/s).

$u :$ The velocity of water at the exit of the nozzle (m/s).

$s :$ Height of vane above tip of nozzle (m).

 Then substitute $u=6.655{m}/{s} ,s=0.037mm and g=9.8 m/s^{2} $in equation (3) to find the velocity of water at the inlet of nozzle

$$u\_{0}^{2}=6.655^{2}-2\*0.037\*9.8$$

$$u\_{0}=6.60 m/s$$

To find the theoretical force of the flat plate:

$$ F\_{p}=\dot{m}\*u\_{0} \left(4\right)$$

Where:

$F\_{p}: $The theoretical force of the flat plate in (N).

Substitute $u\_{0}$=6.60 m/s , and $\dot{m}=0.522 kg/s$ in equation (4) to find $F\_{p}$:

$$F\_{p}= 0.522\*6.60$$

$$F\_{p}=3.45 N$$

To find the force of flat plate experimentally:

 $0.610 g y=0.1525 F$ (5)

Where:

y= distance of the jockey weight in meters (m).

F= the force of flat plate in the vane experimentally (N).

 Substitute y= 0.065m and g= 9.8 m/$s^{2}$ in equation (5) to find the force of the plate in the vane experimentally:

$$0.610\*9.8\*0.065=0.15125\*F$$

$$F=2.55 N$$

 The following equation was used to find the efficiency of the plate:

$$ μ= \frac{F}{F\_{p}}\*100\% (6)$$

Where:

$μ$: The efficiency of the plate in the nozzle.

 Substitute$ F=2.4N and F\_{p}=4.21N$ in equation (6) to find efficiency:

$$ μ=\frac{2.55}{3.45}\*100\% $$

$$μ=73.9\% $$

For **hemispheric cup** run#1:

 Substitute $m=12kg $ and $t=21.94 s$ in equation (1) to find the mass flow rate:

$$\dot{m}=\frac{12}{21.94}$$

$\dot{m}=0.547kg/s$

 Substitute $\dot{m}$= 0.547kg/s , $a\_{0}=78.5\*10^{-6} m^{2}$ in equation (2) to find the velocity of water at the exit of nozzle $\left(u\right):$

$$0.547=78.5\*10^{-6}\*1000\*u$$

$$u=6.97 m/s$$

 Then substitute $u=6.97{m}/{s} ,s=0.037mm and g=9.8 m/s^{2} $in equation (3) to find the velocity of water at the inlet of nozzle:

$$u\_{0}^{2}=6.97^{2}-2\*0.037\*9.8$$

$$u\_{0}=6.92m/s$$

To find the theoretical force of the hemispheric cup:

$$ F\_{c}=2\*\dot{m}\*u\_{0} \left(7\right)$$

Where:

$F\_{c}: $The theoretical force of the hemispheric cup in (N).

Substitute $u\_{0}$=6.92 m/s, and $\dot{m}=0.547 kg/s$ in equation (7) to find $F\_{c}$:

$$F\_{c}= 2\*0.547\*6.92$$

$$F\_{c}=7.56 N$$

Substitute y= 0.130m and g= 9.8 m/$s^{2}$ in equation (5) to find the force of the plate in the vane experimentally:

$$0.610\*9.8\*0.130=0.15125\*F$$

$$F=5.10 N$$

 Substitute$ F=5.10 N and F\_{c}=7.56N$ in equation (6) to find efficiency:

$$ μ=\frac{5.10}{7.56}\*100\% $$

$$μ=67.4\%$$

**Results:**

**Hemisphere:**

Table #1: Time in seconds, y in mm, m (mass flow rate) in kg/sec, u in m/ sec, uo in m/ sec, Force in newton (N) and efficiency in percent (%) for hemisphere.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **run** | **time(s)** | **y(mm)** | **Fexp** | **M.F.R** | **Q** | **Vnozzle** | **Vin** | **Ftheo** | **Efficiency** |
| 1 | 21.94 | 130 | 5.1012 | 0.546946 | 0.000547 | 6.967468 | 6.915177 | 7.564459 | 0.674364 |
| 2 | 22.97 | 126 | 4.94424 | 0.522421 | 0.000522 | 6.655039 | 6.600273 | 6.896236 | 0.716948 |
| 3 | 24.62 | 120 | 4.7088 | 0.487409 | 0.000487 | 6.209027 | 6.150291 | 5.995409 | 0.785401 |
| 4 | 25 | 110 | 4.3164 | 0.48 | 0.00048 | 6.11465 | 6.054998 | 5.812798 | 0.742568 |
| 5 | 27.22 | 100 | 3.924 | 0.440852 | 0.000441 | 5.615953 | 5.550945 | 4.894294 | 0.80175 |
| 6 | 28.38 | 90 | 3.5316 | 0.422833 | 0.000423 | 5.386407 | 5.318594 | 4.497754 | 0.785192 |
| 7 | 31.82 | 75 | 2.943 | 0.377121 | 0.000377 | 4.804093 | 4.727935 | 3.56601 | 0.825292 |
| 8 | 39.28 | 46 | 1.80504 | 0.305499 | 0.000305 | 3.891707 | 3.797294 | 2.320139 | 0.777988 |

**Flat plate:**

Table #2: Time in seconds, y in mm, m (mass flow rate) in kg/sec, u in m/ sec, uo in m/ sec, Force in newton (N) and efficiency in percent (%) for flat plate.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **run** | **time(s)** | **y(mm)** | **Fexp** | **M.F.R** | **Q** | **Vnozzle** | **Vin** | **Ftheo** | **Efficiency** |
| 1 | 22.97 | 65 | 2.5506 | 0.522421 | 0.000522 | 6.655039 | 6.600273 | 3.448118 | 0.739708 |
| 2 | 23.94 | 60 | 2.3544 | 0.501253 | 0.000501 | 6.38539 | 6.328291 | 3.172076 | 0.742227 |
| 3 | 25 | 55 | 2.1582 | 0.48 | 0.00048 | 6.11465 | 6.054998 | 2.906399 | 0.742568 |
| 4 | 25.87 | 50 | 1.962 | 0.463858 | 0.000464 | 5.909016 | 5.847267 | 2.7123 | 0.723371 |
| 5 | 27.41 | 45 | 1.7658 | 0.437796 | 0.000438 | 5.577025 | 5.511557 | 2.41294 | 0.731804 |
| 6 | 29.41 | 40 | 1.5696 | 0.408024 | 0.000408 | 5.197764 | 5.127457 | 2.092128 | 0.750241 |
| 7 | 30.06 | 35 | 1.3734 | 0.399202 | 0.000399 | 5.085371 | 5.013487 | 2.001392 | 0.686222 |
| 8 | 35 | 30 | 1.1772 | 0.342857 | 0.000343 | 4.367607 | 4.283696 | 1.468696 | 0.801527 |

Figure(1): Graph of Fexperimental vs Ftheoretical for hemisphere.

Figure(2): Graph of Fexperimental vs Ftheoretical for flat plate.

**Discussion of the results:**

In conclusion, after we had done the experiment and the calculation we noted that the force on the cup was always higher than that of the plate although initial velocities of fluid were close in three cases.

By graphing the theoretical forces versus the experimental forces, the slope can be easily found, which is equal to the Efficiency of the forces and we notes that the relationship between them can be approximated as linear form. This means that our results can be approximated to the theoretical values, and thus they are acceptable.

The errors may be happened through the experiment;

* Taking timing may have caused some errors because we can't be able to stop the stop watch quickly.
* Distance from center of vane to pivot by 1 mm: if the distance is less than the value that used in calculations by 1 mm the experimental force will decrease, and the efficiency will be less than it should. However, if it is more than the value that used in calculations by 1 mm the experimental force will increase, and the efficiency will be more.
* The errors in the calibrating the equipment, so it will effect on the data then it will effect on the calculation.

**Conclusion: -**

In conclusion, the experiment showed the relationship between a jet of water and the impact it had on plate that it hits. It showed that the efficiency of the hemispherical shape vane is less than 100 % which is expected because the efficiency cannot be more than 100% because there are always losses in any system. This may be resulted due to errors while performing the experiment or recording the data. Also, it was expected that the efficiently of the cup is larger than it in the plate because there is much losses with the plate because the water return in all directions but with the cup it returns with on direction only

, but our result was wrong due to errors in the experiment.

The experimental results were somewhat far from the theoretical, it was mainly errors in taking readings, or errors through calibration the device, or using the stopwatch in calculating the time.

To reduce these errors: Instead of taking time for lever manually a mechanism could be made to register the time automatically when the lever rises, and maybe placing a plate perpendicular to the nozzle could help better determine when balance is achieved.

**Appendices:**

* **Data Sheet:**

Data sheet is attached at the end of the report.

* **References:**
1. Fluid Mechanics Lab Manual.
2. Currie, I.G., 2012. Fundamental Mechanics of Fluids, 4th Edition. Boca Raton, FL: CRC Press