



Momentum Analysis: Jet Impact

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ME309

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Abstract

In this experiment we will measure the percentage of error of the jet force that is produced from the pump that acts in three different surfaces were the first surface is a flat surface and the other two surfaces are concaved with specific angles of (120° , 180°). The theoretical (actual) value of the jet force that we will use to find the percentage of error is the force that the calibrating weights is acting on the on the platform under them. The experimental value of the jet force that we will use to find the percentage of error, we are going to demonstrate the experiment theory and the procedure that we have followed for doing the experiment in the lab. Furthermore, we will do the hand calculation for our experimental and theoretical results. Finally, we will discuss the hand calculation results and graphs and put some future plan to increase the accuracy of the experiment.

Objective

The objective of this experiment is to calculate the theoretical value and the experimental value of the jet force in order to calculate the percentage of error in the jet force in order to observe and verify the conservation of momentum principle and to analysis the values we get.

Introduction

The purpose of momentum analysis: The Jet Impact experiment is to demonstrate the momentum equation of the experiment. The device we used to find the resulting jet force is shown in (Figure1).



Figure 1: The Impact of Jet Device

by using the force that is pumped on the surfaces of different angles, we calculated the force generated by the jet. Furthermore, this experiment shows the effect of the jet and the reaction of the pushed water on the surface. After that, we will compare between the experimental and theoretical results. The possibilities are going to be investigated by:

- Impact of flat surface angle = 90° .

- Impact of surface of 120° .
- Impact of surface 180° .

Theory

The water is deflected to flow along the surface when a jet of water flowing with a steady velocity strikes a solid surface. The magnitude of the water velocity is unaltered if friction is neglected by assuming an inviscid fluid and it is also assumed that there are no losses because of shocks. The water velocity is not changed if the friction is discarded by assuming an undisclosed fluid and also assuming no shock losses. At right angles to the surface, the pressure exerted by the water on the solid surface will everywhere be. As shown in figure 2, a jet of water which effect on to a target surface is causing the direction of the jet to be changed through an angle θ . In case of friction, the volume of the speed across the surface is equal to the speed of the accident. The momentum exerted on the target will be equal and opposite to the force working on the water to bring about a change in direction.

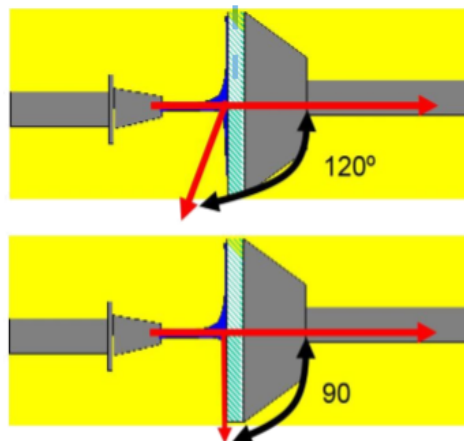


Figure 2: The Turning Angles for Two Different Impact Surfaces

Equation 1 F jet exp

$$(1)$$

Where,

- (F_j) is the force generated by the jet impact in (N).
- (ρ) is the density of the fluid. For water $\rho=1000 \text{ kg/m}^3$.
- (Q) is the volumetric flow rate in m^3/s .
- (V_{jet}) is the jet speed in m/s .
- (α) is the turning angle of the jet.

The jet speed in Equation 1 can be found by knowing the volumetric flow rate which is:

Equation 2 V_{jet}

Where,

- (A) is the nozzle exit area in m^2 .

The jet turning angle α in Equation 1 is determined from the geometry of the impact surface as illustrated in figure 2.

Equation 3 F jet theo

where m is the mass and g is the gravitational acceleration (9.81).

Equation 4 error percentage

❓ Rig Specifications:

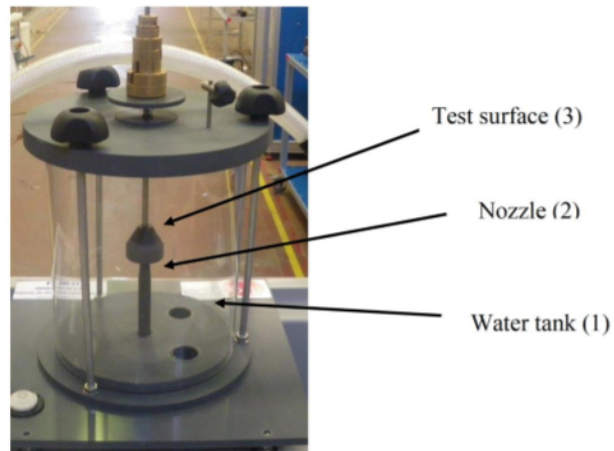


Figure 3: Description of the Various Components

As shown in Figure 3, The attachment consists of a cylindrical tank (1) with transparent side surfaces where a nozzle (2) connected to the FME00 hydraulic seat is aligned with a device with the test surface (3).

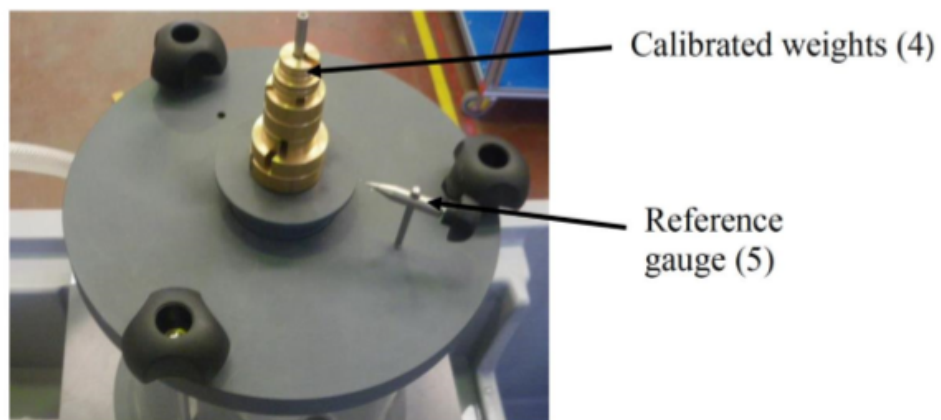


Figure 4: A Close-up Views on the Top Part of the Equipment

As shown in Figure 4, The vertical force produced by the water against the surface is measured using the calibrated weights (4) that balance this force, with reference gauge (5) to the previously measured scale as a zero reference, a sign that appears on the surface of the masses.

Specifications

- Jet diameter: 8 mm
- Impact surfaces diameter: 40 mm
- Impact surfaces:
 - ☐ { Hemi-spherical surface of 180°
 - ☐ { Curve surface of 120°
 - ☐ { Flat surface of 90°
- Weight set of 5, 10, 50 and 100 grams.

Procedure

The steps of this experiment are:

- 1- Disassemble the top cover that is placed over the transparent water tank and screw in the desired Impact surface in the vertical axis joined to the support on which the weights are placed, and cover the tank again.
- 2- Place the device on the Hydraulic Bench FME00 channel and connect the inlet to the water supply.
- 3- Balance the equipment using the help of the bubble level placed on the cover of the cylinder to do this, regulate the height of the adjustable supports until the bubble stabilizes

in the center of the gauge

- 4- Adjust the gauge until it is situated at the same level as the mark of the auxiliary platform.
- 5- Place on the platform a weight and note down its value.
- 6- Close the flow control valve of the FME00 and then switch on the pump.
- 7- Regulate the flow that impacts the surface to get the platform mark at the same height as the gauge indication, that is to say, it must come back at its initial position.
- 8- In this balanced condition, measure the outlet flow through the nozzle. For that purpose, close the Drain of the hydraulic bench and take measurements of the accumulated volume in a known time, obtaining in this way the liters accumulated per unit time
- 9- Repeat the previous steps increasing step by step the weights. Do this for 4 different flow rates.

Results

By using the equations that are mentioned in the theory part we are going to find the values of F_{jet} as following in the below table (1).

Table 1 F_{tho} Vs F_{exp} for $\theta = 90^\circ$

Theta = 90°					
Trial	Q (m ³ /s)	m (Kg)	V _j (m/s)	F theo (N)	F exp (N)
1	0.000294	0.03	5.854252529	0.2943	1.721839
2	0.000323	0.06	6.420793096	0.5886	2.071224
3	0.000333	0.075	6.634819533	0.73575	2.211607
4	0.000385	0.12	7.655561	1.1772	2.944447

5	0.000606	0.55	12.06330824	5.3955	7.311096
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Table 2 Ftho Vs Fexp for theta =120 degree

Theta = 120°					
Trial	Q (m ³ /s)	m (Kg)	Vj (m/s)	F theo (N)	F exp (N)
1	0.000244	0.03	4.854746	0.2943	1.776127
2	0.00027	0.045	5.379583	0.44145	2.180912
3	0.000314	0.1	6.259264	0.981	2.952483
4	0.00037	0.145	7.372022	1.42245	4.095568

Table 3 Ftho Vs Fexp for theta =180 degree

Theta = 180°					
Trial	Q (m ³ /s)	m (Kg)	Vj (m/s)	F theo (N)	F exp (N)
1	0.000222	0.06	4.4232	0.588	1.965
2	0.00025	0.07	4.976	0.686	2.488

3	0.000291	0.115	5.786	1.128	3.364
4	0.000325	0.155	6.4624	1.520	4.1964

Table 4 error percentages

Trial	Theta = 90°	Theta = 120°	Theta = 180°
	Error %	Error %	Error %
1	82.90781	83.4302	70.0591
2	71.58202	79.7585	72.40015
3	66.73233	66.7737	66.46461
4	60.01965	65.2686	63.76554
5	26.20121	-	-

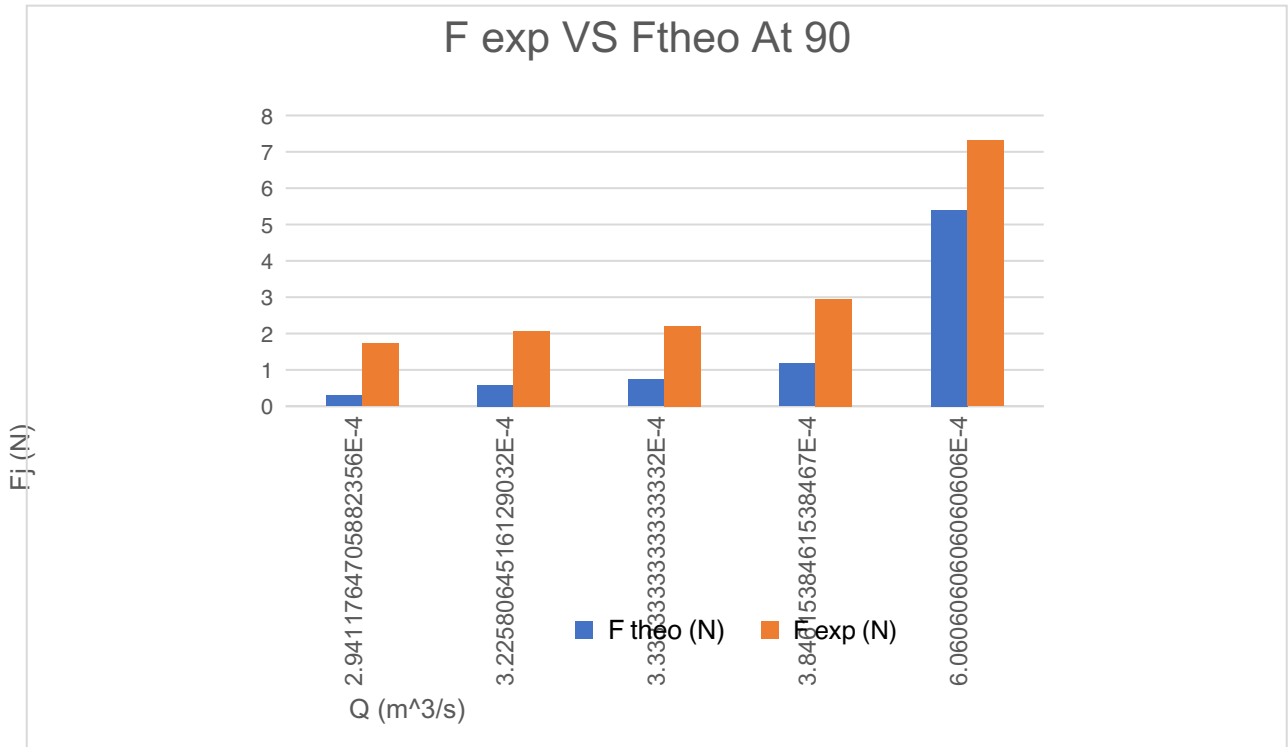
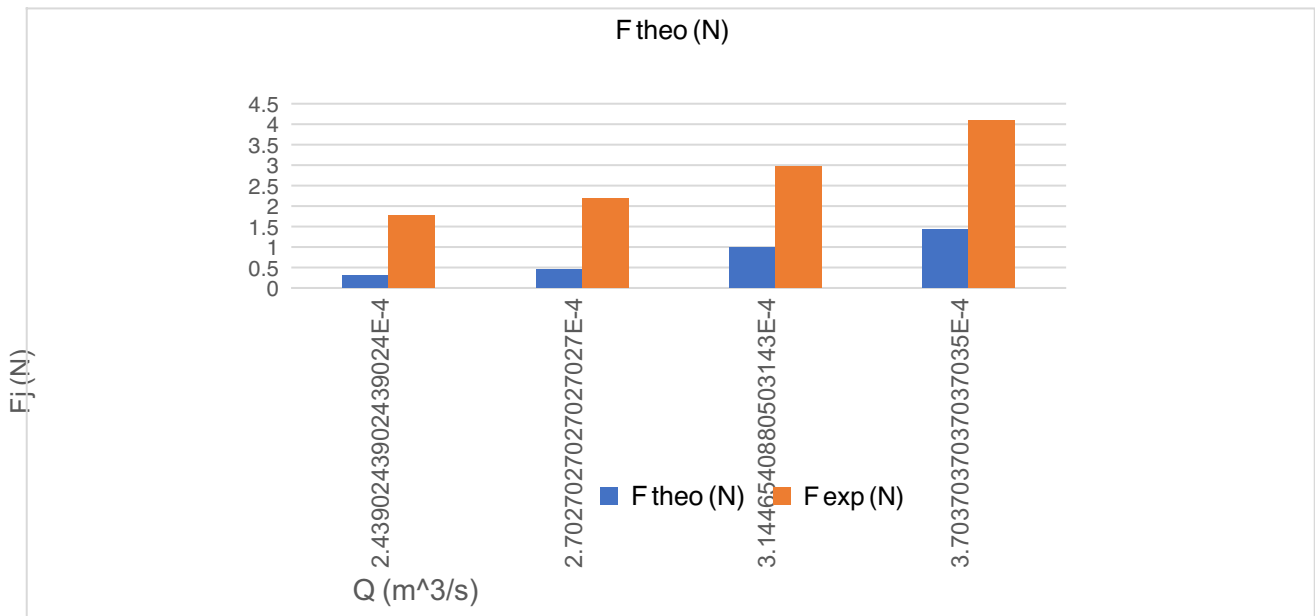


Figure 5 Fexp Vs Ftheo at 90 degree



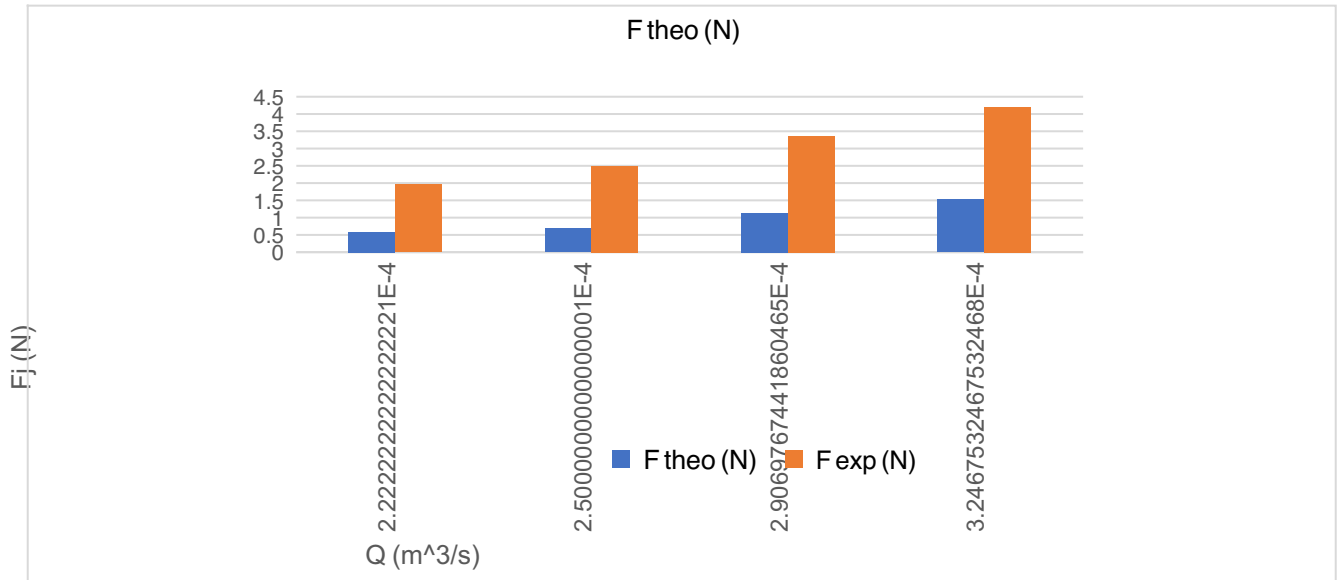


Figure 7 Fexp Vs F theo at 180 degree

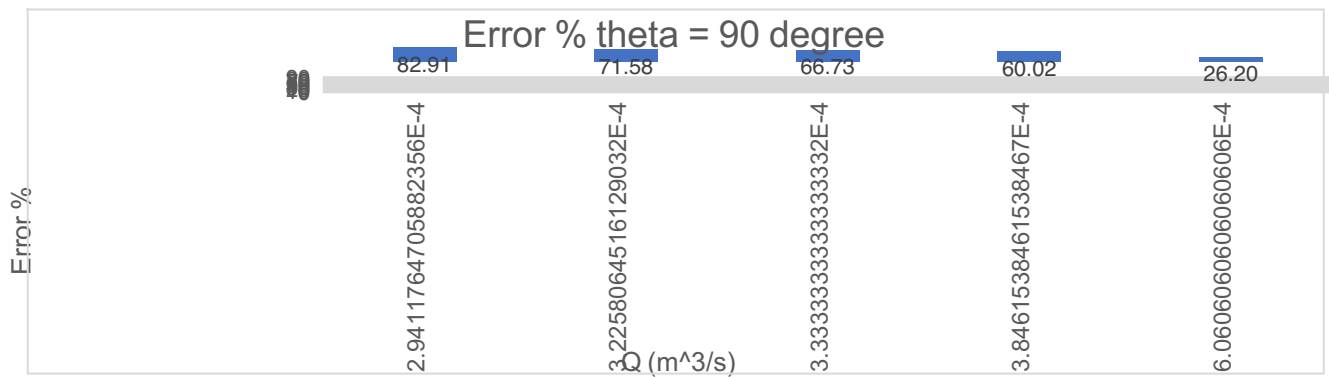


Figure 8 Error % for theta = 90 degree

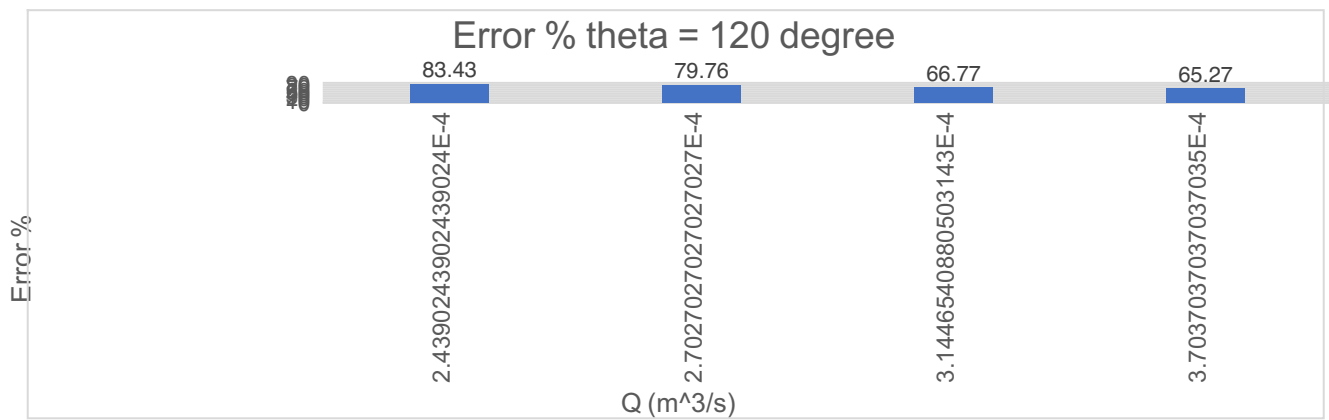


Figure 9 Error % for theta = 120 degree

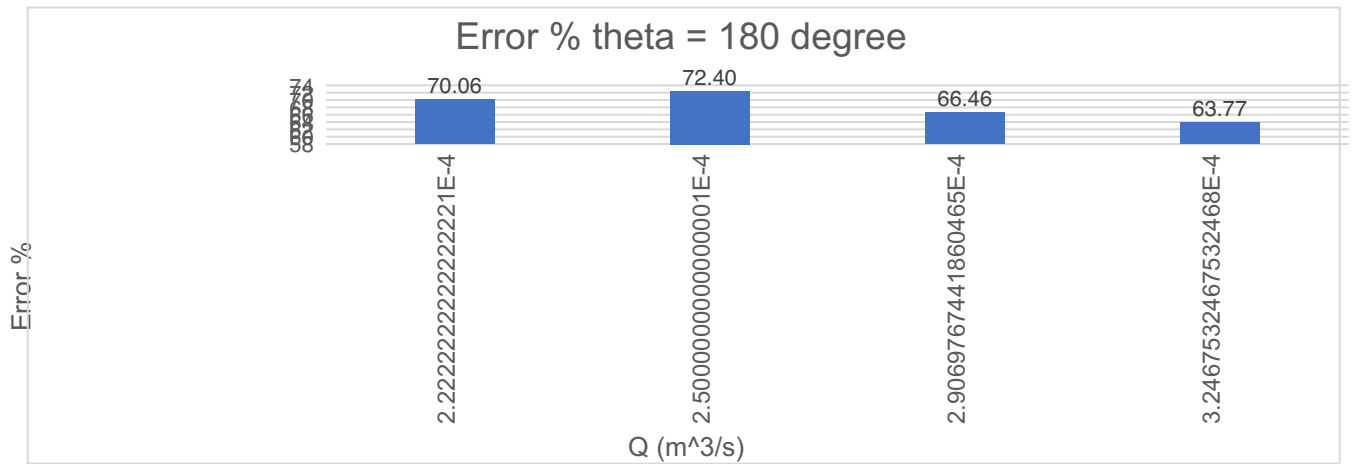


Figure 10 Error % for theta = 180 degree

Discussion

There are a lot of reasons that cause the high values of percentage of error that we get in this experiment; because the device that we were working with is not very accurate especially for the small masses. An example of reasons are that the flow rate that we are getting from the water pump is not steady, the friction that is between the cover of the tank and the rod that is connected to the platform. The bubble was not exactly in the center of the circle. Not accurate values of the water flow rate. Another reason of the percentage of error that the flow rate that we get from the water pump was not stable; because of that the values of the of the flow rate that we have calculated were not accurate and by using this inaccurate values. we get inaccurate values of the velocity of the water and the experimental values of jet force and by this the percentage of error increases.

In other words, we can summarize the sources of error as following:

- 1- The air bubble wasn't in the center 100% (unbalanced system)

- 2- There was resistance between the rod and masses that resist the movement on the spring
- 3- The roundness of gravity or the density
- 4- The device is not sensitive to the small masses
- 5- Human error while taking the time for the flow rate
- 6- Specifications of masses which is 5 grams as minimum mass
- 7- The sink valve is not closed perfectly while taking flow rate
- 8- Impact surfaces has a deformation in the angles
- 9- Neglecting some conditions that affect the experiment like Temperature and friction and the velocity changes

As a result of that, we think the main source of error is because the device is no sensitive for the small masses. In fact, the average error of percentage is around 65 %. However, when we increased the flow rate to a high value at $\theta = 90$ degree; we found that we got 26.2 % which give us a hint about the most significant source of error.

Conclusion

To sum up, the experiment was to demonstrate the linear momentum equation. The generated force by the deflected water jet on the impact surface is measured and compared to the momentum change of the jet. To do the experiment, there are certain procedures have to be done to

get the reading and safety instructions have to be followed. The readings for this experiment were repeated five times for each angle (90-120-180) degrees to verify the results. The results compared to the theoretical one and error percentage was obtained. The values of the error were so high and that due to many sources of random and systematic error. Also, the errors occur because of the assumptions made about neglecting the friction and considering the velocity unchanged. We have learnt many things from this experiment; the first thing that we have learnt is using some formulas and equations that we have studied in class in real life situations. In addition, we have learned how to analyze the results in order to discover the error sources to avoid repeating them in the future. Finally, as a future plan we recommend to use some digital electrical sensors to take the reading from it in order to increase the accuracy. Furthermore, we recommend to make the experiment on higher flow rates hence, we will have higher values of masses that can reduce the error percentage significantly.

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