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Design and Fabrication of a Cavitation Demonstrating Apparatus

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Abstract:- In order to better understand cavitation, this research focuses primarily on the design and manufacturing of cavitating demonstration apparatus that will aid in establishing cavitation's underlying causes and effects. To be clear, this project is purely experimental and is best suited to mild steel for the frame and a centrifugal pump with variable pressure settings, as well as tanks (both suction and discharge tanks) and pipes to transport the fluid through a vented tube (the venturitube itself). From a 0.5hp input and pump speeds of 2850rpm, 950rpm, etc. It was possible to illustrate the circumstances for cavitation in order to estimate the cavitation index by allowing water to flow through a text section (venturitube) and obtaining pressure measurements at both the intake and constriction. Under one, it has been observed that cavitation can be noticed (1). Increasing velocity at a constriction causes the pressure head to decrease in a similar manner, as can be seen from the experimental findings presented in tabular and graphical form.

Keywords:- *Cavitation, venturitube, cavitation index, pressure head.*

I. INTRODUCTION

When it comes to hydraulic phenomena, cavitation is one that can have both unwanted and damaging outcomes. Cavitation is described as a break in the continuity of a liquid at a considerable local pressure drop. The formation of bubbles (cavitation) in liquids can begin even when positive pressures equal to or close to the pressure of saturated vapor of the fluid at the given temperature are present (Fitch, 2002). However, it is true that in some cases, its properties are used for a positive purpose, such as restricting the capacity of particular centrifugal pumps. But in most circumstances, the emergence and expansion of cavitation sets an upper limit on hydraulic equipment performance that impedes the engineer from accomplishing many beneficial tasks. Cavitation has a long list of negative side effects. Hydraulic structures and machinery are among the most generally recognized and economically significant effects. Because cavitation damage is so prevalent and so severe, many people consider it to be the phenomenon itself rather than the result of cavitation (Robert, 1955).

Cavitation can occur in any type of hydraulic equipment whenever there is a restriction in the flow of fluid that causes a decrease in pressure, which can cause a fluid to reach its vapor point. However, most hydraulic machines are designed and built without considering the effect of cavitation on the materials used or how to minimize this phenomenon through design.

Cavitation happens when a pressure drop caused by an external force causes a vapor pressure drop, which causes the vapor bubbles to forcefully collapse, and then the fluid returns to a liquid condition. An extremely high-velocity jet of liquid is created by the rapid, uneven collapse of the vapor bubble. This jet can harm surfaces because the low energy it contains is so intensely focused (Ganz, 2012). Because of the shock waves generated by the vapor bubble collapsing, there is also undesired sound and vibration. In addition to damaging mechanical equipment, cavitation can also cause damage to autos and maritime vessels (ships and submarine blades). Flashing or cavitation can occur regardless of the type of liquid being used (Ruiker, et al 2019).

The pealing of the metal surface causes cavitation-induced metal degradation to be uneven and erratic. A single collapse of vapor bubbles may not cause any harm, but repeated collapses of vapor bubbles can lead to serious equipment damage. Metal surfaces like as iron and steel are damaged by cavitation as a result of cavitation. The cavitation wear process necessitates surface deterioration and material displacement caused by large relative motions between a surface and an exposed fluid. Such movements reduce the local pressure of the fluid, allowing it to rise over the boiling point and generate microscopic vapor holes (Fitch, 2002). When excessive energy is released during cavitation, it destroys and erodes the system's solid components, as may be seen in pumps, turbines, and dams (Julien, 2005). As a result, hydraulic machine designers and engineers in general must deal with the problem of cavitation on an individual basis. Product design in particular for cavitation-prone equipment necessitates an extensive investigation of material and process possibilities, unlike previous methods when a single designer was responsible for the majority of design.

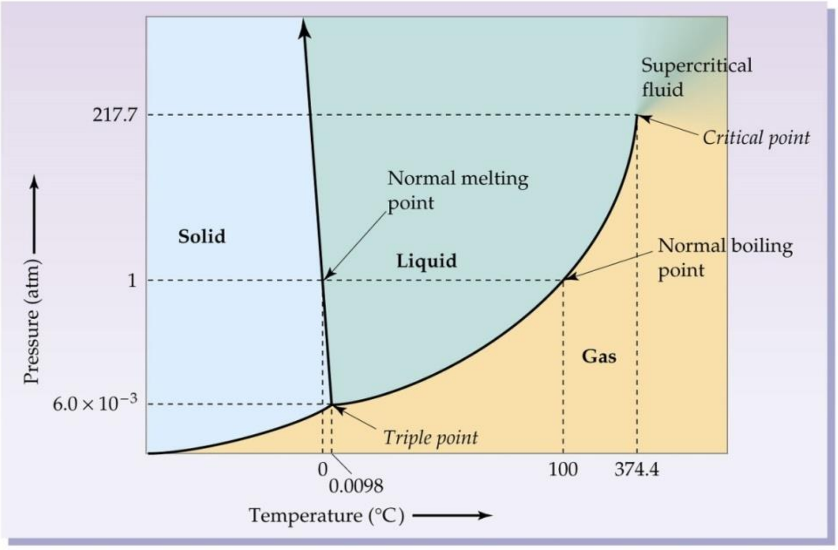

Fig. 1: Cavitation in water is depicted in this phase diagram.

Source: *(http://wps.prenhall.com/wp-media/objects/4678/4791085) ch10 11.htm)*

The solid state of the fluid (water) is depicted in sky blue, the liquid state is shown in dark blue, and the vapor state is shown in brown in the above pressure-temperature diagram. As the temperature of the system changes, tshe fluid will begin to evaporate or vaporize at a specific temperature, depending on the type of fluid being heated. As a matter of fact, water is an incompressible fluid that vaporizes at 100 degrees Celsius at constant air pressure, which we'll use as an example here. It's at this stage that the water boils and doesn't move.

With constant pressure, however, any dissolved air in water is observed to be expelled as vapor bubble when the pressure falls below that of the fluid's vapor pressure, which means that pressure decreases to approximately the level of liquid vapor pressure. After the initial development of the bubble, the vapor bubble implodes and returns to liquid state. An indentation formed by recovery pressure causes the bubble to break open, releasing a stream of liquid. Right now, cavitation is taking place.

Using the proper production materials can help design engineers limit the risk of cavitation damage. As an alternative to aluminum, stainless steel might be utilized (Figure 2.0), with a robust facing and a cavitation-resistant alloy on the exposed surface. Rubber and other elastomeric coatings have also helped to prevent cavitation wear. These surfaces, despite their low cavitation resistance, reflect the shock wave and do not cause considerable harm.

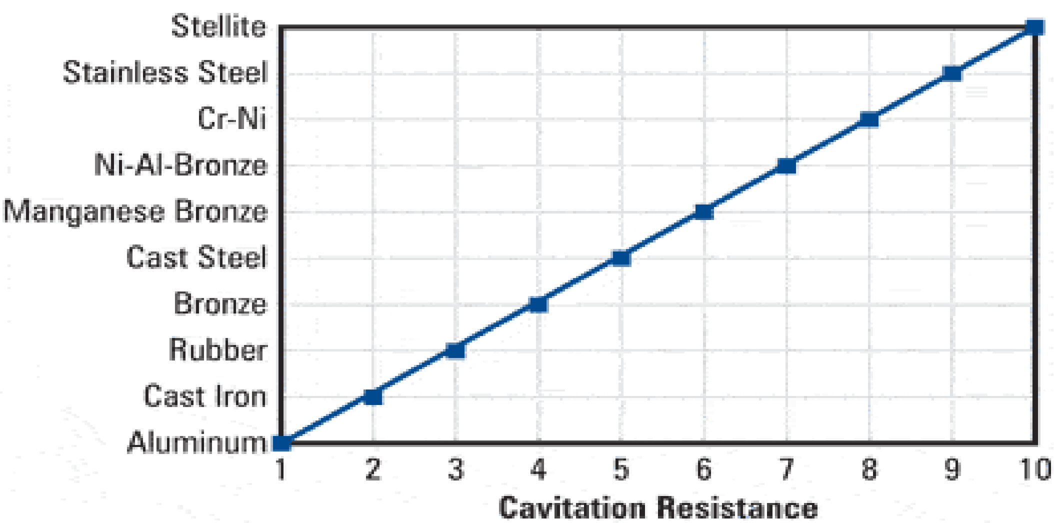

Fig. 2: Order of relative resistance of material

(Source*: https://www.machinerylubrication.com/Read/380/cavitation-wear-hydraulic*)

Hydraulic machine designers should have extensive knowledge of cavitation because it is a unique problem in engineering. Fluid mechanics students' incapacity to link their theoretical understanding to real-world difficulties has caused a moment of concern since students with little or no practical experience of their field of study (mechanical engineering) will find it difficult to practice engineering.

To connect the theoretical and practical aspects of cavitation in fluid mechanics has been a challenge for most mechanical engineering students in higher education. As a student, you have just a theoretical understanding of cavitation (fluid mechanics) but find it difficult to apply this knowledge to the real-world application. As a result, a device to show this fluid phenomenon is required in order to bridge the gap. Using the cavitation apparatus, students can learn about cavitation's basic principles and the impact they have on hydraulic machines' performance. This is done by examining the causes and effects of cavitation, which the cavitation apparatus makes simple to grasp. It is possible for students to observe the cavitation phenomena, measure flow and pressure, and learn about the origins and effects of cavitation through both theoretical and practical experiments. The hydraulic system's flow and pressure can be calculated using Bernoulli's equation, the continuity equation, and the actual measurements. Using the cavitation demonstration equipment, researchers have been able to better understand how to anticipate the beginning of cavitation and its impacts through both theoretical and experimental investigations.

This apparatus has played a critical role in helping mechanical engineering students and hydraulic machine designers around the world better understand cavitation's causes and effects through hands-on experiments and in learning how to predict when cavitation will occur. This knowledge has been invaluable to both groups.

It was necessary to develop cavitation demonstration equipment in order to better explain the phenomenon. Sump tank, pump, and other components make up the self-contained water-recirculation system of this device. A Flow control valve and a by-pass valve are used to control the water flow in order to conduct the experiment at different flow rates. In order to create cavitation, the most basic tool is the Venturi tube. The liquid is accelerated from the point of input into the tube to the point of exit through the throat. This leads in a decrease in the pressure that is necessary to develop a cavity. After exiting the throat, the flow is decelerated and reaches the diffuser, where the rise in pressure generates the necessary circumstances for cavity collapse. An indentation formed by recovery pressure causes the bubble to break open, releasing a stream of liquid. This implosion generates high local pressure waves. The combination of a local pressure wave and micro jets can seriously harm mechanical components or bodies if they are placed near the surface of the material.

Conversion and diversion components of an acrylic test section make up part of the lab set-up. Pressure tapings are used to measure the line pressure during the test. Water flow rate in the upstream channel can be modulated using a control valve in the test section. Two pressure gauges display the pressure by the use of pressure tapes attached to the gauges. There are two pressure gauges linked to the pressure tapings that show the pressure at the moment the flow passes through the test section of the test.

II. CAVITATION WEAR IS POSSIBLE

According to Fitch (2002), the following are some of the sites in hydraulic systems that are susceptible to cavitation wear:

- Reduced cross sections with subsequent expansions (in cocks, flaps, valves, diaphragms) and other deformations in all devices where fluid flow is subjected to extreme twisting are found in rapidly moving actuators (including linear and rotary types).
- A condition known as wire-drawing can occur in leakage paths (such as across seals, valve seats, and the spool lands of valves) where high velocities cause pressure levels to drop below the fluid's vapor pressure (a cavitation condition known as wire-drawing).

Cavitation is a problem in fluid-type mechanical systems because it disrupts normal functioning and degrades component surfaces. A cavity forms while pressures are low; subsequent bubbles form when pressure is stabilized, and finally the cavities (gaseous or vaporous bubbles) collapse when high pressure is applied to the cavities.

III. MATERIALS AND METHODS

A. Materials

With regards to the proposed apparatus and the components required for its construction, it is critical to make the appropriate material selection to ensure a high quality standard and a long service life, as well as to minimize initial and ongoing costs, material performance, availability, and environmental impact. The materials used in this apparatus are chosen depending on the nature of the design and the components required for the apparatus, as well as on other mechanical and chemical features such as shear stress, corrosion resistance, weight, and ability to sustain fluctuating high pressures.

There are six different types of material required for this design, and their attributes will help guide the decision process. The materials chosen are determined by the type of equipment and the application.

a) Procurement

The materials chosen were chosen with the goal of keeping transport costs to a minimum; the heavier or more bulky the materials, the higher the shipping cost; thus, the heavier or more bulky materials were found locally.

- **Availability:** materials are chosen depending on their availability, as this effects material selection selections, and as lengthy lead-in times were permitted, since delays can result in project delays, cost overruns, and even energy loss.
- **Cost:** Cost considerations encompass both the initial purchase price and the material's life cycle cost. This life cycle encompasses all aspects of

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operation, including maintenance, replacement, demolition, and disposal.

The materials chosen are chosen for their inherent properties that are required for this type of project.

- Stainless steel
- Vinyl Chloride Polyvinyl Chloride
- Glass Fiber

- **Mild steel:** Steel is a composite material composed of carbon and iron, with a far higher proportion of iron than carbon. Mild steel is a widely used construction material. It is extremely robust and may be constructed using easily accessible natural resources. Mild steel is extremely strong and resistant to shattering due to its low carbon content. Additionally, mild steel is extremely malleable, which results in a material with a high tensile and impact strength. Mild steel is more desired and a better choice for building purposes due to its machinability, weldability, and polishability. (Scott, David, 2018).
- **Polyvinyl Chloride (PVC):** Polyvinyl is a brittle polymer that comes in two kinds during manufacturing: rigid and flexible. The rigid kind is a tough, robust substance that is resistant to chemical deterioration and weathering. It is frequently utilized due to its low cost and excellent physical, chemical, and weathering characteristics. (2005) (MuskeshDoble et al.)

Fiber glass was chosen specifically for the venturi tube due to its low coefficient of thermal conductivity, strong tensile strength, and dimensional stability. Additionally, due to the effects of cavitation on materials, cavitation damages materials it comes into contact with, particularly metals, necessitating the use of fiber glass. Most significantly, the equipment is intended for demonstration purposes, and as such, clarity is required regarding the location of the cavitation.

b) Equipment

The equipment is portable and self-contained. A water tank (or reservoir), an electric pump, a flow control valve, a flow meter, and a Venturi are all contained within a robust frame constructed of mild steel hollow squire inch pipe. The frame includes a convenient tabletop for the pumps regulator. Pressure gauges display the pressure upstream of the Venturi and the pressure at the Venturi throat. Both the suction and discharge tanks are equipped with a thermometer that indicates the water temperature in the tank. The water tank is equipped with a splash cover to prevent water leakage, and the pump is protected electrically. Additionally, there is a roller to facilitate the apparatus's mobility. The hydraulic bench, water tank (reservoir), electric centrifugal pump, two flow control valves, pressure gauge, venturitube, PVC pipes, pipe fittings (adapters), acrylic gum (binder), and bed roller casters are required for this project.

c) Selection of Materials and Specifications

Due to the fact that the components (electric centrifugal pump and water tank) will be mounted on the bench, the load will induce stress on the hydraulic bench. As a result, a material must be chosen that will remain rigid and stiff with sufficient load bearing capacity under varying tension or load, and this material will be chosen based on its availability and market need.

After establishing the material criteria, screening and ranking the surviving materials, the materials required to create the hydraulic bench (framework) are mild steel. It was selected for its hardness, elasticity modulus, thermal strength, fatigue strength, and shear modulus. And the water tank (or reservoir) will be constructed of aluminum due to its less weight and greater strength than stainless steel. Polyvinyl chloride will be used to construct the piping system (PVC).

B. Techniques

a) Consideration of Design

Taking into account that the materials chosen are based on their inherent properties that are required for this sort of apparatus. These factors include accessibility, material cost, mechanical qualities, production consideration, physical properties, and machinability, among others.

S/N	Component	Chosen Material	Considered factors
1	Hydraulic bench	Mild steel	Cost, machinability, high strength in tension and availability
2	Venturitube	Transparent fibre glass	High strength in compression and high thermal conductivity
3	Screw	High carbon steel	High strength in tension and shear
4	Reservoir	Transparent fibre glass(Plastics)	High strength in ductility and durability
5	Pressure gauge	Transparent toughened glass	High strength in compression and high thermal conductivity
6	Polyvinyl chroride Pipe	Rubber	High compressive strength and can stand the test of time
7	Fluid flow control valve	Brass mated	Corrosion resistance
8	Manometer	Transparent glass	High strength in ductility and durability

Table 1: Chosen Materials for the Components of the flow channel

(Source: www.google.com/search?q=properties+of+mildsteel+fibreglass+rubber)

a. Design of the Bench Frame

The bench frame is a metallic structure that is made from mild steel based on its cost effectiveness and availability. A hollow square pipe with dimensions of approximately 1219mm long by 406mm wide by 1219mm high. The bench frame is designed with the intent that it could support the whole components that would make up the apparatus, considering the stress built up on the system. The mild steel has a density of $7850kg/m^3$, young modulus of 200GPa and poison ratio of 0.303.

The force which the material can withstand is calculated as follows.

$$F_m = Mg \quad (1.1)$$

Where F_m force of mild steel in newton (N), M is the mass in kilogram (kg), g is the acceleration due to gravity (m/s^2).

$$M = \square v \quad (1.2)$$

Where ƒ is density in (kg/m^3), v is volume in (m^3)

$$v = lht \quad (1.3)$$

Where, l is length (m), h is height (m), t is thickness (m)

$$A\_b = l(d_o - d_i) \quad (1.4)$$

Where A_b is area of the bar (m^2), d_o is the distance of the outer square (m), d_i is the distance of the inner square (m)

Therefore the weight of which the bar can withstand must not exceed 100N.

b. Design of the Reservoir Tank

This component houses the hydraulic fluid needed for the operation of the system. There are two tanks needed for the setup of the apparatus (suction tank and the discharge tank). And the two tanks are made up of aluminum due to its resistance to corrosion. With the suction tank having a dimension of the length, width, height as 500mm,406mm, and 295mm respectively. And the discharge water tank having a dimension of the length, width, height, as 335mm, 294mm, and 406mm respectively. This two tanks are built to contain of capacity of 60liters and 40liters of water respectively. This component houses the hydraulic fluid needed for the operation of the system. The volume of the rectangular reservoir is

$$V_s = h_s l_s b_s \quad (3.5)$$

Where; V_s is the volume of the suction tank in mm^3.

h_s is the height of the suction tank in mm.

l_s is the length of the suction tank in mm.

b_s is the breath of the suction tank in mm.

For the discharge tank, the volume of the rectangular

c. Design of the Pipe

The piping system which will connect the components of the apparatus is made of polyvinyl chloride in which the diameter of the pipe connecting the pump to the reservoir depends on the diameter of the suction head of the pump.

Pipe outer diameter, D_o= 32 degrees

Pipe inner diameter, D_i= 25 degrees

Pipe thickness, t= 7mm

d. Fluid Losses in Pipes

The fluid loss of head due to the bend in the pipe is calculated as

Loss due to bending in pipe $h = (kv^2)/2g \quad (1.7)$

For 0.5KW pump,

The discharge $Q = AV \quad (1.8)$

Where V is velocity of fluid flow (m/s).

Calculating loss of head due to pipe friction h_f.

Power P = Qwh_f

$$h\_f = P/Qw \quad (1.9)$$

Where Q = rate of discharge (m^3/s), h_f is loss due to pipe fitting (m)

The velocity of the fluid passing through the pipe V = $\frac{Q}{A}$

The fluid loss of head at the entrance of the pipe is given as

Loss of head at the entrance $h_i = 0.5v^2/2g \quad (1.10)$

The fluid loss of head at the exit of the pipe is given as

Loss of head at the exit $h_e = v^2/2g \quad (1.11)$

b) Construction method

This project is time bound as such requires a project plan and management. In order to achieve this project, there are processes and actions needed to implement the project which comprises the planning, implementation and analysis that must be followed and they include;

- **Research:** This process involves the sourcing of information, gathering of data, reviewing of the gathered data from the internet or other sources to gather the knowledge needed in the construction of the press machine.
- **Data compilation:** In this process, the acquired data from research is compiled and examined to arrive at a particular sequence of operation. Data compilation gives the designer the step by step method for the creation of a machine.

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- **Material selection:** This process involves the cost of materials selected for the production process and aims at lowering cost of production while boosting quality and reliability of the selected material.
- **Design:** After selection of materials, the parts selected are considered and their dimensions calculated, The sketch of the apparatus will be drawn on a sheet with the required dimensions and then if critical components like a shaft exists in the design, then forces, reactions, moments, torque acting on the shaft are considered.
- **Construction:** At this stage, work is done on the different pieces that constitute the system to bring them to a proper shape and size necessary for the design. The procedure for fabrication includes marking out operation, metal casting operation, cutting operation, drilling operation etc.
- **Marking out operation:** The marking out of the required measurements or requirements for the bench, water tank and pipes on the material received. This technique entailed marking dimensions and punching out locations on the metal we used to create the structure. Marking out is required since it indicates where to cut, shape, drill, or weld.
- **Cutting operation:** This step entails measuring and marking dimensions, as well as providing essential clearance. The steel rule, bench vice, hack saw, power hand grinder, and drilling are all examples of equipment or tools used in this operation. This operation entailed lowering the cross sectional area of the indicated materials; this included cutting the transparent fiber glass to the desired size for the hydraulic bench. This process was carried out using both a manual and an electric saw.
- **Drilling:** Drilling is a cutting technique that utilizes a drill bit to create or enlarge a circular cross-section hole in solid materials. Drill bit is a rotary cutting instrument that is frequently multipointed. During this procedure, holes are drilled in components to fulfill a purpose, such as drilling holes in the upper flat plate to allow it to be locked to the hydraulic bench through nuts, or drilling holes in the base plate to secure the engine and tires.
- **Assembling:** This step entails assembling all of the system's various elements or components. This stage entails welding, followed by abrasive screwing and finishing processes.
- **Welding operation:** This step requires precisely aligning the cut metals and welding them with an electrode after testing for alignment with a try-square. The operation was conducted safely, with the use of a welding shield, gloves, and coveralls. Welded components include a hydraulic bench and a metal flat plate, among others.

C. Experimentation

Install the cavitation demonstration device on top of the hydraulics bench. Connect the pipe and one of the bourdon pressure gauges on the left hand end of the cavitation demonstration equipment to the water outlet on the hydraulic bench, which is pushed by the centrifugal pump (it will be necessary to add a valve and a connector before screwing the fitting onto the outlet in order to aid disassembling). Remove the union on the valve to separate the pipe tube from the cavitation demonstration device during installation. Ensure that the union is tightened after reassembly (hand tight only).

To minimize interruptions in the volumetric tank, position the venturitube at the top of the hydraulic bench and the pressure gauge to measure tube at the right hand end of the cavitation demonstration apparatus within the hydraulic bench's volumetric tank, with the end inside the stilling baffle.

While operating the cavitation demonstration apparatus at or near the liquid's vapour pressure, the vacuum gauge will be slow to respond. This is because when the gauge is operated at vapour pressure, the liquid contained within the gauge converts to water vapour, a process that takes time. When pressure is increased and cavitation is terminated, the impact is more evident - there is a delay before the vacuum gauge reading changes after cavitation is plainly and audibly terminated in the test area.

- Experimentation

The following steps outline how to conduct an experiment to generate and detect cavitation in a water-circulating piping system.

To begin, all valves on the entire line were entirely opened except for the inlet valve to allow for easy circulation of water throughout the pipe system and text component. Then, in order to calculate the flow rate, the control valve on the discharge tank on the hydraulic bench was closed. The regulator was used to activate the pump, and the speed produced by the pump was varied. As water passes through the cavitation apparatus, it is noted that the clear acrylic test section and flexible connecting tubes are completely filled with water and contain no air. To maximize system flow, the input valve is gently opened until it is completely open. A milky deposit in the throat indicates the presence of cavitation. Additionally, it is observed that the cavitation was followed by a loud audible crackling sound. It is noted that observable cavitation occurs during the test section's expansion, not in the throat, where the pressure is lowest (with the exception of the pressure tapping hole in the throat that causes a local disturbance to the flow). The temperature of the water at the outlet (that is, the temperature of discharged water) was measured and recorded using a thermometer. The procedures were repeated by raising the speed of the electric pump and observing the entire process. The pressure of the water upstream (P1 in Bar), the pressure at the throat (P2 in Bar), and the pressure of the water downstream (P3 in Bar) (P3 in Bar). By timing the collection of a known volume of water, the flow rate was determined (Of about 3mm in height from the discharge tank). When the pressure at the back of the neck reaches the vapour pressure of water, visible and audible changes occur (air bubbles released from the water at higher static pressure make a softer noise that is not true cavitation). Additionally, when the flow of water rises, the pressure in the neck does not continue to fall below the water's vapour pressure. The input diaphragm valve observations are made together with the properties of the water until the valve is fully opened and the maximum flow of water is obtained. As the pressure climbs above the vapour pressure of the water, the inflow diaphragm valve is gradually closed and cavitation is observed to halt (again there will be a long delay before the reading on the pressure gauge starts to fall because vapour inside the gauge is converting back to water). Close the inlet diaphragm valve until water flows slowly through the apparatus without cavitation in the test section (usually 0.1 Bar on the upstream gauge P1), ensuring that the test section remains full of water. The outflow ball valve is completely shut off (the valve is perforated to allow water to flow when fully closed). The process is repeated with a different setting of the exit ball valve (partially closed). At the conclusion of the experiment, the hydraulic bench's flow control valve is closed, and the pump switch is likewise switched off.

IV. RESULTS AND DISCUSSION

A. Results

Cavitation is depicted by pushing water through a contraction, which lowers the water's static pressure. Any dissolved air in the water is released as bubbles when the static pressure is decreased. When the static pressure is lowered to the water's vapor pressure, severe cavitation (water vaporization) ensues. The static pressure in the test segment is raised by limiting the flow downstream of the test section. When the static pressure is held above the vapor pressure, the flow rate through the test section can be raised without cavitation.

The lab set-up comprises of a test section which is made of Acrylic and has conversion and diversion portions accordingly. Pressure tapings are installed at important pressure sites to analyze the line pressure under experiment. A control valve is placed in the test section to regulate the water flow rate at upstream path. Two pressure gauges are linked to the pressure tapings which display the pressure at the time of flow flowing through the test section.

This equipment is a self-reliant water re-circulating unit, furnished with a sump tank and a centrifugal pump etc. Flow in the water line is changed using Flow control valve and by-pass valve to conduct the experiment on varied flow rates.

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The laboratory set-up comprises of an acrylic test section with conversion and diversion portions. At important pressure places, pressure tapings are installed to allow for the analysis of the line pressure under experiment. In the test portion, a control valve is supplied to modulate the water flow rate upstream. Two pressure gauges are linked to the pressure tapings and are used to display the pressure in the test section during flow passage.

This apparatus is a self-contained water recirculation system equipped with a sump tank and a centrifugal pump, among other components. To conduct the experiment at various flow rates, the flow in the water line is regulated using a flow control valve and a by-pass valve.

Volumetric Flow rate m^3/sec	**Temperature °C**	**Vapour pressure Kpa**
3.8×10^{-4}	19	2.1974
	23	2.8099
	25	3.1686
	26	3.3625
	32	4.7574
	37	6.2793
	42	8.2053
	43	9.1075

Table 2: Vapour pressure of water at different temperature

There is need to get the relationship between vapour pressure and temperature

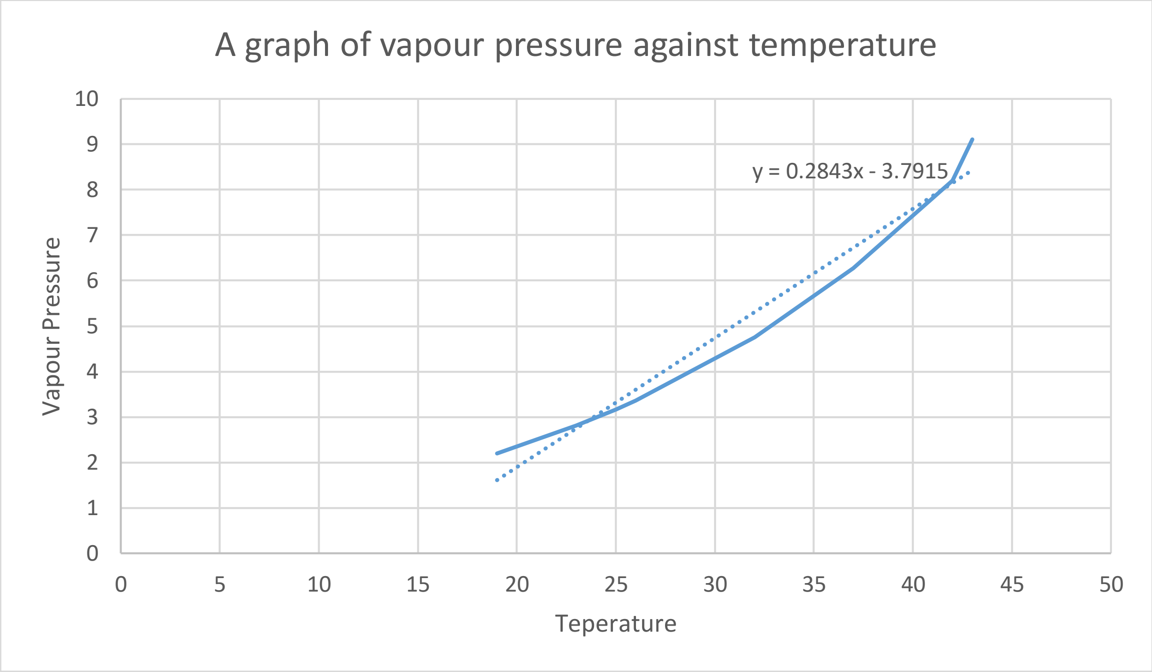

Fig 3: A graph of vapour pressure against temperature

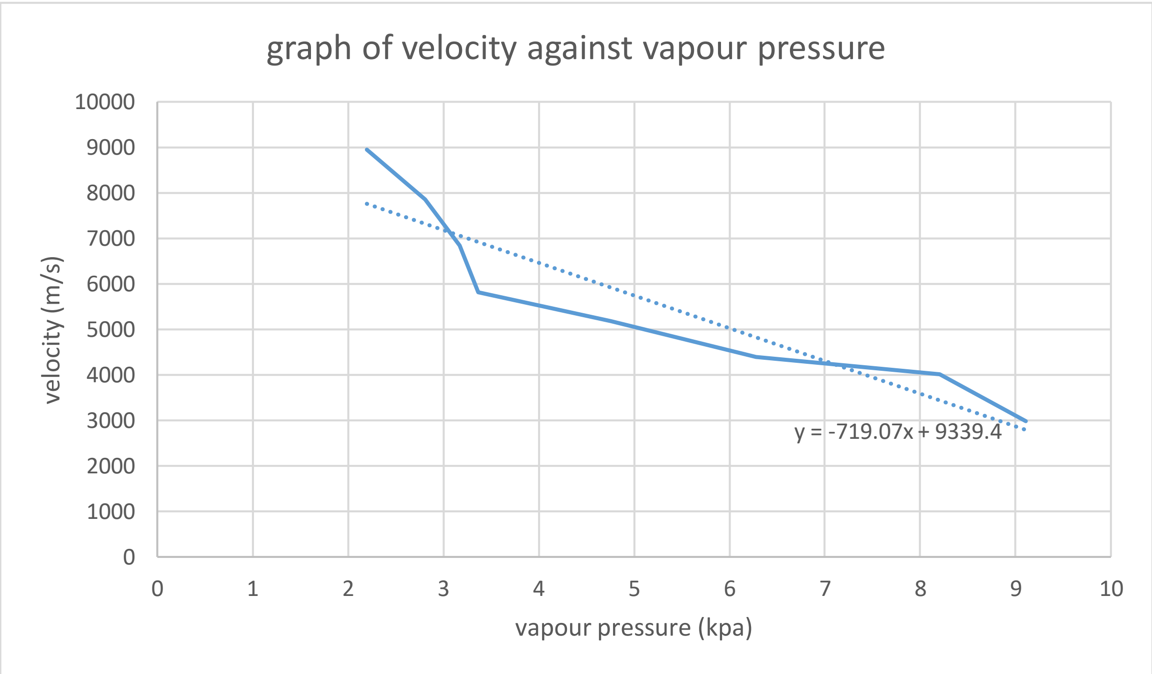

Fig 4: graph of velocity against vapour pressure

For each set of data, the volume flowrate is calculated, and then a graph of P2 vs volume flowrate Q is provided for each set of findings. The vapour pressure of water can be determined using the table below and a known water temperature. The measurements are used to determine the minimum static pressure at the neck of the test section, confirming that it agrees with the water vapour pressure. The figures show that as the flowrate (velocity) across the test section increases, the static pressure drops (as predicted by the Bernoulli equation) until the water reaches its vapour pressure. When the downstream ball valve is throttled, the onset of cavitation is delayed due to the increased static pressure in the system (higher flowrate is possible before cavitation occurs).

As the flow / velocity of the water increases, the pressure at the neck drops, as predicted by the Bernoulli equation. Additionally, it demonstrates that, despite increasing water velocity, the pressure approaches an unsurpassed minimal value. Consider the consequences of allowing cavitation to occur in a hydraulic system. The example explains how cavitation can be avoided by increasing the static pressure of the fluid. However, this strategy is inefficient because it requires more energy / a larger pump to compensate for the increased system losses. Cavitation is best prevented by carefully designing the system to exclude any potential sources of high velocities, low pressures, or high temperatures.

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Pump speed: 2850rpm

Volumetric flow rate: $3.85 \times 10^{-4} m^3/sec$

Upstream pressure Kpa	Constriction pressure Kpa	Downstream pressure kpa	Volume m^3	Time seconds	Cavitation
0.1	0.04	0	2	19.2	No
0.2	0.05	0	2	16.58	No
0.3	0.06	0	2	15.5	No
0.4	0.07	0	2	15.47	No
0.6	0.98	0	2	8.82	Yes
o.8	0.98	0	2	7.28	Yes

Table 3: Completely opened (Experiment A)

Upstream pressure Kpa	Constriction pressure Kpa	Downstream pressure Kpa	Volume m^3	Time seconds	Cavitation
0.1	0.06	0.13	2	16.78	No
0.2	0.1	0.22	2	13.94	No
0.3	0.14	0.28	2	13.64	No
0.4	0.18	0.37	2	11.08	No
0.5	0.2	0.42	2	10.32	No
0.6	0.24	0.48	2	8.58	No

Table 4: Completely closed (Experiment B)

Upstream pressure Kpa	Constriction pressure Kpa	Downstream pressure kpa	Volume m^3	Time seconds	Cavitation
0.1	0.62	0.075	2	10.51	No
0.2	0.82	0.04	2	9.69	No
0.3	0.95	0.075	2	8.59	Yes
0.4	0.95	0.09	2	8.39	Yes
0.5	0.97	0.1	2	7.76	Yes

Table 5: Partially Opened (Experiment C)

B. Results on experiment A, B, C

From tables 4.2, 4.3, 4.4 above, it is observed that at a particular vapour pressure and inlet pressure cavitation is set to occur, using the cavitation index to predict the onset of cavitation from equation 4.0.The table 4.6 shows the conditions of cavitation damage risk. That cavitation is set to occur when the cavitation index obtained is less than one (1).

Cavitationindex: Cavitation index is standard measure of cavitation calculated by formula

$$\sigma = \frac{p - p_v}{0.5\rho U^2} \quad (2.0)$$

Where

P, ρ, U^2 are upstream values of pressure, density and velocity, all evaluated at inlet

P_V is saturated vapour pressure at the throat.

Cavitation index	Level	Cavitation damage risk
σ>1	1	No cavitation damage
<σ≤ 1	2	Possible cavitation damage
0.25< σ ≤ 0.45	3	Cavitation damage
0.17<σ ≤ 0.25	4	Serious damage
σ ≤ 0.17	5	Major damage

Table 6: showing conditions of cavitation damage risk

V. CONCLUSION AND RECOMMENDATION

A. Conclusion

This project is primarily concerned with the design and construction of cavitation demonstration apparatus that will aid in establishing the conditions under which cavitation can occur and the conditions under which the causes of cavitation and their effect can be minimized to the barest minimum, taking into account the effect of velocity increase on the constriction and the corresponding effect on the pressure head at that same constriction. Additionally, it is critical to note that this project is intended solely for laboratory experimental purposes and can be accomplished using mild steel for the frame, a variable centrifugal pump to apply pressure to the fluid, tanks (both suction and discharge tanks), and pipes to transport the fluid through the venturitube.

This cavitation phenomena is analogous to the cavitation that occurs naturally within pipes and pumps during fluid transmission. To begin, when the flowrate increases, the pressure at the entrance increases dramatically, resulting in a rise in the temperature of the water. This is to demonstrate that our experiment complies with the Bernoulli equation. Additionally, as water flowrate increases, the noise generated by explosionvapour bubbles caused by cavitation increases. Simultaneously, the temperature of water increases somewhat. All of this contributes to energy loss.

Finally, because cavitation is the occurrence of liquid rupture and the associated effects of cavity motion (Lauterborn et al, 1996). It is a very common occurrence in pumps. As engineers, we must grasp the mechanism and concept of cavitation and deal with it efficiently, as cavitation can damage the internal components of hydraulic machines, such as the pump, as well as degrade the equipment's overall performance.

B. Appropriate Recommendation

For future design and manufacture of a cavitation demonstration device, the venturitube should be made of transparent fiber glass to clearly demonstrate what cavitation looks like. Additionally, due to cost constraints, a flow meter was not included in the system; instead, the flow rate was computed; consequently, a flow meter should be included in the system to obtain accurate flow rate figures.

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APPENDIX

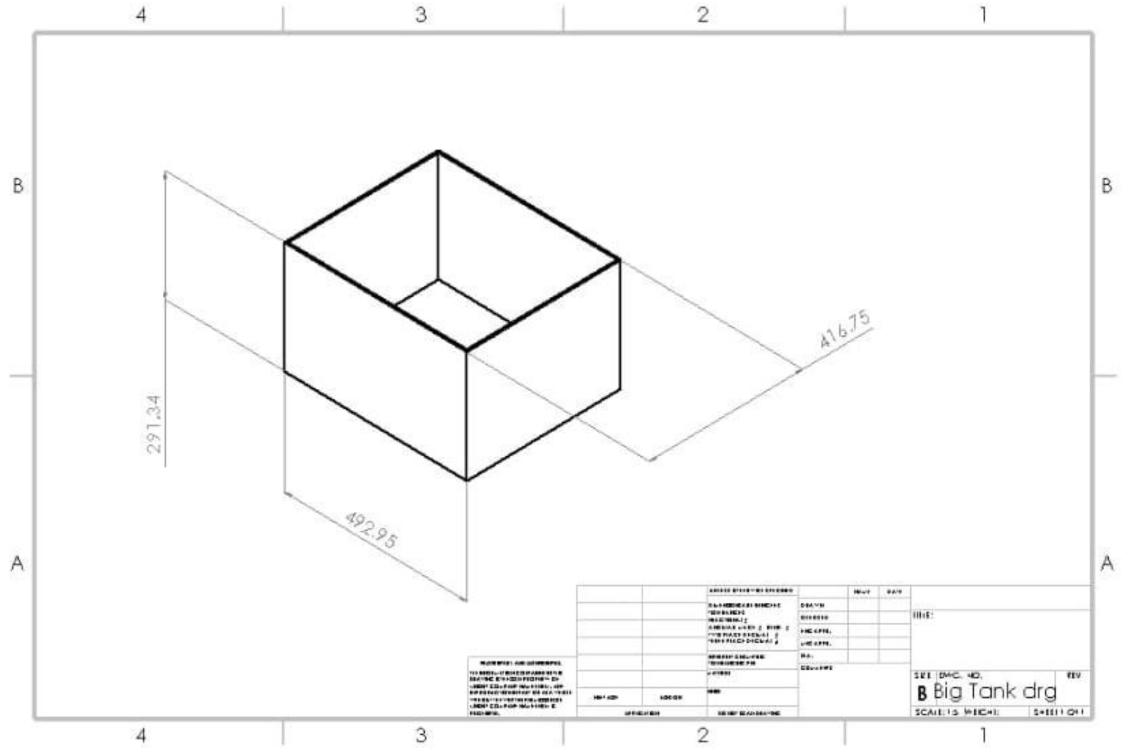

Fig 5: A drawing of the tank with its dimensions

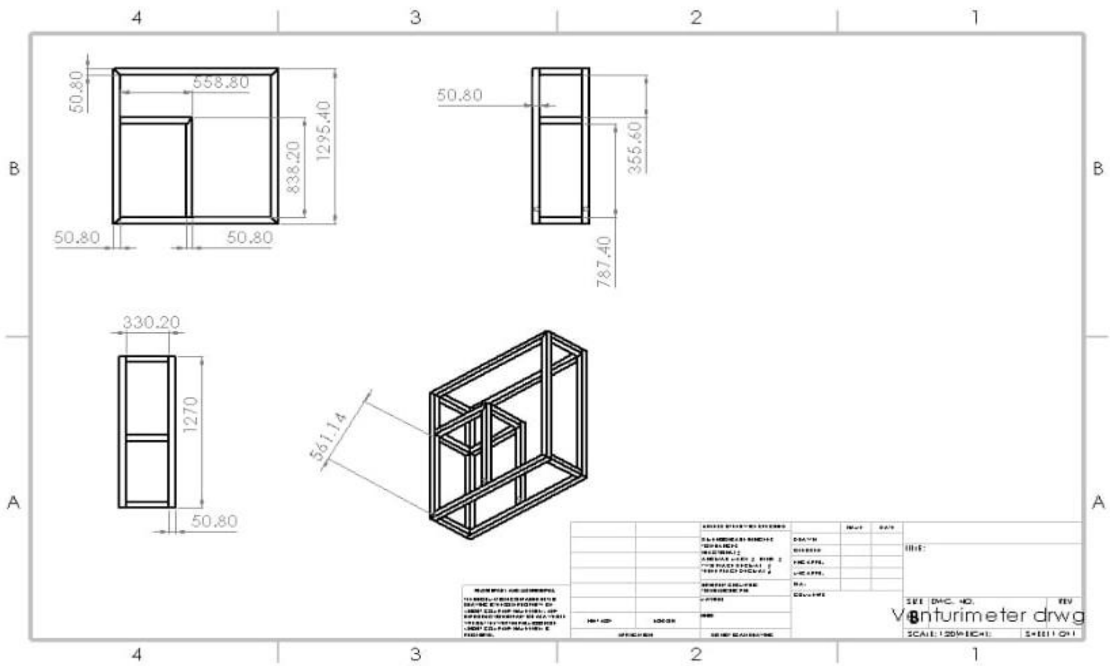

Fig. 6: Solidwork design of the frame with dimensions

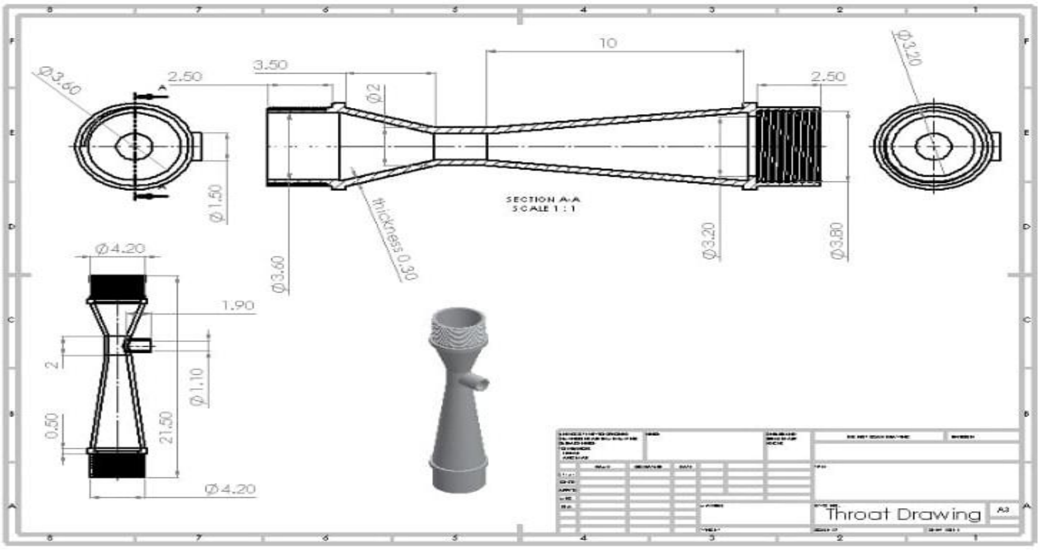

Fig 7: Picture of the venturitube

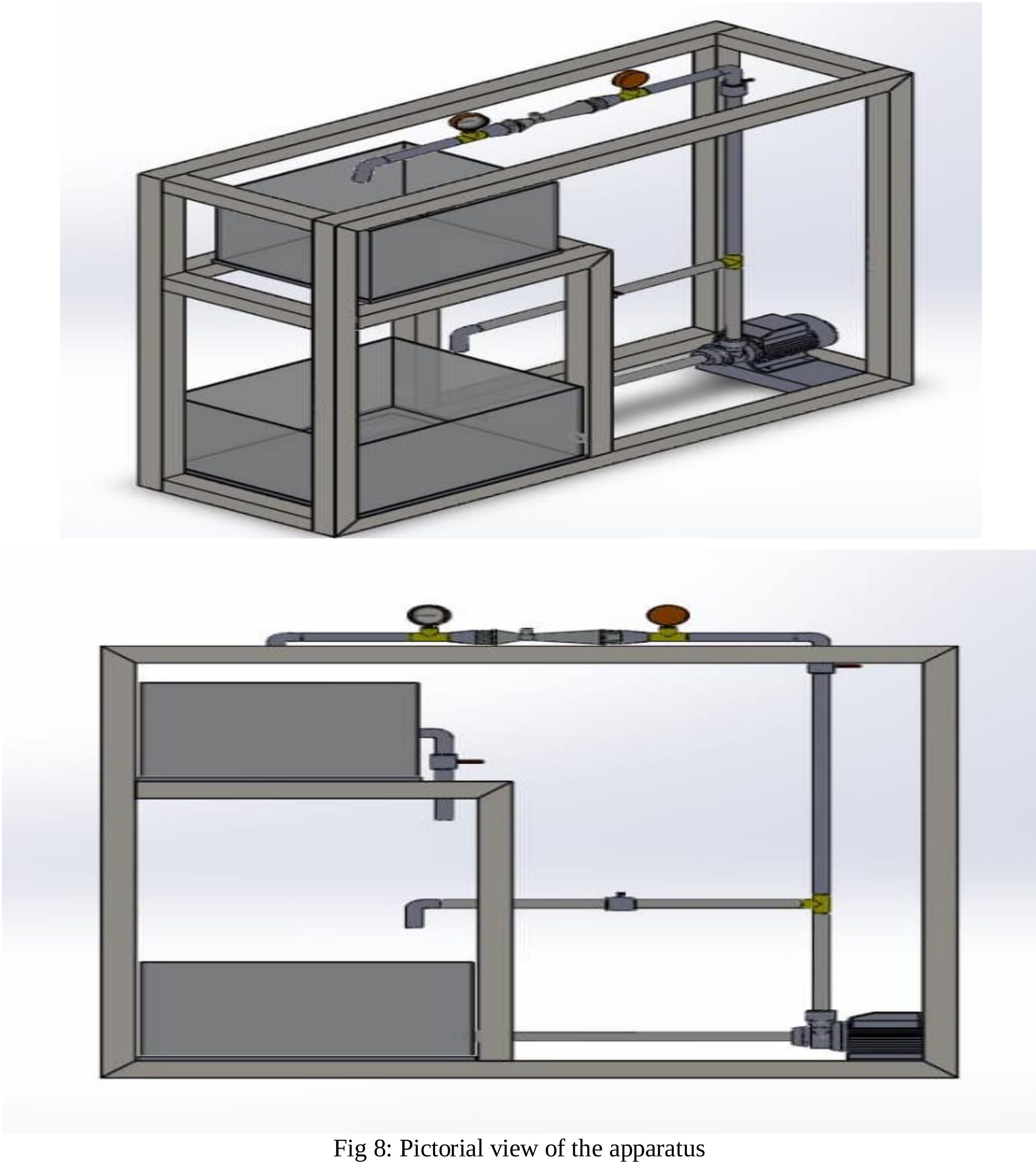

Fig 8: Pictorial view of the apparatus

Pictorial views of the materials and construction processes

Cutting operation

PVC cut in different sizes.

The tank made from fiber glass.

Finishing process of the bench.

The assembled apparatus.