Design and Fabrication of a Classical Fibre Glass Laboratory Venturimeter Apparatus

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Abstract:- The venturimeter has a fundamental principle that is based on Bernoulli's principle; when the cross sectional area of a cylindrical flow conduit is reduced, a pressure difference is created, this pressure difference is used in calculating the flow rate or discharge through a pipe. The venturimeter can accurately measure volumetric flowrate using Bernoulli's principle. In fluid dynamics, Bernoulli's principle states that an increase in the speed of a fluid occurs simultaneously with a decrease in static pressure or a decrease in the fluid's potential energy. Bernoulli's principle can be derived from the principle of conservation of energy. This states that, in a steady flow, the sum of all forms of energy in a fluid along a streamline is the same at all points on that streamline. This requires that the sum of kinetic energy, potential energy and internal energy remains constant. Over time it has been discovered that the common metals being used to manufacture the tanks gets rusted and therefore affects the accuracy of the equipment as corroded metal tanks don't give exact values when calculating the flowrate and also there is no clear way of checking the water level in the measuring tanks. This project has solved the design problem maintaining functionality, durability and aesthetics, rein enforced fiber glass in the design and manufacturing of venturimeter laboratory equipment. With the help of Solidworks Simulation, a well fabricated frame and rein enforced fiber glass, I have been able to Design and Fabricate a functional, aesthetic and durable laboratory venturimeter apparatus for practical use in the universities. There is no case of corrosion, and the liquid levels in the measuring tanks can be accurately taken with ease due to the transparency of the rein enforced fiber glass.

Keywords:- *Venturimeter, Bernoulli's Principle, Volumetric Flowrate, Rein Enforced Fiber Glass, Solidworks Simulation.*

I. INTRODUCTION

A venturimeter is a device or equipment used for measuring the discharge or flowrate of a fluid flowing through a cylindrical conduit. Venturimeter is also used to increase the velocity of any type of fluid in a cylindrical conduit at a point in the flow. The venturimeter restricts the flow at a point that has the smallest area along the pipe called the throat along a converging-diverging cylindrical conduit. The device which works with pressure gauges, takes the pressure before the throat and at the throat. From these pressures, a pressure difference is gotten, that pressure difference is then included in the formulae to get the volumetric flowrate of the flowing fluid. Venturimeter is also used mostly in the Oil and Gas industries to determine the flow of fluids such as liquid propane, water, and few other liquid crude product.

A venturimeter is sometimes used not just to calculate the flowrate of a flowing fluid but also to increase the flowrate of that particulate fluid, at various points in the flow. To achieve this, fluids with characteristics of high pressure and low velocity, flowing through a cylindrical fluid of small cross sectional area gains wore kinetic energy as a result of the drop in pressure at the throat, and then goes back to its initial state of high pressure and low velocity once it passes the constricted area. One of the pressure gauges will be mounted at a point before the constricted area and then another at that point with the smallest cross section, as it is expected that there will be maximum velocity and minimum pressure at that constricted point.

There are several application of the Bernoulli's principle, one is found in the nozzle of the garden hose. When the water flows freely from the nozzle fully open, the velocity of the water is low and the jet of the water cannot travel far from the nozzle. But when the nozzle is restricted partially, the velocity increases inversely with the area of flow; it prevents the free flow of the water and thereby increasing its velocity. The pressure held behind the nozzle builds and the velocity can carry the water for great distances.

The apparatus which is a laboratory equipment used in fluid mechanics to demonstrate and illustrate the Bernoulli's principle consists of the arrangement of pipe and instrument to measure flow by a venturimeter. The flow meter is connected to a pressure measuring instrument called a manometer. The rate of flow in a pipe is determined from the pressure reading on the manometer. Manometers are used to determine the change of energy caused by the sudden enlargement or contraction of the channel through which the fluid is passing; there is also loss of energy caused by a combination of friction and the turbulence created when the fluid passes through a globe valve or around a bend; and the loss of energy caused by the friction of the fluid flowing in a long straight pipe.

II. LITERATURE REVIEW

In recent years there has been a considerable development of sophisticated flow meters. It is estimated that at least 100 flow meter types are commercially available, and new types are continually introduced (Paik, 1994). Various research efforts have been made in order to improve the performance of flow meters. A fundamental understanding of the effects of flow meter operational conditions upon the discharge coefficient is necessary to reduce or to eliminate installation effects which decrease the accuracy of flow meter, (Mattingly and Yeh,(1991).

Flow meters used for measurement has become a device with the advent of the industrial age because of the need for controlled flow process, accounting methods and more efficiently in operation and also because of the realization that controls flow rate is simple and convenient method to other process variable such as temperature and pressure. Among the differential pressure flow meters, the Venturimeter has a long and distinguished history and still dominates the flow measurements scene despite the development of more sophisticated flow meters. The Venturimeter was invented by Clemens Herschell in 1887, a graduate of the Harvard University. Since then, the Venturi has been used in the oil and gas industry especially where energy conservation is an important consideration in large pumped flows. Its low head loss, comparatively to the orifice flow meter, continues to be one of its major advantages.

The venturimeter apparatus precisely calculates the volumetric flow rate of a fluid using a computed formula. This computation considers the radius of the pipeline, whether or not the measured liquid is compressible, and the total volume of fluid present. Various coefficients are added to compensate for the viscosity of the fluid, changes in the conical angles of the venturi and other variables. When these numbers are calculated, along with the pressure measurements taken by the manometer, an accurate description of the liquid flow rate can be ascertained.

For this procedure the venture tube chosen is been made of PVC pipe, forged form of the Herschel-type Venturi, and will be connected to a long PVC pipe with diameter of the inlet and outlet of the converging and diverging part of the venturi. The venturi meter has less degradation of the pressure head due to the tube's design. In this project write up, more emphasis will be placed on fabrication process, the working principles of the venturi meter, the advantage and disadvantage and finally it uses.

III. MATERIALS AND METHODS

3.1Materials

In selecting materials for the venturimeter apparatus, the following factors were considered:

- Size and weight of the materials
- Strength of material
- Resistance to service conditions
- Availability, material cost and manufacturing cost.

This design of this venturimeter apparatus for laboratory use was based on component by component method of design. In this process of fabrication, some of the components were bought based on design specification, while others were designed and fabricated.

Table 3.1 **Components**

Component selected	Components fabricated
Venturimeter	Frame
Pump	Rein enforced Fiber glass tanks
U-Tube Mercury Manometer	
Pressure gauge	
PVC pipe and fittings	
Bolts, nuts and washers	
PVC fittings	

3.2Mathematical model and calculation

Consider the pumping arrangement shown in Figure 2 below;

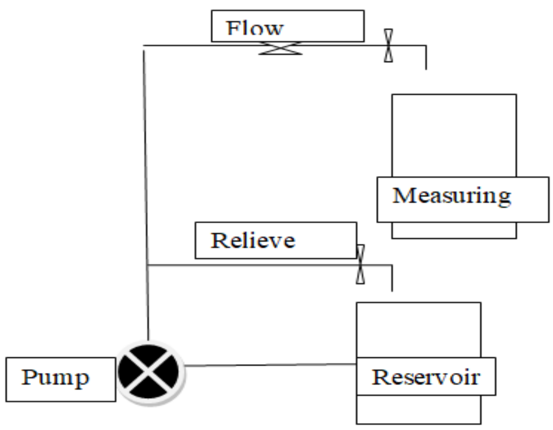


Fig 3.1: The hydraulic circuit

To achieve a required flow through a pumping system, we calculate what the operating pressure of the system will be to select a suitable pump.

Water is pumped from the reservoir into a receiving tank. The water level in the reservoir varies but the discharge level in the receiving tanks remains constant as the water is discharged from a point above the water level.

The operating pressure of a pumped system is calculated in the SI unit of meters (m). To maintain dimensional consistency, any pressure values used within the calculations are therefore converted from kPa into m using the following conversion;

$1Kpa = 0.102m$ (as measured by a water filled U tube manometer)

$H_{Total} = H_s + H_D + (P_{rt} - P_{res})$ .... (3.1)

Where, H_s= Static head (m)

H_D = Dynamic head (m)

P_{rt}= Pressure on the surface of the water in the receiving tank (m)RES

P_{res}= Pressure on the surface of the water in the reservoir (m)

Pressure that occurs over the pumping height is often so small that it can be considered negligible.

$P_{rt} - P_{res} = 0$ ……………………….. (3.2)

Therefore, equation (3.1) becomes:

$H_{Total]} = H_S + H_D$ .... (3.3)

The static heads H is the physical change in elevation between the surface of the reservoir and the point of discharge into the receiving tank. As the water level in the reservoir can vary, the static head for the system will vary between a maximum and a minimum value.

T_{wl} = Discharge level - Reservoir level

And

H_{Smax} = Discharge level – Reservoir B_{wl}

Where

T_{wl}= Top Water Level (reservoir)

B_{wl} = Bottom Water Level (reservoir)

The discharge point at a level of 0.7m

And the reservoir level varies between 0.4 m AOD and 0.2 m AOD, then

H_{Smin} = 0.7 -0.4 =0.3m

H_{Smax} = 0.7 – 0.2 = 0.5m

As a result of the variation in the static head, the total system head, Total H, will also have a maximum and minimum value which was calculated here.

The dynamic head is generated as a result of friction within the system. The dynamic head is calculated using the basic Darcy Weisbach equation given by

$H_D = \frac{kv^2}{2g}$ ……………… …… (3.4)

K = loss coefficient

V = velocity in the pipe (m/sec)

g = acceleration due to gravity (m/sec^2)

$v = \frac{Q}{A}$ ………………………… (3.5)

Where

Q = flow rate through the pipe (m^2/sec)

A = pipe cross section area (m^2)

$A = \frac{\pi D^2}{4} = \frac{\pi \times 0.0254^2}{4}$ = 0.000506m^2

3.2.1 Pipe sizing

System losses depend on the size of the pipe in other words flow velocity is the governing factor which determines the losses in a system. Optimum flow velocities have been determined from previous experience. Recommended flow velocities differ for suction pipes and delivery pipes.

Recommended flow velocities for water extracted from Hand Book of valves piping and pipe lines are given in appendix A.

Therefore taking the assumed velocity = 1.0m/sec, the supposed discharge will be

$Q = VA$……………………………… (3.6)

$Q = 1 \times 0.000491 = 4.91\times10^{-4}$ m^3/sec = 29.5 l/min

The loss coefficient K is made up of two elements:

$K = K_{fittings} + K_{pipe}$ .... (3.7)

$K_{fittings}$ is associated with the fittings used in the pipe works of the system to pump the water from reservoir to the receiving tank. Values can be obtained from standard tables and a total $K_{fittings}$ value can be calculated by adding all the $K_{fittings.}$ values for each individual fitting within the system.

The following table shows the calculation of $K_{fittings}$ for the system under consideration:

Table 3.2; $K_{fittings}$ for the system under consideration

Fitting items	No. of items	$K_{fittings}$ Value	Total Item
Pipe entrance	1	0.5	0.5
Pipe exit	2	0.75	1.5
90˚ Bend	3	0.75	2.25
Ball Valve	2	0.07	0.14
Contraction	1	1	1
Expansion	1	0.5	0.5
T fittings	3	1	3
Coupling	6	0.04	0.24
Total $k_{fittings}$ value			9.47

Source : Fluid mechanics and hydraulic machine by Rajput (2008)

Perry's chemical Engineers handbook, (2008).

Hence, the total K fitting for the system under consideration is 9.47.

k_{pipe} associated with the straight lengths of pipe used within the system and is defined as:

$k_{pipe} = \frac{fl}{D}$ …………………… (3.8)

Where

f= friction coefficient

L= pipe length (m)

D= pipe diameter (m)

The friction coefficient f can be found using a modified version of the Colebrook White equation:

$$f= \frac{0.25}{[\log\{\frac{k}{3.7\times D}+\frac{5.74}{Re^{0.9}}\}]^2} \text{ ....} (3.9)$$

Where
k= Roughness factor (m)
Re = Reynolds number

The pipe roughness factor k is a standard value obtained from standard tables and is based upon the material of the pipe, including any internal conditions of the pipe. For pvc pipe, the roughness value is 0.0015 because it is smooth.

Reynolds number which is a dimensionless quantity associated with the smoothness of flow of a fluid and relating to the energy absorbed within the fluid as it moves. Therefore for any flow in pipe, Reynolds number can be calculated using the following formula:

$$Re = \frac{VD}{v} \text{ .... } (3.10)$$

Where
v = Kinematic viscosity (m2 /s)

The total pipe length is 3.2 m, the PVC pipe has a roughness factor of 0.0015 mm (ASME B31.3, Process Piping Guide) and the kinematic viscosity of water is 1.13×10^{-6} m^2/sec, then from equation (3.10), we get:

$$Re = = \frac{1\times0.8}{1.31\times10-6} = 6.11\times10^5$$

Using this value in equation (3.9), we get;

$$f = \frac{0.25}{[\log\{\frac{0.0000015}{3.7\times0.0254}+\frac{5.74}{611000^{0.9}}\}]^2} = 0.0136$$

Using this value in equation (6), we get:

$$k_{pipe} = \frac{0.0136\times3.2}{0.0254} = 1.71$$

Using equation (5), the total Kvalue for the system is:

K = 1.71 + 9.47 = 11.2

Now calculating the dynamic head using equation (3.4) as follows:

$$H_D = \frac{11.2\times1^2}{2\times9.8} = 0.57m$$

The dynamic head is the same for both the maximum and minimum static head conditions as the dynamic head is independent of the system elevation.

Therefore, the maximum and minimum total head values for the system at a flow of 4.91×10^{-4} m^3/sec can now be calculated using equation (3.3)

$H_{total(max)}$ = 0.5 + 0.57 = 1.07m
$H_{total(min)}$ = 0.3 + 0.57 = 0.87m

Therefore, we can conclude that in order to pump 4.91×10^{-4} m^3/sec at the bottom level in the reservoir, the pump will need to overcome a system pressure of 1.07m. At the top level, the pump will only need to overcome a system pressure of 0.87m.

Converting to pascal gives
P=ρgh = 1000×9.81×1.07
P=10496.7pa

The maximum operating pressure of one inch PVC pipe, schedule 40 for 25mm size pipe is 1.86MPa, shown in the figure 3 in appendix A gotten from ASTM D1785 'standard specification for PVC pipes schedule 40 and 80. **Engineering toolbox (piping system, 2009).** hence the pipe is safe.

3.2.2 Pump selection

The centrifugal pump were selected to achieve either the maximum or minimum head condition was 0.5hp, this would likely result in too much flow at the head condition. Instead, if we use a variable speed pump by adjusting the pump speed we can control the flow to the receiving tank to 4.91×10^{-4} m^3/sec over the entire head range.

The pump speed needs to be reduced in order to achieve the required flow at the TWL and the required speed can be calculated using the affinity laws:

First affinity law– Flow is proportional to the shaft speed, i.e

$$\frac{Q1}{Q2} = \frac{N1}{N2} \text{.................................... } (3.11)$$

Where
Q= Flow through the pipe (m^3/sec)
N= Shaft speed (rpm)

Second affinity law –
Head is proportional to the square of the shaft speed, i.e.

$$\frac{H_1}{H_2} = \frac{N_1^2}{N_2^2} \text{ .... } (3.12)$$

H= Head (m)

From the above laws we can determine the required speed of the pump for the TWL condition by adjusting the pump speed and calculating the resultant flow and head.

From manufacturer's details the pump has maximum head of 35m, maximum flow rate at 35l/min = 5.83 $\times10^{-4}$, maximum speed at 2850rpm and efficiency of the pump 60%;

Therefore to get the speed that will give us our flow rate, we have;

$$\frac{35}{0.88} = \frac{2850^2}{N_2^2}$$

$$N_2 = \sqrt{\frac{0.88\times2850^2}{35}} = 450 \text{ rpm}$$

Hence, 450rpm is the speed needed to achieve a flow rate of 4.91×10^{-4} m^3/sec.

The power requirement for the pump can be calculated by

$$P = \frac{Q \times H \times g \times \rho}{pump\ efficiency} \ldots\ldots\ldots\ldots\ldots\ldots (3.13)$$

Where

P= Power (W)

ρ = Density (Kg/m^3) = 1000 kg/m 3 for water

Therefore

$$P = \frac{4.91\times10^{-4}\times1.07\times9.81\times1000}{0.60}$$

P = 9W = 0.012hp

Hence, to overcome the required head of 1.07m, we need a variable speed pump with 8W.

3.2.3 Stress analysis of pipe

The stress cylinder wall can be expressed using **Lame's** formula:

$$\sigma_{t\,max} = \frac{p_i^2(r_o^2 + r_i^2)}{(r_o^2 - r_i^2)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.14)$$

where

$\sigma_{t\,max}$ = maximum tangential stress (MPa)

p_i = internal pressure in the pipe (kPa)

r_i = internal radius of pipe

r_o = external radius of pipe

$$\sigma_{t\,max} = \frac{10496.7(0.0144^2+0.0127^2)}{0.0144^2-0.0127^2} = 83994.1Pa$$

This is the maximum stress by the fluid on the pipe wall.

3.2.4 Thickness of pipe

In other to withstand the internal fluid pressure , the thickness of the pipe can be obtained using Lame's equation;

$$t = R\left[\sqrt{\frac{\sigma_t+p}{\sigma_t-p}} - 1\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.15)$$

Where;

T = thickness of the pipe

R = Inner radius of the pipe,

P= Intensity of internal pressure

σ_t = tangential stress

The strength of the pipe can be gotten from standard ASTM D1785 table,

From the table3.6 in Apendix A, σ_t for 1" PCV pipe is 581lb

To convert to Mega pascal (Mpa), we have

581lb =263.77

Therefore,

$$\sigma_t\,(MPa) = \frac{F}{A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.16)$$

$$\sigma_t = \frac{263.17\times9.81}{\frac{\pi\times0.0254^2}{4}} = 5.1MPa$$

Putting factor of safety of 2.5

Allowable tensile strength

$$\sigma_{ta} = \frac{5.1\times10^6}{2.5} = 2.04\ MPa$$

3.2.5 Maximum pressure of the pump

For a pump that gives maximum head of 35m,a maximum flow rate of 35ltr/min (5.833×10^{-4} m^3 /s), and a power rating of 0.37KW.

Power = flow rate ×pressure ……………………. (3.17)

$$\text{Maximum pressure} = \frac{370}{4.91\times10^{-4}} = 753564.2N/m^2$$

Hence, using equation 3.14 to get thickness gives, $t = 0.0127\left[\sqrt{\frac{2.04\times10^6+753564.2}{2.04\times10^6-753564.2}}\right] - 1$

t = 2.03mm

Therefore the thickness that can withstand such maximum pressure is 2.03mm. the thickness of pipe chosen was to the nearest standard pipe thinkness which is 3mm.

3.2.6 Fibre glass tanks (sump tank and measuring tank)

As with many other composite materials (such as reinforced concrete), the two materials act together, each overcoming the deficits of the other. Whereas the plastic resins are strong in compressive loading and relatively weak in tensile strength, the glass fibers are very strong in tension but tend not to resist compression. By combining the two materials, GRP becomes a material that resists both compressive and tensile forces well. It is in the form of sheets which can be cut and form in to the desired shape vessel. Adhesive is used for the joining. Water is pumped from the sump tank and is discharged in the measuring tank.

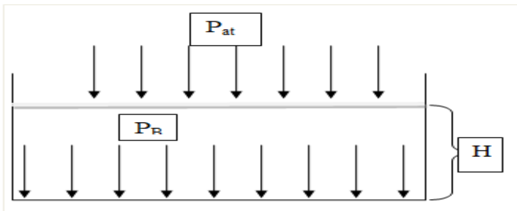


Fig 3.2 forces on tank

$P_B = \gamma H$ ……………………….. (3.18)

P_B = pressure at the bottom of tank due to the liquid head

γ = specific weight of the liquid

H = head of liquid above the tank

γ of water = 9.777 KN/m^3

P_B = 9777×0.4 = 3910.6Pas

Magnitude of the resultant force acting on the tank bottom is;

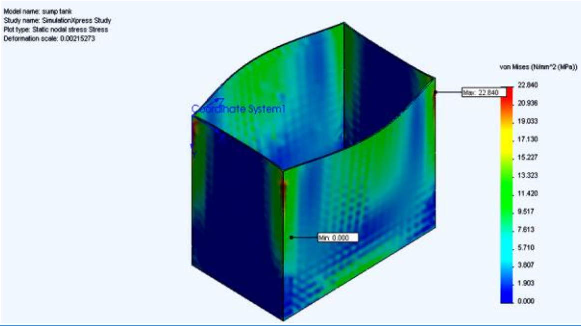
$F = P_B A_B$ …………………….(3.19)

Where A_B = Area of the tank bottom

Note; pressure is constant, resultant F_B acts at the centroid of the tank bottom area

F_B = 3910.6 × (0.5 ×0.3) = 586.6N

Name
Stress analysis
sump tank-SimulationXpress Study-Stress-Stress



Name	Type	Min	Max
Displacement	URES: Resultant Displacement	0 mm Node: 133	23226.3 mm Node: 15467

Fig 3.3 Stress Analysis on Sump Tank

In plane walls, the liquid pressure is resisted by both vertical and horizontal bending moments. An estimate should be made of the proportion of the pressure resisted by bending moments in the vertical and horizontal planes. The direct horizontal tension caused by the direct pull due to water pressure on the end walls, should beaded to that resulting from horizontal bending moments.

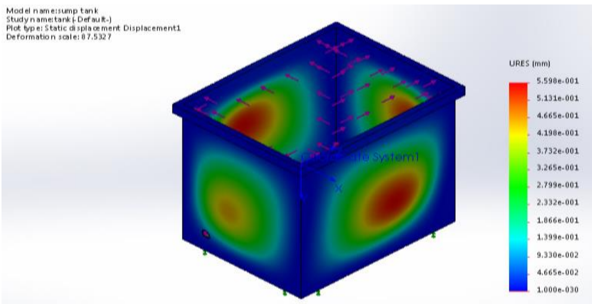


Fig 3.4a Stress Analysis of a reinforced Measuring Tank

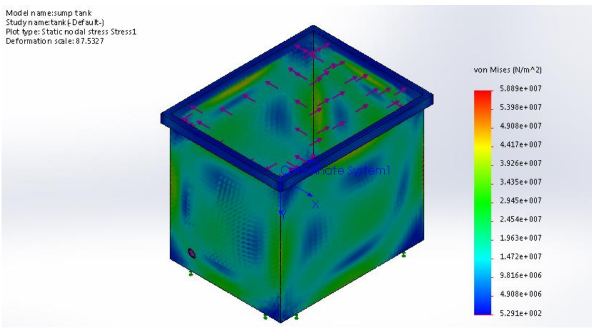


Fig 3.4b: Stress Analysis of Reinforced Sump Tank

3.2.7 For the pipe

Horizontal pipe connection to the pump

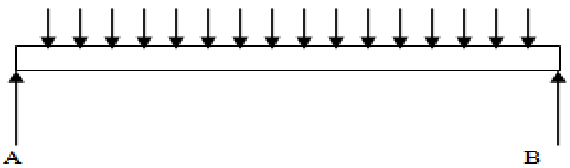


Fig 3.5: force distribution on horizontal pipe

Moment at the centre of the beam, $M_c = \frac{wl^2}{12}$ …… (3.20)

Volume of horizontal pipe $v = \pi r^2 h$
$\pi \times 0.0127^2 \times 0.5 = 2.53\times10^{-4} m^3$
Mass = density × volume …….. (3.21)
$M = 1000\times9.8\times10^{-5} = 0.253kg$
Weight = 0.098 ×9.81= 2.5N
Weight of the PVC pipe of 1inch is 0.476224kg/m
For the length of 0.5m
m =0.5 ×0.476224 = 1.2kg
Weight = 11.6N
Total weight = 2.5 + 11.6 = 14N
$M = \frac{14\times0.5^3}{12} = 2.91\times10^{-1}Nm$
Bending stress $\sigma_b = \frac{My}{I}$ ………………….. (3.22)
$I = \frac{\pi(d_0{}^4 - d_i{}^4)}{64}$ = second moment of inertial …….(3.23)
$= \frac{\pi(0.0288^4 - 0.0254^4)}{64} = 1.3\times10^{-8}$ m^4
$y = \frac{0.0254}{2} = 0.0127m$
$\sigma_b = \frac{2.91\times10^{-1}\times0.0127}{1.3\times10^{-8}} = 0.284Mpa$

Allowable stress of PVC pipe of one inch is 2.04Mpa, therefore the pipe can withstand the bending stress.

3.2.8 For the vertical pipe;

The vertical height of the pipe will include the height of sump tank (0.4m) plus the height of the measuring tank and some allowances allowance.

This gives;
0.4+0.5+0.1 = 1m
The pipe is to be treated as a column. Maximum length of a column suggested by Greenhill (1881)
$l_{max} \approx (7.8373\frac{EI}{\rho g A})^{\frac{1}{3}}$………………………… (3.24)
E= young modulus = 3.4GPa for PVC
A= cross sectional area
I= second moment of inertial
$A = \frac{\pi(d_0{}^2 - d_i{}^2)}{4} = \frac{\pi(0.0288^2 - 0.0254^2)}{4} = 1.5\times10^{-4} m^2$
$I = \frac{\pi(d_0{}^4 - d_i{}^4)}{64} = \frac{\pi(0.0288^4 - 0.0254^4)}{64} = 1.3\times10^{-8}$ m^4
$L_{max} = (7.8373\frac{3.4\times10^9\times1.3\times10^{-8}}{1000\times9.81\times1.5\times10^{-4}})^{\frac{1}{3}} = 4m$
Therefore
L_{max} = 6m, which is way longer than the height of the vertical pipe. Hence the pipe will not buckle under its own weight.

3.2.9 The frame

The simple way to evaluate the frame is to consider it as a pin jointed frame work, and that means is that each of the trusses shown can only exert either compressive or tensile force. Therefore to overcome these loads the material frame should have two main properties that it,

- Strength and
- High stiffness

One of the important attributes that the members of the apparatus must possess is the ability to resist bending (a stiffness and rigidity properties) and at the same time be light. When it comes to bending the resistance to bending of different shapes can be found using the second moment of inertia. A shape that has a high second moment of inertial for bending in all directions is the **cylindrical tube**. So if we want to use a material for the members of the frame of venturimeter apparatus, it is advantageous if that the material can be readily shaped into **tubes** or comes inform of tubes.

As in finding a short list of candidates for a job, we get basic information about the materials from the database and eliminate candidates that are not suitable for the job.

Mild steel square pipe and angle iron (iron containing a small percentage of carbon, strong and tough but not readily tempered), also known as plain-carbon steel and low-carbon steel, was used for the construction of the frame. It is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for this application.

Fig3.6 frame showing the forces

As shown in Fig 3.5 the upward forces at the stands of the frame and then the downwards forces, which is the load that will be exacted on the frame. At section A and section B includes the reservoirs which are to carries the maximum load and since the load will lie at the entire area as shown above, it is considered as a distributed load. While the load of at C is considered as point load, which is the weight of the pump.

Since the total weight is carried by the beam is the weight of the water (586.6N) plus weight of tank (125.2N) which is = 586.6+125.2 =711.2N

The weight is supported by 4 beams, therefore each beams holds

$\frac{711.2}{4}$=178N

Moment of inertia of a rectangular beam = $\frac{bd^3}{12}$ of 0.002m depth, 0.0508m breadth.

=$\frac{0.0508\times0.002^3}{12}$ =3.39×10^{-11} m^4

Considering the weight of the reservoir to be evenly distributed over the span of the beam;

Maximum deflection = $\frac{-5wl^4}{384EI}$ (3.17)

= $\frac{-5\times178\times0.508^4}{384\times210\times10^9\times3.39\times10^{-11}}$

= 0.02m

As per IS code the general maximum deflection should not exceed 1/325 of the span

Which is 0.5/325 = 1.5×10^{-3}m

3.2.9 WELDING

Types of welds used

1. Electric arc welding; In electric arc welding, the work is prepared in the same manner as for gas welding. In this casethe filler metal is supplied by metal welding electrode. Used to tack i.e. hold the joints in place before final welding
2. Gas welding; A gas welding is made by applying the flame of an oxy-acetylene or hydrogen gas from a welding torch upon the surfaces of the prepared joint. The intense heat at the white cone of the flame heats up the local surfaces to fusion point while the operator manipulates a welding rod to supply the metal for the weld. A flux is being used to remove the slag. Since the heating rate in gas welding is slow, therefore it can be used on thinner materials. Reasons for using gas welding include;

- It is more economical.
- It has low porosity after welding.
- It has a finer surface finish as compared to arc welding.

3.2.10 STRENGTH OF THE WELD

The type of joint used for this operation was the fillet joint. **Fillet welding** refers to the process of joining two pieces of metal together whether they be perpendicular or at an angle. These **welds** are commonly referred to as Tee joints which are two pieces of metal perpendicular to each other or Lap joints which are two pieces of metal that overlap and are **welded** at the edges.

Tensile strength of the joint for fillet weld,

$P = 2 \times 0.707s \times l \times \sigma t$

Where: p - tensile strength; s – size of weld; l – length of weld; σt – allowable stress.

Length of the weld = 25.4mm (dimension of the mild steel pipe)

Size of weld:

Cubic Height of pipe(mm)	3 – 5	6 – 8	10 – 16	18 – 24	26 – 55	Over 58
Minimum size of weld (mm)	3	5	6	10	14	20

Cubic height of pipe = 25.4

By Interpolation, the minimum size of weld = 10.736

Allowable stress:

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Type of weld	Steady load (MPa)	Fatigue load (MPa)
1.Fillet weld (all types)	80	21
2.Butt welds		
Tension	90	35
Compression	100	35

Therefore, tensile strength (P) = $0.707s \times l \times \sigma t$
For steady load:
$P_{max} = 0.707\times 10.736\times 80\times 25.4\times 10^{6}\times 10^{-5}\times 10^{-2}$
P_{max} = 1.542KN
For fatigue load:
$P_{max} = 0.707 \times 10.736\times 21\times 25.4\times 10^{6}\times 10^{-5}\times 10^{-2}$
P_{max} = 0.405KN

In order to ensure that the weld doesn't yield at any point, the total weight of the heaviest part of the apparatus (the sump tank) is calculated and compared to the max tensile strength for steady load as shown below;

3.2.11 Sump tank;
Total weight of water in the tank (W_{water}) = density (ρ) × volume of water (v_{water})×acceleration due to gravity (g)
Total volume of water = 60litres = $0.06m^3$
$W_{water} = 1000\times 0.06\times 10 = 0.6KN$
Total weight of the sump tank only (W_{sump}) = density of reinforced fiber glass (ρ) × volume of tank (v_{sump}) × acceleration due to gravity (g)
Density of reinforced fiber glass – 1522.3948 kg/m^3
$V_{sump} = v_{outer} - v_{inner}$
$v_{outer} = 0.052\times 0.041\times 0.0320 = 0.068224m^3$
$v_{inner} = 0.05 \times 0.04 \times 0.03 = 0.06m^3$
$\therefore V_{sump} = 0.068224 - 0.06 = 0.008224m^3$
$W_{sump} = 1522.3948\times 0.008224\times 10 = 0.1252KN$
Therefore, the total steady load (P_{total}) = $W_{sump}+W_{water}$
$P_{Total} = 0.1252 + 0.6 = 0.7252KN$

Comparing the max tensile strength and the total steady load it can be seen that the welded joint would withstand the stress exerted by steady loading.

3.2.12 The manufacturing process includes:
1) Machining; this involves removing materials using cutting tools for getting rid of the unwanted materials from some workplace and converting it into desired shape. The machining operations used in this construction are:
2) Drilling operation; for drilling holes for fasteners.
3) Grinding operation; grinding process is used for improving the finish of the surface and tightening up the tolerance by removing the remaining unwanted materials from the surface. Grinding machines are used for this purpose to produce parts of identical shape, size and finish.
4) Joining; the method of joining used in this operation includes;
5) Welding; in this process the mild steel square pipe are heated and melted using gas welding and arc welding in some parts, causing the joined parts to function as one. It is used for the construction of the frame.

6) **Adhesive**

The most established adhesives are polymers that enable connections of different materials at temperatures ≤ 200 °C. Adhesive bonding (also referred to as gluing or glue bonding) describes a wafer bonding technique with applying an intermediate layer to connect substrates of different types of materials. Here it is use for joining of pipes and fittings, and the type use is araldite. Araldite is a fast setting, very strong adhesive, which will bond ceramics, wood, chipboard, glass, metal and most hard plastics. Solvent free, heat and cold, water and oil resistant

To create a desirable surface for the adhesive bonding of plastics, there are three major requirements:

The weak boundary layer of the given material must be removed or chemically modified to create a strong boundary layer;

- **Degreasing;**

The adherend is cleaned with a solvent or an aqueous detergent solution to clean any greasy surface after the degreasing process.

After degreasing a good test to determine the cleanliness of the surface is to use a drop of water. If the droplets spread on the surface, a low contact angle and good wettability have been achieved, indicating that the surface is clean and ready for adhesive application. If the droplets rises or maintains its shape, the degreasing process must be repeated.

- **Abrasion**

To prepare the adhesive for bonding, sand or blast the surface with adhesive materials or scratch the surface and remove any loose material. Rough surfaces produce stronger adhesion because they have an increased surface area for adhesive bonding compared to relatively smooth surfaces.
After abrasion, always wipe adhered matter with a solvent or detergent water solution to clean the surface of any oil or loose materials, and then wipe dry. Once this process is complete, adhesive is applied.

6) Coating

It is a covering that is applied to the surface of an object, usually referred to as the substrate. The purpose of applying the coating may be decorative, functional, or both. The coating itself may be an all-over coating, completely covering the substrate, or it may only cover parts of the substrate. In the coating process of this apparatus, oil paints were used; which mostly have dual uses of protecting the substrate and being decorative.

3.2.12 Fabrication Process

In the manufacture of the all-terrain robot, various processes were considered and they include.

(1) **Research:** This process involves the sourcing of information, collection of data, reviewing of the collected data from the internet or other sources to gather the knowledge needed in the manufacture of the Venturi meter apparatus.

(2) **Data compilation:** In this process, the gather data from research is compiled and analyzed to arrive at a particular sequence of operation. Data compilation gives the designer the step by step process for the design of a machine.
(3) **Material selection:** This process covers the cost of materials selected for the production process and aims at minimizing cost of production while increasing quality and reliability of the selected material.
(4) **Design:** After selection of materials, the parts selected are considered and their dimensions calculated.
(5) **Fabrication**: At this stage, work is done on the different parts that form the system to bring them to a suitable shape and size required for the design.
(6) **Assembly:** This process consist putting together of all individual elements or parts that have been worked on to form the system. The frame were first constructed, followed by the attachment of the reservoir and measuring tank. We started the installation of the electrical pump connecting the pipes to it; the horizontal pipe was connected to the reservoir, while the vertical pipe was connected to the upper horizontal pipe. Then, after that we did the installation of the Venturi meter in the upper part of the frame. This step was followed by the attachment of pipe for the discharge of water into the measuring tank.
7) Finally, powering the whole unit and testing.

Fig 3.8a: Assembled Venturimeter

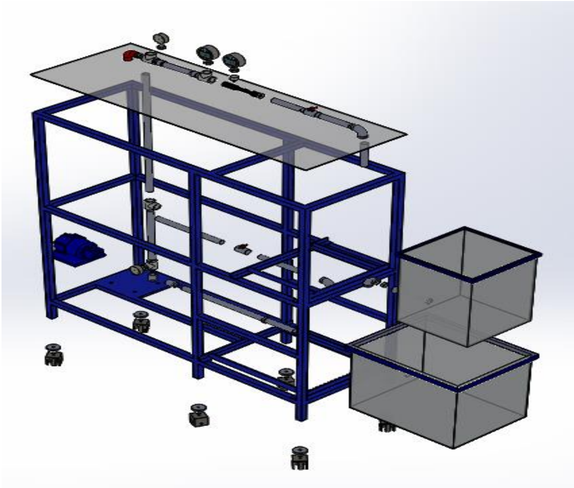

Fig 3.8b Blown up Venturimeter

IV. TEST AND RESULT

The apparatus described was constructed primarily to be used for laboratory instruction on the flow of fluids in pipes. It has been design to include operations illustrating the important factors that mechanical engineers should be familiar with in the transportation of fluids through piping systems. Therefore provision has been made for the following experimental operations;

1. To determine volumetric flow rate.
2. To verify the Bernoulli's Theorem.

The apparatus consists essentially of different component parts and their functions. The basic experimental facility is presented in figure 1. It consists of a long PVC pipe with an inner diameter of 25mm. The test section (Venturi type flow meter) is an accurately machined perplex duct of varying circular cross section. The geometry of the test section was consistent with the ISO 5167 design requirements. The converging section is 21° angle and 56.95 mm long. The diverging section has an angle of 15° and a length of 58 mm. The Venturi test meter was mounted in the long pipe (at the fully developed flow condition) using union couplings, which are leak proof. The static pressure can be measured simultaneously from wall pressure tappings at 2 sections (inlet and throat) along the Venturi meter. The pressure tapings were connected to a U tube manometer. Water is pumped from the sump tank through the pipe section. The flow rate can be determined from the measured differential pressure along the Venturi and directly measured from a constant volume tank system.

4.1 EXPERIMENT NO. 1

Aim: - To determine volumetric flow rate or discharge.

Apparatus used: - A supply tank of water, a horizontal pipe fitted with manometer tubes point, measuring tank, scale, and stop watch.

Theory:-Q is the theoretical discharge under ideal conditions. Actual discharge will be less than the theoretical discharge. The actual discharge is given by the formula. An actual meter is not practical for the tubes to be taken straight up as shown since the pressure would require the use of long tubes. A more practical arrangement is to measure the difference in pressure rather than the absolute values.

Formula Used:- $Q_{th} = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$ 4.1.1

$Q_{act} = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$ 4.1.2

Q_{th} = Theoretical discharge
Q_{act} = Actual discharge
C_d = Coeficient of discharge
h = Pressure difference as indicated by the manometer
a_1 and a_2 = area before converging and area at the throat respectively

Sice the areas are constant, therefore the equation becomes;

$Q_{act} \propto \sqrt{2gh}$ 4.13

Procedure:-
1. Open the inlet valve slowly and allow the water to flow from the supply tank.
2. Now adjust the flow to get a constant head in the supply tank to make flow in and out flow equal.
3. Under this condition the pressure head will become constant in the manometer tubes.
4. Note down the quantity of water collected in the measuring tank for a given interval of time.
5. Compute the area of cross-section under the manometer tube.
6. Compute the other area of cross-section under the tube.
7. Change the inlet and outlet supply and note the reading.
8. Take at least three readings as described in the above steps.

Observation

Table 4.1: water flow test data for experiment1

S/N	Time (s)	Difference in head (m)	Actual volumetric flow rate (m^3/s) (10^{-4})	Theoretical volumetric flow rate (m^3/s) (10^{-4})	Square root of deference in head ($m^{0.5}$)
1	31.9	0.055	1.212	1.317	0.23
2	23.93	0.086	1.617	1.647	0.29
3	18.97	0.136	2.040	2.086	0.37
4	17.29	0.166	2.238	2.288	0.41
5	16.52	0.182	2.343	2.396	0.43
6	16.04	0.193	2.413	2.467	0.44
7	15.12	0.218	2.560	2.622	0.45

Precautions:-
1. When fluid is flowing, there is a fluctuation in the height of manometer tubes, note the mean position carefully.
2. Carefully keep some level of fluid in inlet and outlet supply tank.

❖ **Result:-**

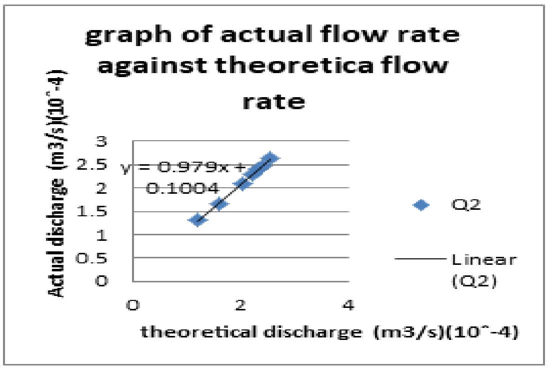

Fig 4.1

From the figure 4.1, it could be seen that Q_{act} rises steadily with respect to the Q_{theo}. Therefore it can be said here that actual discharge is directly proportional the theoretical discharge.

Slop of graph = 0.979, which is the coefficient of dischargewhich is refer to as the ratio of actual discharge to theoretical discharge.

$C_d = \frac{Q_{act}}{Q_{theo}}$

A classical venturimeter coefficient of discharge is 0.985 as described in ISO 5167-1: 1991. From the graph it can be seen that the value gotten approaches that in the ISO 5167-1, therefore the experiment can be said to be successful. The difference can be due to some errors gotten while taken the readings.

Thus the result of the experiment can be summarizing as thus;

This experiment shows that the actual volumetric flowrate is lesser than the theoretical flowrate.

Volume flow increases as pressure decreases.

A graph was plotted and a value for the coefficient of discharge was found from the gradient.

V. DISCUSSION

The construction of the venturimeter was based on the knowledge gained from the workshop technology practice, fluid mechanics, engineering drawing and technical drawing and researched work. Before the commencement of the construction, an Engineering Design was done which includes the drawing of the venturi meter apparatus to be constructed with full dimensions and all mathematical models for the component that will be constructed, while selections were made for other components that was bought based on specifications as determined by the calculations, which acts as guide during the measurement and construction of the venturi meter apparatus.

The constructed venturimeter could be suitable for any process requiring measurement of fluid flow through pipes.

From the experiments performed, it can be seen that the actual volume flowrate is lower than the flowrate of theoretical volume. This is due to the fact that the liquid is not completely unusual, that is, the fact that there is a loss of energy in process of experiment. The loss of the head is reduce and ends between the mouth for all values. When the pressure head becomes a velocity head with your mouth, there is head loss between all velocity heads that don't become velocity head. This is due to the viscosity, which returns the actual volume flowrate lower than the flowrate of theoretical volume.

The experiment also aimed to study the validity of Bernoulli's equation when applied to a constant flow of water through a constant flow of water through a venturi. In addition, the experiment also measured the flow velocity and static pressure head and total pressure head in the rigid convergent and divergent pipes have of known geometric shape to obtain a stable flow velocity range. According to calculation after the experiment, when the fluid flows from a wider pipe to a narrower pipe, the velocity of the flowing fluid increases, regardless of the pressure difference and flow type of each result. These can be seen in all result table.

VI. RECOMMENDATION

Proper funding should also be provided by the institution to the young scientists undertaking the task of Fabrication of an apparatus for laboratory experimentation in order to ensure that the results are quality products with optimal longevity and high efficiency.

Having performed the experiments, it is important to note that adequate care should be taken to minimize/eliminate errors on the results. This situation may be due to some errors or weaknesses in the measurement of each data. One of them is that the observer did not correctly read the level of static head, where the eye is not perpendicular to the water level on the manometer.

Furthermore, for satisfactory operation of the venturi, the flow should be established one as it passes from the upstream section to the downstream section. To ensure this, the venturimeter should be installed downstream from a section of straight and uniform pipe.

VII. CONCLUSION

The construction of venturimeter apparatus was carried out using mild steel square hollow pipes, pvc valve gauge taps, pipes and Heschel venturi tube, cast iron centrifugal surface pump. This research was based on selecting the optimum material for the laboratory fluid flow apparatus, which allows the measurement of flow in pipes by a venturi meter. A plastic venturi meters could be a great means of checking or measuring flowrate with reliable and great accuracy for a range of physical applications. The tangible geometry and the performance that can be expected of the meter were in alliance with the ASME code. Both the pipes and venturimeter were plastic for smooth running operation with minimum losses. The materials were obtained locally and the construction was done in the university workshop**.**

The life of venturimeter is longer because the flow is inferred by the geometry of the meter. From the experiments carried out and result obtained it can be concluded that the project was successful.

The venturimeter will function satisfactory for any school laboratory experimental purposes especially for incompressible fluid when placed in straight pipeline.

REFERENCES

[1]. Biggs, B. (2015). Factors That Impact Venturimeter Accuracy. *Water technology* .

[2]. Clancy, L.J. (1975). *Aerodynamics*. Wiley. ISBN 978-0-470-15837-1.

[3]. Batchelor, G.K. (2000). *An Introduction to Fluid Dynamics*. Cambridge: Cambridge University Press. ISBN 978-0-521-66396-0

[4]. LANL. (2009). *Engineering standard Manual*. New mexico: LANL.

[5]. Mishra, P. (2016). Venturimeter priciple, construction and working diagrame. India: PDF.

[6]. *"Hydrodynamica". Britannica Online Encyclopedia. Retrieved 2008-10-30.*

[7]. Patrick Little, a. D. (2003). *Engineering Design*. Austell, USA: wiley.

[8]. R.K, R. (2007). *Strenght of material*. Rajasthan: S chard.