ME207-FLUID DYNAMICS PROJECT

DESIGN AND DEMONSTRATION OF ATOMIZER

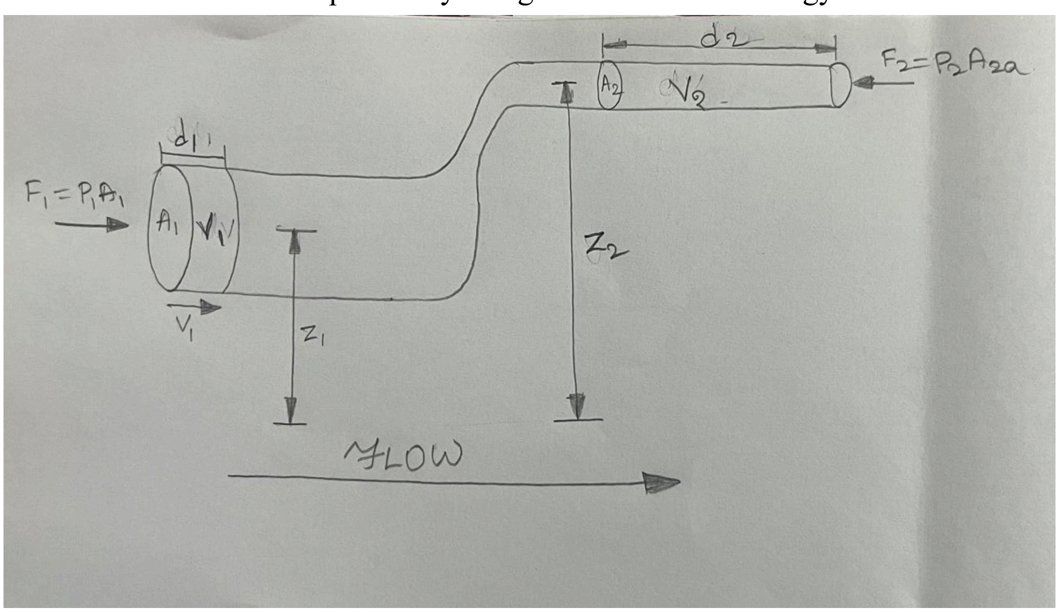
Objective: To design, develop, and optimize an atomizer based on Bernoulli's principle for efficient and accurate liquid dispensing, with the goal of improving atomization performance, reducing energy consumption, and making it more usable in a variety of applications.

Bernoulli's Principle:

Bernoulli's principle states that the entire mechanical energy of a moving fluid, which includes the gravitational potential energy of elevation, the energy associated with fluid pressure, and the kinetic energy of fluid motion, is constant. Bernoulli's principle is based on the notion of energy conservation.

Bernoulli's principle is based on the notion of energy conservation. This means that in a constant flow, the sum of all kinds of energy in a fluid is the same at all sites where there are no viscous forces. This demands that the total kinetic energy, potential energy, and internal energy be constant.

Let's derive Bernoulli's equation by using conservation of energy:



The change in the kinetic energy(KE) of the system equals the net work(W)done on the system. So, the work done by the forces in the fluid equals an increase in kinetic energy.

$$W = KE \qquad \_\_\_\_\_\_\_\_\_\_\_\_(1)$$

$$\rho * A_1 * d_1 = \rho * A_1 * v_1 * \Delta t = \Delta m$$

$$\rho * A_2 * d_2 = \rho * A_2 * v_2 * \Delta t = \Delta m$$

The work done by the pressure acting on the areas A_1 and A_2

$$W_{pressure} = F_{1,p} * d_1 - F_{2,p} * d_2$$

$$W_{pressure} = P_1 * A_1 * d_1 - P_2 * A_2 * d_2$$

$$W_{pressure} = \Delta m * \frac{P1}{\rho} - \Delta m * \frac{P2}{\rho}$$

Work done by the gravity

$$W_{gravity} = \Delta m * g * z_1 - \Delta m * g * z_2$$

the total work done in this time interval Δt is

$$W = W_{gravity} + W_{pressure} \qquad \_\_\_\_\_\_\_\_\_\_\_\_\_\_(2)$$

The increase in kinetic energy is

$$KE = \frac{1}{2} * \Delta m * v_2^2 - \frac{1}{2} * \Delta m * v_1^2 \qquad \_\_\_\_\_\_\_\_\_\_\_\_\_\_(3)$$

By keeping the equations in 2 and 3 in 1

$$\frac{1}{2} * \Delta m * v_2^2 - \frac{1}{2} * \Delta m * v_1^2 = W_{gravity} + W_{pressure}$$

$$\frac{1}{2} * \Delta m * v_2^2 - \frac{1}{2} * \Delta m * v_1^2 = \Delta m * g * z_1 - \Delta m * g * z_2 + \Delta m * \frac{P1}{\rho} - \Delta m * \frac{P2}{\rho}$$

$$\frac{1}{2} * \Delta m * v_2^2 + \Delta m * g * z_2 + \Delta m * \frac{P2}{\rho} = \frac{1}{2} * \Delta m * v_1^2 + \Delta m * g * z_1 + \Delta m * \frac{P1}{\rho}$$

Divide the equation with Δm

$$\frac{1}{2} * v_2^2 + g * z_2 + \frac{P2}{\rho} = \frac{1}{2} * v_1^2 + g * z_1 + \frac{P1}{\rho}$$

$$\frac{1}{2} * v^2 + g * z + \frac{P}{\rho} = \text{constant}$$

Bernoulli’s principle assumptions:

- Flow is steady.
- It is applicable for incompressible and laminar flows.
- Density is constant

- Friction losses are negligible.

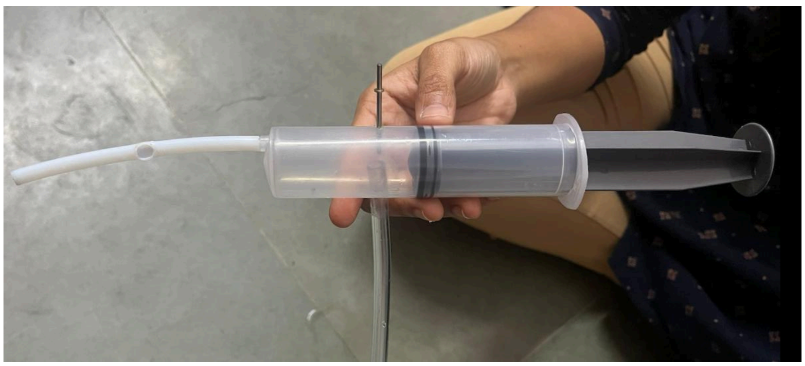
PRELIMINARY THEORY:

An atomizer is a device used to convert a liquid into a fine spray or mist. Initially, our aim was to develop a simple atomizer with a rubber bulb using a T-tube as the venturi. The second try was to use a hand pump to pump the air to create liquid flow, but we did not have a sufficient flow rate.So, after a lot of research, we came up with this model that uses automatic pressure pumps and syringes as its main body.

DESCRIPTION OF THE SETUP:

MATERIALS USED:

- Main syringe

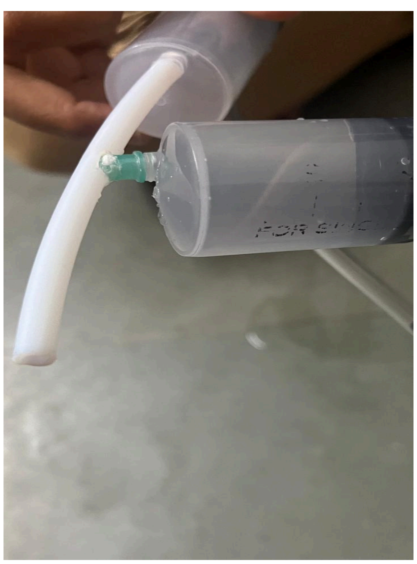


- Syringe used as water container

- Pressure pump(Tyre inflator)

- Nylon tube

- Small PVC pipe for the venturi, the green small tube and the PVC pipe make T-Tube



- Container to store the water that comes out as spray

MATERIAL	DIMENSIONS
Length of the PVC pipe	9.7cm
Diameter of PVC pipe	0.4cm
Length of venturi connecting to PVC pipe(the green one)	0.7cm
Diameter of venturi connecting to PVC pipe(the green one)	0.5cm
Length of syringe	14.2cm
Length of nylon pipe	14.2cm
The diameter of the nylon pipe	0.6cm

EXPERIMENTAL SETUP:

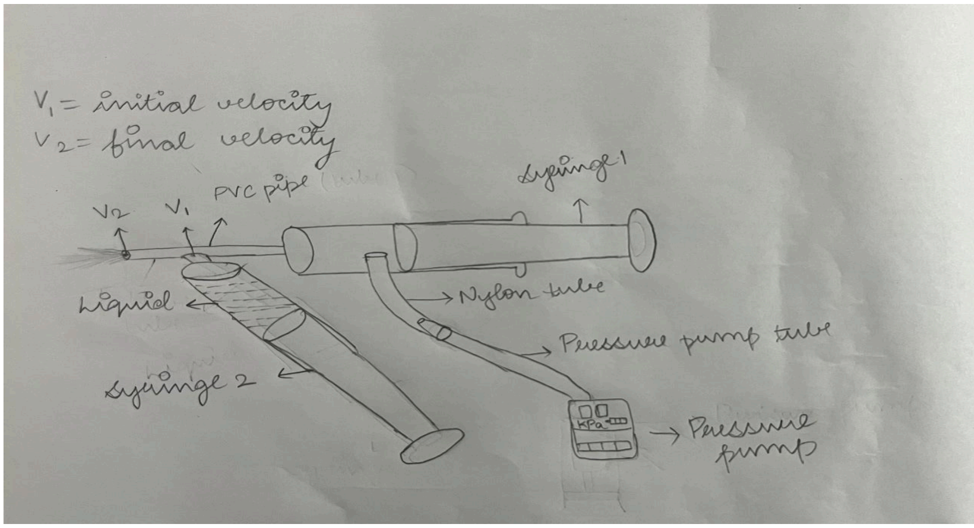
Our atomizer model is ingeniously constructed from two syringes, each serving a distinct purpose in the atomization process

AIR SUPPLY: The first syringe, which is the main body of our model, is drilled with a hole to connect the nylon pipe. The nylon pipe is connected to the pressure pump. This part of the setup supplies the air to the atomizer.

VENTURI: The ending of this syringe is connected to a PVC pipe which has an opening to it, from which the liquid is sprinkled out, the liquid we are using is water. This PVC pipe also has a hole for the water supply, so this part of the setup acts as the venturi of the atomizer.

WATER CONTAINER: The second syringe is used as a water container and is fit into the hole in the pvc pipe. This syringe has few holes for the free flow of air, we observed that without these holes, the water won't flow out.

DRAWING OF THE SETUP:



Procedure:

This setup creates an atomizer mechanism where pressurized air from the pressure pump propels water out of the system, producing a spray effect when the predetermined pressure is attained.

- Begin by carefully drilling a precise hole into the body of the syringe. Ensure that the diameter of the hole matches the size of the nylon pipe intended for insertion.
- Gently insert the nylon pipe into the drilled hole, making sure it fits snugly to prevent any leaks or disconnections. This step forms a secure connection between the syringe and the nylon pipe, establishing a vital pathway for airflow within the system.
- With the nylon pipe securely in place, proceed to connect its other end to the pressure pump. Ensure a firm and secure attachment to prevent any air leakage during operation.
- Now, take a small PVC tube and affix it securely to the end of the syringe opposite the nylon pipe connection. This PVC tube will serve as the conduit for the atomized liquid. The PVC pipe has a hole to which we connect the syringe, which we use as a water container.
- Drill small pores into the syringe, which we use as a water container for the free flow of air.
- With the PVC tube firmly attached to the syringe and the hole drilled, proceed to insert the syringe designated as the water container into the opening of the PVC tube. Ensure that the fit is tight and secure to prevent any potential leaks or disconnections.
- Once all components are properly assembled, it's time to initiate the atomization process. Activate the pressure pump to apply force and generate airflow through the system. As the pressure builds up to a predetermined threshold, the atomizer mechanism will be triggered, causing water to be ejected from the assembly in the form of a fine spray.

PHOTO OF THE EXPERIMENTAL SETUP:

Calculations:

By using Bernoulli's equation, we calculate the change in pressure

$$\frac{1}{2}*v^2 + g*z + \frac{P}{\rho} = \text{constant}$$

$$\frac{1}{2}*v_2^2 + g*z_2 + \frac{P2}{\rho} = \frac{1}{2}*v_1^2 + g*z_1 + \frac{P1}{\rho}$$

$$\frac{\rho}{2}*v_2^2 + \rho *g*z_2 + P_2 = \frac{\rho}{2}*v_1^2 + \rho*g*z_1 + P_1$$

In this we consider at point 1 and point 2

At point1, the velocity is 0 as there is no flow $v_1 = 0$

$$\frac{\rho}{2}*v_2^2 + \rho *g*z_2 + P_2 = \rho*g*z_1 + P_1$$

$$P_2 - P_1 = \rho*g*z_1 - \frac{\rho}{2}*v_2^2 - \rho *g*z_2$$

$$P_2 - P_1 = \rho*g*\Delta z - \frac{\rho}{2}*v_2^2$$

Where $\Delta z = z_1 - z_2$

Δz = 0.4 cm (measured value)

Finding of velocity v_2 from the experiment:

First we collected the water quantity in a certain time and we measured calculated it's volume

$v = \frac{V}{a*t}$

v= velocity of the flow
V = volume of the water
a = area of the cross-section of the PVC pipe
t= time taken to collect that specific volume of water

S.No	Pressure we gave(KPa)	volume(cm^3)	time(s)	area(cm^2)	velocity(m/s)
1.	50	6	78	0.50265	0.01530
2.	100	11	52	0.50265	0.04208
3.	150	12	38	0.50265	0.062824
4.	200	18	38	0.50265	0.094237
5.	250	21	34	0.50265	0.122878
6.	300	29	35	0.50265	0.164840

Now we calculate the change in pressure and flow rate.

$$P_2 - P_1 = \rho * g * \Delta z - \frac{\rho}{2} * v_2^2$$

$$\text{Flow rate}(Q) = v * a$$

s.no	Pressure we gave(KPa)	$P_{2,} - P_1$	Flow rate(x 10^{-6})
1.	50	390.85179	7.692
2.	100	390.731	21.1153
3.	150	389.6457	31.5789
4.	200	387.1837	47.368
5.	250	384.08079	61.7647
6.	300	378.05625	82.8571

OBSERVATIONS:

- Orientation of Water Container: When the water container is perpendicular to the syringe, the spraying of water becomes imperceptible. This might occur because the alignment affects the flow of air from the water container. In this perpendicular orientation, the airflow may be disrupted or impeded, resulting in insufficient air reaching the atomization point. As a result, the atomization process is compromised, leading to a lack of observable spraying.
- Minimum Pressure Requirement: The existence of a minimum pressure threshold,10kPa for our atomizer to function efficiently could be attributed to the design and mechanics of the atomization system. At pressures below this threshold, the force exerted on the liquid may not be sufficient to overcome resistance within the system, such as friction in the tubing or nozzle. Consequently, the liquid fails to atomize effectively, and spraying does not occur.

- Effect of Gap in the Syringe Body: The observation that the presence of a gap in the syringe body does not impact the flow rate of water or air may be due to the overall design and functionality of the atomizer system. It's possible that the gap does not significantly alter the flow dynamics or create obstructions that impede the flow of water or air. Alternatively, the gap may be small enough that its impact on flow rates is negligible compared to other factors.

In the first case and the second case the gap does not affect the flow of water or air

- Relationship Between Pressure and Sprinkling: The observable changes in sprinkling as pressure increases can be explained by the fundamental principles of fluid dynamics. Increasing the pressure within the system enhances the force exerted on the liquid, thereby accelerating its flow rate. As a result, more liquid is delivered to the atomization point within a given time frame, leading to more pronounced spraying.

- Importance of Holes in the Water Container: The necessity of holes in the water container to ensure the free flow of air is crucial for maintaining proper airflow dynamics within the atomizer system. Without these holes, air trapped within the water container cannot escape efficiently, creating a vacuum effect that inhibits the flow of liquid. Consequently, inadequate airflow leads to reduced atomization efficiency and the failure of the atomizer to function effectively.

- The change in the nylon pipe does not affect the flow of pressure

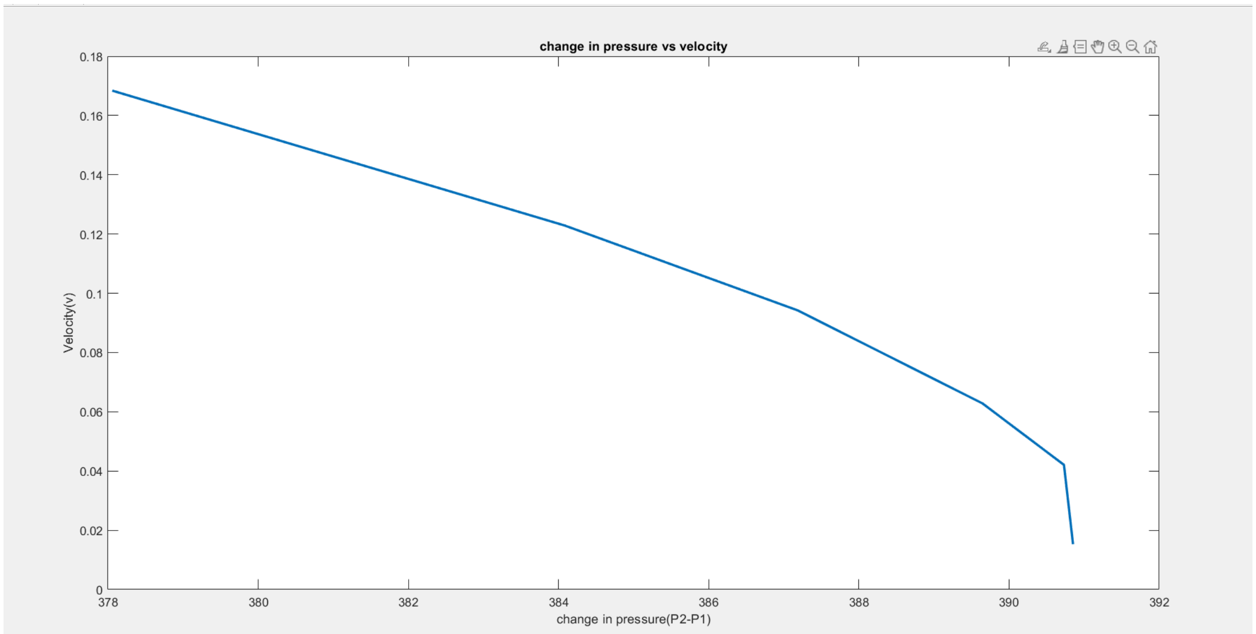
We observed experimentally that both of the nylon pipes showed the same results.

- From experimental values and graphs, we observe that as pressure is increased, the flow rate increases and vice versa

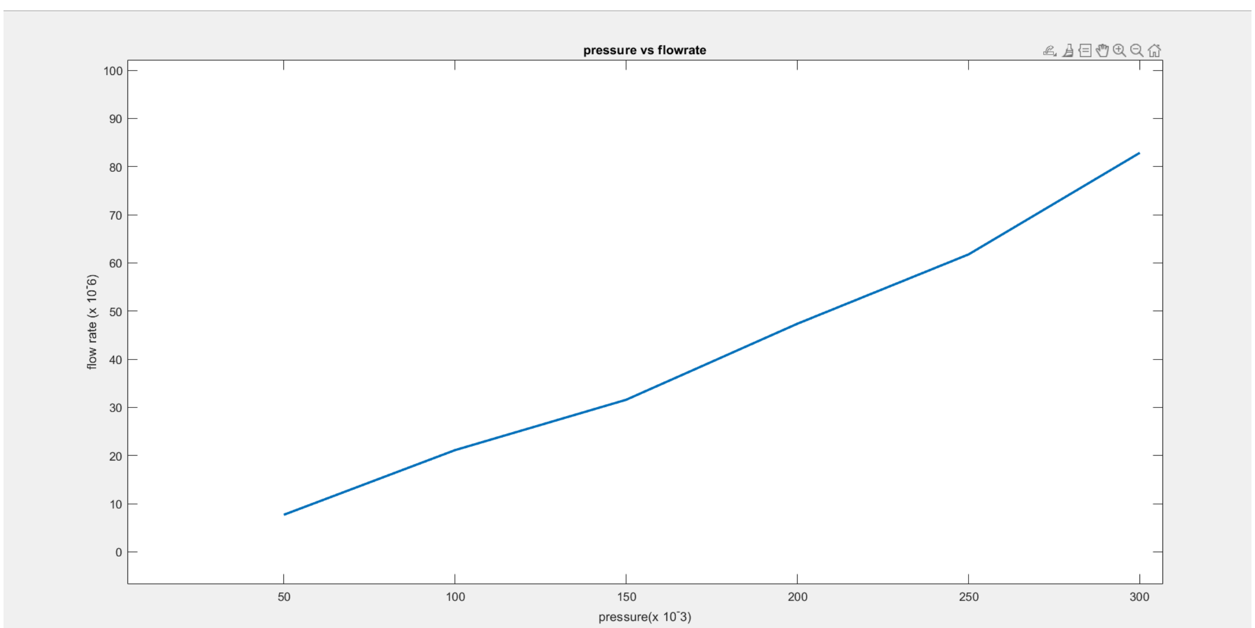
- When the change in pressure increases, velocity decreases and vice versa. Change in pressure is inversely proportional to velocity.

Graphs:

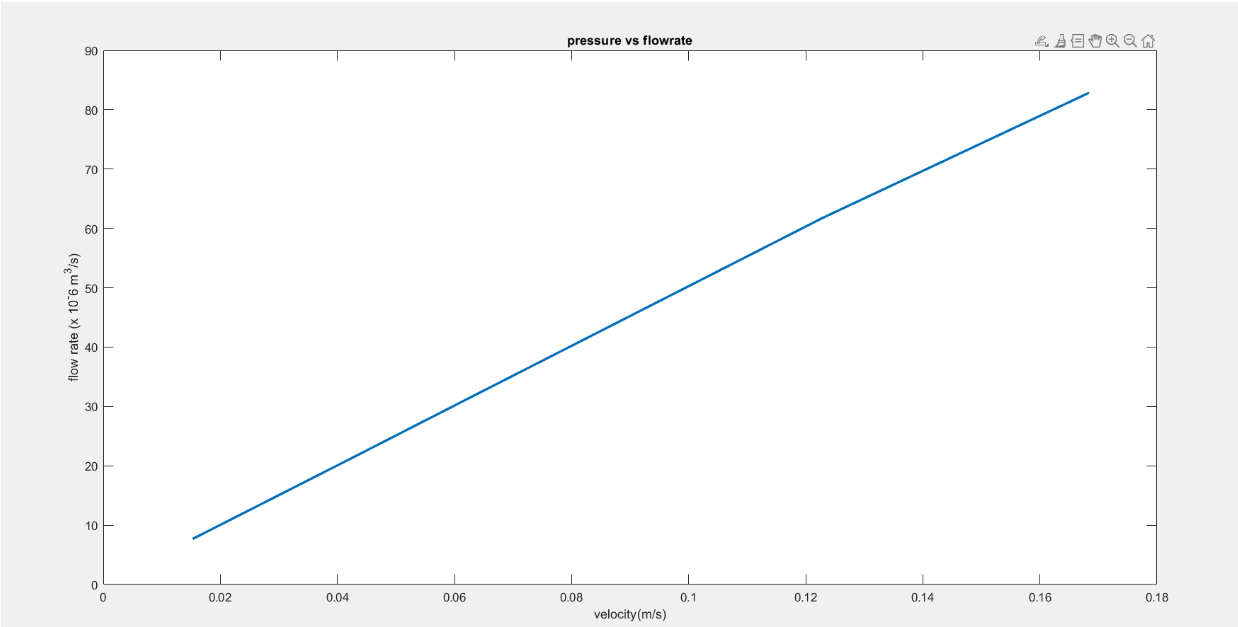
Change in pressure vs velocity:



Pressure vs flow rate:



Velocity vs flow rate:



LINK TO THE CODES:
https://docs.google.com/document/d/1yCNRHRwfhG0VD8BA42VmVXeBegR5bgp3_sv-1h3oCTM/edit

LEARNING OUTCOMES:
Through our experiments, we gained valuable insights into the behavior of our atomizer system. Our experiments provided clarity on the critical factors influencing fluid flow and atomization efficiency, emphasizing the importance of pressure control and proper ventilation in achieving optimal performance.

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