# AE 204 FLUID MECHANICS

## BERNOULLI EXPERIMENT / EXP4

**2024**

## OBJECTIVE

The aim of this experiment is to verify Bernoulli Equation by using a venturi meter to observe fluid elevation through the tube with different flow rates and research the reasons of different between theory and practice.

## THEORY

The Bernoulli equation is an approximate relation between pressure, velocity, and elevation, and is valid in regions of steady, incompressible flow where net frictional forces are negligible (Fig. 1). Despite its simplicity, it has proven to be a very powerful tool in fluid mechanics. In this section, we derive the Bernoulli equation by applying the conservation of linear momentum principle, and we demonstrate both its usefulness and its limitations.

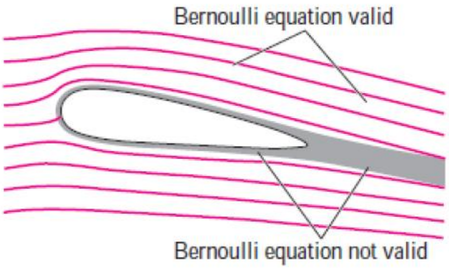

Figure 1. Practicable regions of Bernoulli equation

Consider the motion of a fluid particle in a flow field in steady flow:

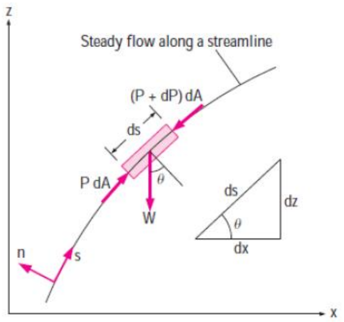

Figure 2. The forces acting on a fluid particle along a streamline

Applying Newton’s second law (which is referred to as the conservation of linear momentum relation in fluid mechanics) in the s-direction on a particle moving along a streamline gives:

$$\sum F_S = ma_S \tag{1}$$

In regions of flow where net frictional forces are negligible, the significant forces acting in the s-direction are the pressure (acting on both sides) and the component of the weight of the particle in the s-direction (Fig. 2). Therefore, Eq. 1 becomes:

$$PdA - (P + dP)dA - Wsin\theta = mV\frac{dV}{ds} \tag{2}$$

where θ is the angle between the normal of the streamline and the vertical z-axis at that point, m = ρV = ρ.dA.ds is the mass, W = mg = ρ.g.dA.ds is the weight of the fluid particle, and sinθ = dz /ds. Substituting;

$$-dP\ dA - \rho g\ dA\ ds\frac{dz}{ds} = \rho\ dA\ ds\ V\frac{dV}{ds} \tag{3}$$

Canceling dA from each term and simplifying,

$$-dP - \rho g\ dz = \rho\ V\ dV \tag{4}$$

Noting that V dV =1/2 d($V^2$) and dividing each term by ρ gives;

$$\frac{dP}{\rho} + \frac{1}{2}\ d(V^2) + gdz = 0 \tag{5}$$

For steady flow along a streamline equation becomes;

$$\int\frac{dP}{\rho} + \frac{V^2}{2} + gz = constant$$

since the last two terms are exact differentials. In the case of incompressible flow, the first term also becomes an exact differential, and its integration gives;

$$\frac{P}{\rho} + \frac{V^2}{2} + gz = constant \tag{6}$$

The value of the constant can be evaluated at any point on the streamline where the pressure, density, velocity, and elevation are known. The Bernoulli equation can also be written between any two points on the same streamline as;

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + gz_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + gz_2 \tag{7}$$

The Bernoulli equation states that the sum of the flow, kinetic, and potential energies of a fluid particle along a streamline is constant. Therefore, the kinetic and potential energies of the fluid can be converted to flow energy (and vice versa) during flow, causing the pressure to change. This phenomenon can be made more visible by multiplying the Bernoulli equation by the density ρ;

$$P + \rho\frac{V^2}{2} + \rho g z = constant \qquad (8)$$

Each term in this equation has pressure units, and thus each term represents some kind of pressure:

- P is the static pressure (it does not incorporate any dynamic effects); it represents the actual thermodynamic pressure of the fluid. This is the same as the pressure used in thermodynamics and property tables.
- $\rho V^2/2$ is the dynamic pressure; it represents the pressure rise when the fluid in motion is brought to a stop isentropically.
- $\rho g z$ is the hydrostatic pressure, which is not pressure in a real sense since its value depends on the reference level selected; it accounts for the elevation effects, i.e., of fluid weight on pressure.

The sum of the static, dynamic, and hydrostatic pressures is called the total pressure. Therefore, the Bernoulli equation states that the total pressure along a streamline is constant.

The sum of the static and dynamic pressures is called the stagnation pressure, and it is expressed as:

$$P_{stag} = P + \rho\frac{V^2}{2} \qquad (9)$$

## DESCRIPTION OF APPARATUS

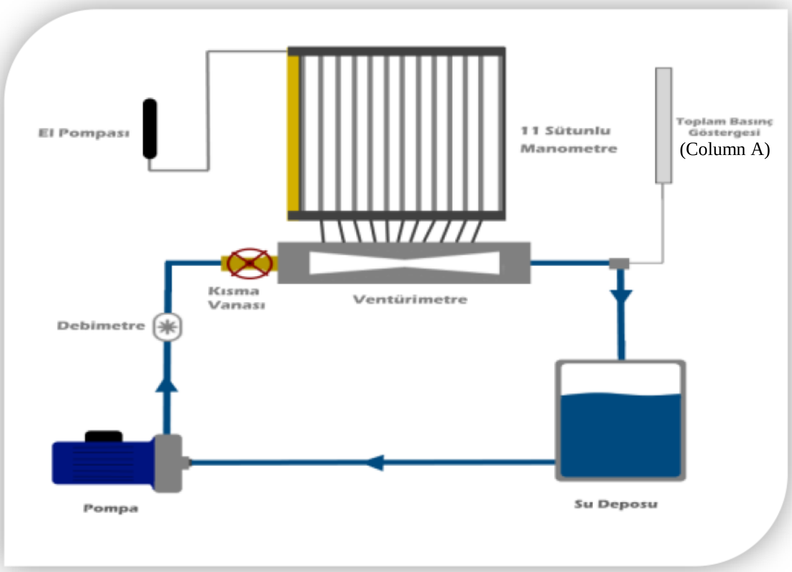

Figure 3. Experimental setup

As seen from Fig. 3 that there are 7 water columns from inlet to outlet through the main tube in the setup. Diameter and cross section area are not constant (see Fig. 4) and diameter values are given in Table 1. Also a comprehensive informing will be performed on the experiment day.

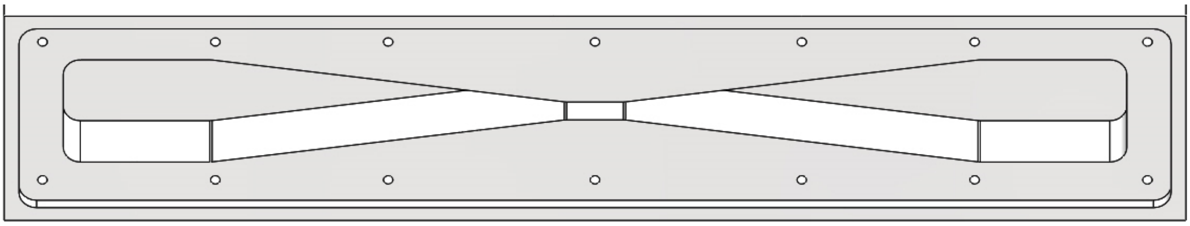

Figure 4. Venturimeter

Table 1. Diameters through the Venturi tube for Pressure Measuring Locations

| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| 40 mm | 30 mm | 20 mm | 10 mm | 20 mm | 30 mm | 40 mm |

## PROCEDURE

1. Plug in and switch on the main unit.
2. Open the water drain valve.
3. Start the pump and slowly open the water inlet valve.
4. Evacuate the system air by using the vane on the manometer column.
5. Adjust the inlet and outlet valves simultaneously to keep the water height in the pressure gauges at traceable levels.
6. Read and note the static pressure values at all points. Also read the volumetric flow rate and note it. Use the rotameter to measure the volumetric water flow rate.

## REFERENCES

**1.** https://aybu.edu.tr/bolumroot/contents/muhendislik_makina/files/BERNOULLI%20EXPERIMENT(1).pdf, Access date: Mar 12th, 2024.

**2.** Munson, B.R. et al., Fundamentals of Fluid Mechanics, 7th Ed., (2013).

**BERNOULLI EXPERIMENT / LAB 4 DATA SHEET** DATE:

STUDENT NAME, SURNAME:

SIGNATURE:

TABLE 1

| Data No | Volumetric Flowrate (l/min) | Manometer Heights (mm) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |

TABLE 2

| Data No | Velocities (m/s) | | | | | | |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |

TABLE 3

| Data No | Static Pressures (kPa) | | | | | | |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |

TABLE 4

| Data No | Dynamic Pressures (kPa) | | | | | | |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |

TABLE 5

| Data No | Total Pressure (kPa) |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |

Calculation steps:

1. Do necessary calculations and fill the table 1.
2. Fill in tables 2, 3 and 4 after the experiment.
3. Plot the graph showing the static pressure values at 7 points for each data (in one graph) along the venturi tube and comment on the results.
4. Plot the velocity distribution along the venturi tube for each data (in one graph).
5. Calculate the total pressure along the venturi tube for each data and fill in table 5.

LAB RULES:

- Each group should submit one report.
- Each group should write each parts by their own and get together with their group members to merge all of them.
- Reports are due to <u>next Monday</u>. They must be submitted to the corresponding assistant **till 17:00** on the next Monday.
- Students must sign the data sheet from the lab assistant at the end of each experiment and the signed sheet must be attached with the report. Reports without the signed data sheet will not be graded.
- Students are advised to read the detail of each experiment sheet before coming to the corresponding lab class.

LAB REPORT FORMAT (<u>HANDWRITTEN EXCEPT COVER PAGE, TABLES AND PLOTS</u>):
The lab report (no longer than 15 pages – all included –) should include the followings (unless otherwise specified):

1. Objective
2. Theory
3. Procedure
4. Results
5. Sample calculation
6. Necessary plots
7. Discussion on results, errors and graphs
8. Conclusion