EXPERIMENT (4)

FLOW MEASUREMENT

By:
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PURPOSE:

To study some of the famous instruments used in flow measurements.

- The measurement of water flow rate is an important topic in the study of fluid dynamics. There are many instruments used in flow measurements such as:
  - Venturi
  - Orifice plate
  - Variable area meter
DESCRIPTION OF APPARATUS

Water Flow Measuring Apparatus is designed as a free-standing apparatus for use on the Hydraulics Bench, although it could be used in conjunction with a low pressure water supply controlled by a valve and a discharge to drain. Water enters the apparatus through the lower left-hand end and flows horizontally through a sudden enlargement into a transparent venturi meter, and into an orifice plate, a 90° elbow changes the flow direction to vertical and connects to a variable area flow meter, a second bend passes the flow into a discharge pipe which incorporates an atmospheric break.
Flow Measurement:

- The static head at various points in the flow path may be measured on a manometer panel. The water flow through the apparatus is controlled by the delivery valve of the Hydraulics Bench and the flow rate may be confirmed by using the volumetric measuring tank of the Hydraulics Bench.
Flow Measurement:

**Theory:**

1. **Sudden Enlargement**

The head loss through the sudden enlargement $h_e$

$$ h_e = ke \frac{V_1^2}{2g} $$

$$ V_1 = \sqrt[2]{\frac{2gh_e}{\left(1 - \frac{A1}{A2}\right)^2}} $$

*Where: $h_e = h_2 - h_2$*

$$ Q_{th} = V_1 A_1 $$

$$ Q_{actual} = \frac{Volume}{time} $$

&

$$ Q_{act} = C_d Q_{th} $$

Where $C_d$ is the coefficient of discharge.
2. Venturi Meter

The flow through venturi meter can be calculated from the following equation:

\[ V_2 = \sqrt{\frac{2gH}{1 - \left(\frac{A_2}{A_1}\right)^2}} \]

Where: \( H = h_2 - h_1 \)

\[ Q_{th} = V_2 A_2 \]

\[ Q_{act} = C_d Q_{th} \]

\[ Q_{actual} = \frac{Volume}{time} \]

Where \( C_d \) is the coefficient of discharge.
3. Orifices plate
The flow through venturi meter can be calculated from the following equation:

\[ V_2 = \sqrt{\frac{2gH}{1 - \left(\frac{A_2}{A_1}\right)^2}} \]

Where: \( H = h_2 - h_1 \)

\[
Q_{th} = V_2 A_2 \\
Q_{act} = C_d Q_{th} \\
Q_{actual} = \frac{Volume}{time}
\]

Where \( C_d \) is the coefficient of discharge.
4. Elbows

The head loss through the elbow $h_b$

$$h_b = k_b \frac{V^2}{2g}$$

$$V = \sqrt{\frac{2gh_b}{k_b}}$$

Where $h_b = h_2 - h_1$

Where $k_b$ is the coefficient of the elbow (let $K_b = 0.5$)

$$Q_{th} = VA$$

$$Q_{actual} = \frac{Volume}{time}$$

$$Q_{act} = C_d Q_{th}$$

Where $C_d$ is the coefficient of discharge.
Flow Measurement:

5. Rotameter

The Rotameter reads the flow directly \( Q_{rot.} = Q_{theor.} \).

\[
Q_{act} = k \cdot Q_{rot} \rightarrow K = \frac{Q_{act}}{Q_{rot}}
\]
Flow Measurement:

Procedure:

1. Prepare the instruments such that the water passes Sudden Enlargement, then Venturi meter, Orifice plate, Elbow, and finally Rotameter.

   (Position the Water Flow Measuring Apparatus on the horizontal operating surface of the Hydraulics Bench)

2. Switch the pump on, allow the water to enter the flow measurement instruments, which are connected to Manometers tubes.

   (Ensure that there are no air bubbles trapped in the manometer tubes, if necessary open the supply valve until water spills out of the top of the manometer tubes so that the water flushes out all air bubbles)
Flow Measurement:

- **Procedure:** (cont.)

3. Close the valve and allow the level to stabilize with no flow when the height of the water in each manometer tube should be level with the top of the air vent (Check for horizontal surface).

4. Control the flow valve to obtain different readings of the heads in manometers and the corresponding flow from the volume tank.

5. Record the results.

6. Calculate the head losses from the manometer readings and the flow and Cd. (some calculations need Graph)
Flow Measurement:
Data & Results:

<table>
<thead>
<tr>
<th>Reading #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume flow (Liters)</td>
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<td></td>
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<tr>
<td>Time (min)</td>
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<tr>
<td>Head at tapping 1 (cm)</td>
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<tr>
<td>Head at tapping 2 (cm)</td>
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<td>Head at tapping 3 (cm)</td>
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<td>Head at tapping 4 (cm)</td>
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<tr>
<td>Head at tapping 5 (cm)</td>
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<tr>
<td>Head at tapping 6 (cm)</td>
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<tr>
<td>Head at tapping 7 (cm)</td>
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<tr>
<td>Rotameter flow rate (Liter/min)</td>
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</tbody>
</table>
CALCULATIONS:

○ Sudden Enlargement
Draw a relationship between Qact. in y-axis and Qth. in x-axis, the slope of the best line is the coefficient Cd. \[ \text{Slope} = C_d \]

○ Venturi meter
Draw a relationship between Qact. in y-axis and \( \sqrt{H} \) in x-axis, the slope of the best line is:
\[ \text{Slope} = C_d A_2 \sqrt{\frac{2g}{1 - \left( \frac{A_2}{A_1} \right)^2}} \]

Then, Calculate Cd ..
**Calculations:**

- **Orifices plate**
  Draw a relationship between Q_{act.} in y-axis and \( \sqrt{H} \) in x-axis, the slope of the best line is
  \[
  \text{Slope} = C_d A_2 \sqrt{\frac{2g}{1 - \left(\frac{A_2}{A_1}\right)^2}}
  \]
  Then, Calculate C_d

- **Elbow**
  Draw a relationship between Q_{act.} in y-axis and Q_{th.} in x-axis, the slope of the best line is the coefficient C_d.
  \[
  \text{Slope} = C_d
  \]
**Calculations:**

- **Rotameter**

  Draw a relationship between $Q_{act.}$ in y-axis and $Q_{rot.}$ in x-axis, the slope of the best line is the coefficient $K$.

  \[
  \text{Slope} = K
  \]