**Experiment (11): Cavitation demonstration**

**Introduction:**

Cavitation is demonstrated by forcing water through a contraction so that the static pressure of the water reduces. When the static pressure is reduced, any dissolved air in the water is released as bubbles. When the static pressure is reduced to the vapour pressure of the water, violent cavitation (vaporisation of the water) occurs. By restricting the flow downstream of the test section, the static pressure in the test section is increased. When the static pressure is maintained above the vapour pressure, increased flowrate is possible through the test section without cavitation occurring.

**Purpose:**

To demonstrate the appearance and sound of cavitation in a hydraulic system.
To demonstrate the conditions for cavitation to occur (liquid at its vapour pressure).
To show how cavitation can be prevented by raising the static pressure of a liquid above its vapour pressure.

**Apparatus:**

1. Cavitation demonstration apparatus.
   The following dimensions from the equipment are applicable:
   - Upstream diameter = 16mm.
   - Contraction included angle = 20°.
   - Contraction length = 33mm.
   - Throat diameter = 4.5mm.
   - Throat length = 20mm.
   - Expansion included angle = 12°.
   - Expansion length = 55mm.
   - Downstream diameter = 16mm.
2. Hydraulics Bench to supply water to the cavitation demonstration apparatus (the flow of water can be measured by timed volume collection).
3. A 0 - 50°C thermometer to determine the temperature of the water.
4. A stopwatch to time the accumulation of water in the volumetric tank.
1. Bourdon gauge for the pressure at the upstream (P1), Range 0-2 Bar (gauge).
2. Bourdon gauge for the pressure at the throat (P2), Range 0-1 Bar vacuum.
3. Bourdon gauge for the pressure at the downstream (P3), Range 0-1 Bar (gauge).
4. Support plate.
5. A quarter-turn ball valve (ball perforated to prevent excessive back pressure in the test section when the valve is fully closed).
6. Right-hand / outlet end.
7. The test section (circular venturi-shaped).
8. Left-hand / inlet end.

**Theory:**

In accordance with Bernoulli’s equation, the pressure at the throat of the venturi-shaped test section falls as the velocity of the water increases. However, the pressure can only fall as far as the vapour pressure of the water at which point the water starts to vaporise - cavitation occurs. Any further increase in velocity cannot reduce the pressure below the vapour pressure, so the water vaporises faster - stronger cavitation occurs and Bernoulli’s equation is not obeyed.

**Equipment Set Up:**

Locate the cavitation demonstration apparatus on top of the hydraulics bench. Connect the flexible tube at the left hand end of the cavitation demonstration apparatus to the water outlet on the hydraulic bench (it will be necessary to remove the yellow quick release connector before screwing the fitting onto the outlet). To aid assembly, the flexible tube can be disconnected from the cavitation demonstration apparatus by unscrewing the union on the valve. Ensure that the union is tightened (hand tight only) following reassembly.
Locate the flexible tube at the right hand end of the cavitation demonstration apparatus inside the volumetric tank of the hydraulic bench with the end inside the stilling baffle to minimize disturbances in the volumetric tank.

**Note:** that when operating the cavitation demonstration apparatus near or at the vapour pressure of the liquid, the vacuum gauge will be slow to respond. This is because the liquid inside the gauge turns to water vapour when operating at the vapour pressure and this process will not be instantaneous. The effect is more noticeable when the pressure is raised and cavitation stops – there will be a delay before the reading changes on the vacuum gauge after cavitation ceases visibly and audibly in the test section.

**Procedures:**

1. Open the ball valve (right hand end) fully then close the inlet diaphragm valve (left hand end) fully.
2. Close the flow control valve on hydraulic bench. Switch on the hydraulic bench, then slowly open the flow control valve on hydraulic bench until it is fully open.
3. Slowly open the inlet diaphragm valve at the left hand end of cavitation apparatus and allow water to flow through the cavitation apparatus until the clear acrylic test section and flexible connecting tubes are full of water with no air entrained.
4. Continue to open the inlet diaphragm valve slowly until fully open to obtain maximum flow through the system. Note the milky formation at the throat indicating the presence of cavitation. Also note the loud audible cracking sound accompanying the cavitation. Observe that the visible cavitation occurs in the expansion of the test section and not in the throat where the pressure is at its lowest (with the exception of the pressure tapping hole in the throat that causes a local disturbance to the flow).
5. If a thermometer is available measure and record the temperature of the water.
6. Close the inlet diaphragm valve until water flows slowly through the equipment with no cavitation in the test section (typically 0.1 Bar on the upstream gauge P1) ensuring that the test section remains full of water.
7. Record the following parameters:
   - Upstream water pressure P1 Bar.
   - Pressure at the throat P2 Bar (Vacuum).
   - Downstream water pressure P3 Bar.
8. Determine the flowrate by timing the collection of a known volume of water.
9. Gradually open the inlet diaphragm valve to increase the upstream pressure in small steps (typically 0.1 Bar increments on the upstream gauge p1). At each setting repeat steps (7) and (8) and note the presence of any tiny bubbles in the water. At each setting wait for the vacuum gauge to settle before recording the pressure at the throat (there will be a long delay before the reading changes on the gauge when near to or at cavitation because water inside the gauge is converting to vapour).
Observe the change in appearance and change in sound when the pressure at the throat reaches the vapour pressure of the water (air bubbles released from the water at higher static pressure make a softer noise that is not true cavitation).

Also observe that the pressure at the throat does not continue to fall below the vapour pressure of the water as the flow of water is increased.

10. Continue opening the inlet diaphragm valve in steps and recording / observing the characteristics of the water until the maximum flow of water is achieved with the valve fully open.

11. Gradually close the inlet diaphragm valve and observe that the Cavitation ceases as the pressure rises above the vapour pressure of the water (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).

12. Close the inlet diaphragm valve until water flows slowly through the equipment with no cavitation in the test section (typically 0.1 Bar on the upstream gauge P1) ensuring that the test section remains full of water.

13. Close the outlet ball valve fully (the valve is perforated to allow water to flow when fully closed).

14. Repeat steps 6 – 10 with the outlet restricted.

15. Repeat step 14 with different settings of the outlet ball valve (partially closed).

16. Close the flow control valve on the hydraulic bench, then switch off the pump.

**Results:**

For each set of readings calculate the volume flowrate, then plot the graph of $P_2$ against volume flowrate $Q$ for each set of results.

If the temperature of the water is known, determine the vapour pressure of the water using the table below. From your results determine the minimum static pressure achieved at the throat of the test section and confirm that this agrees with the vapour pressure of the water.

Analysis of the graphs should show that increasing flowrate (increasing velocity) through the test section results in decreasing static pressure (as predicted by the Bernoulli equation) until the water reaches its vapour pressure.

Results obtained with the downstream ball valve throttled should show that the onset of cavitation is delayed due to the higher static pressure in the system (higher flowrate is possible before cavitation occurs).

**Conclusion:**

The graphs should clearly show how the pressure at the throat falls as the flow / velocity of the water is increased as predicted by the Bernoulli equation. It should also show that the pressure reaches a minimum value that cannot be exceeded despite increasing water velocity.

Consider the effect of cavitation if allowed to occur in a hydraulic system.

The exercise shows that the cavitation can be prevented by increasing the static pressure of the fluid. However, this technique can only be applied to delay the effect (a slight increase in flowrate...
without cavitation occurring) and is not efficient as additional energy / a larger pump is required to overcome the additional losses in the system. Cavitation is therefore best avoided by careful system design to eliminate any high velocities, low pressures or high temperatures that could lead to cavitation.

Table 1: Vapour pressure of water at different temperature

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<tr>
<th>Temp. °C</th>
<th>Vapour pressure KN/m²</th>
<th>Vapour pressure Bar (abs.)</th>
<th>Temp. °C</th>
<th>Vapour pressure KN/m²</th>
<th>Vapour pressure Bar (abs.)</th>
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