AE 204 FLUID MECHANICS

CAVITATION EXPERIMENT / EXP2

2024

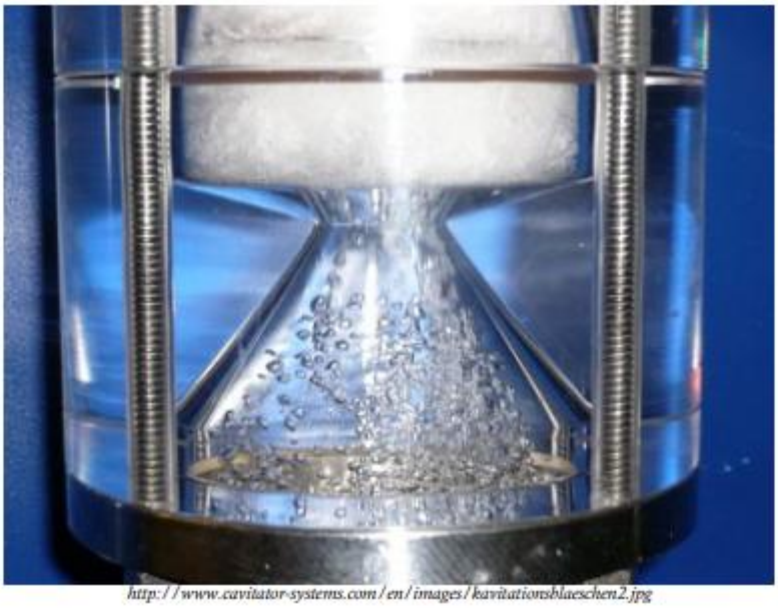
OBJECTIVE

Cavitation is the occurrence of small bubbles in a hydraulic system due to a pressure decrease such that the pressure in the water is less than vapor pressure. When water pressure is lower than vapor pressure, the water vaporizes within the liquid and small bubbles are formed. Pressure of the liquid around the bubbles causes the bubbles to then collapse which releases energy. In a hydraulic system, cavitation releases so much energy that damage and erosion can occur on the solid aspects of the system. We can see the negative results of cavitation in pumps, turbines and dams.

THEORY

Cavitation is a phenomenon that occurs when the pressure within a flowing fluid reaches the vapor pressure of the fluid, resulting in the formation of vapor bubbles. It is generally characterized by a loud crackling noise and a "cloud" of vapor bubbles that form where the cavitation is initiated (see Figure 1). These audible and visible signs, along with damage to surfaces within the pipe, are often the most recognizable aspects of cavitation. There are two different types of cavitation, depending on the properties of the vapor voids: *vaporous cavitation* when the bubbles consist of water vapor and *gaseous cavitation* when the bubbles contain gasses other than water vapor. Cavitation occurs due to a pressure drop as a result from an increase in the velocity of the fluid through a specific zone, often as a result of a decrease in the cross sectional area of the flow. Since pressure decreases at higher altitudes cavitation can also occur with an increase in the elevation of the hydraulic system. This concept is explicitly expressed by Bernoulli's Equation (Eqn. 1), in which it is evident that an increase in velocity or elevation on either side of the equation will result in a decrease in the associated pressure in order to maintain equilibrium (constant total head).

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + z_2 \qquad \textbf{(1)}$$



http://www.cavitator-systems.com/en/images/kavitationsblaeschen2.jpg

Figure 1. Formation of Cavitation Bubbles

Cavitation is often confused with the process of boiling, which is a similar phenomenon with several key differences. During the boiling process, the temperature of water is increased while maintaining constant external pressure (e.g., an open pot on a stove). As the water begins to undergo a phase change once the temperature reaches the boiling point, with vapor bubbles forming and collapsing when they reach the surface. Cavitation is similar in the way that it too consists of water changing from liquid to vapor state. However, the primary difference is that boiling occurs by changing the temperature while holding the pressure constant, and cavitation occurs by changing the pressure while holding the temperature constant.

Like many other phenomena, cavitation comes in a variety of magnitudes and intensities. Vapor bubbles may vary in size depending on which stage of cavitation the fluid is undergoing. The size of vapor bubbles is what affects the extent of damage and noise within the system. Two terms used to describe the progression of the cavitation process are incipient cavitation and desinent cavitation. The first refers to the critical state when cavitation first begins to occur as velocity increases and pressure reaches the value of the vapor pressure of the fluid. Desinent cavitation refers to the point at which velocity fluid is reduced and the pressure is greater than the vapor pressure. Flow can also reach a point of supercavitation, in which a single large bubble is present as opposed to the numerous individual bubbles. Supercavitation is especially applicable to the study of the motion of fast-moving objects submerged in a liquid. When a fast moving object is submerged in a liquid, a large vapor bubble encompassing the object greatly reduces the drag and aids its travel. The parameter commonly used to distinguish whether cavitation will occur and to what level is called the cavitation index, σ.

$$\sigma = \frac{p_0 - p_v}{\frac{1}{2}\rho v_0^2} \qquad \textbf{(2)}$$

The smaller the cavitation index, the greater the likelihood of cavitation. When σ remains greater than σ_i (incipient cavitation number) cavitation will not take place.

DESCRIPTION OF APPARATUS

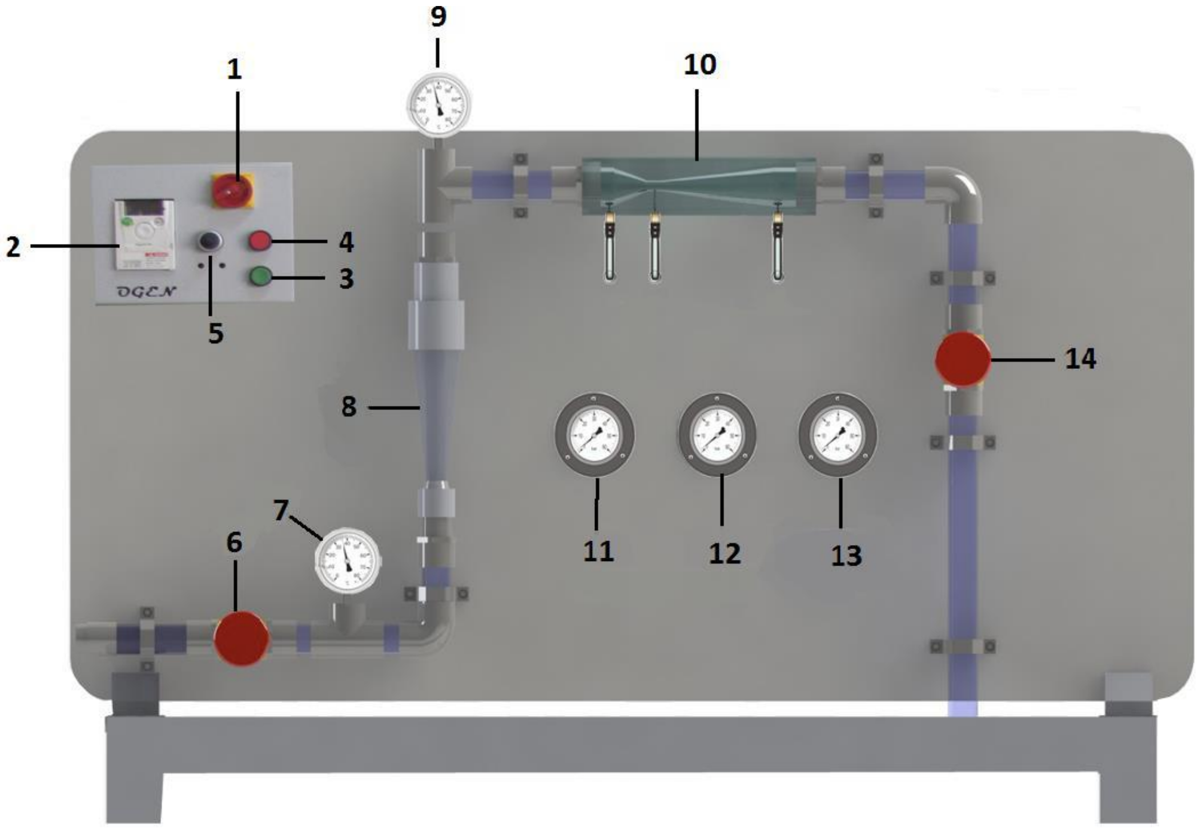


Figure 2. Experimental Apparatus

Experimental apparatus consists of;

1. Main switch
2. Frequency inverter
3. Pump start button
4. Pump stop button
5. Pump speed switch
6. Water inlet flow regulating valve
7. Inlet water pressure
8. Rotameter
9. Mechanical Thermometer
10. Venturi
11. Venturi inlet pressure manometer
12. Cavitation throat vacuum manometer
13. Venturi outlet manometer
14. Output side throttle valve

PROCEDURE

1. Water is filled into the tank of the test set (at least ½ of the total height).
2. Plug the device into a grounded outlet to switch the main switch (1).
3. Press pump start button (3).
4. The pump speed switch (5) increases the flow rate slowly.
5. After passing 0.6 bar, bubbles appear in cavitation throat (12).
6. Adjust the output throttle valve (14) to reduce the flow rate of water.
7. After the test is completed, the pump speed switch (5) is reset.
8. Press pump stop button (4).
9. Switch off the main switch (1).

REFERENCES

1. Fritz, C., Glover, J., Griswold, M., Cavitation, CIVE 401, Hydraulic Engineering, Dr. P.Y. Julien, November 19, 2014.

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

CAVITATION EXPERIMENT / LAB 2 DATA SHEET DATE:

STUDENT NAME, SURNAME:

SIGNATURE:

Volumetric flow rate (m^3/h)	Venturi inlet pressure (P_0)	Cavitation throat vacuum pressure (P_v)	Observations (Is there any visual evidence of bubbles?)

Calculation steps:

1. Fill in the table above.
2. Calculate the cavitation index for each data. (Inner diameter of the pipe is 29 mm).
3. Draw the P_0 vs P_v graph. Investigate the cavitation occurrence and comment on the graph.
4. Explore the vapor pressure of the water in the experimental conditions (i.e. temperature). Comment on the vapor pressure and cavitation index relation.

LAB RULES:
•Each group should submit one report.
•Each group should write each part by their own and get together with their group members to merge all of them.
•Reports are due to next Monday. 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 (HANDWRITTEN EXCEPT COVER PAGE, TABLES AND PLOTS):
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

Temperature, °C	Density, kg/m^3
15	999,0
16	998,8
17	998,7
18	998,5
19	998,4
20	998,2
21	998,0
22	997,8
23	997,5
24	997,3
25	997,0
26	996,8
27	996,5
28	996,2
29	995,9
30	995,6

Table 1: Density of water at different temperatures