THE VISUALIZATION OF CAVITATION

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Abstract - *The technological landscape of the 21st century will be shaped by the engineers that we educate in our classrooms. This paper describes efforts to utilize laboratory investigations to achieve early high quality student team projects aimed at applications and experiences. A research program was conducted in the fluid mechanics at PUCRS laboratory to investigate impulse pressure caused by the collapse of cavitation bubbles. A brief definition of cavitation and various cavitation numbers are presented. Various effects involved in the formation, growth and collapse of bubbles are also characterized and studied. The paper describes some experimental investigations of the formation and collapse of cavitation bubbles. A detailed study of the formation and collapse of the individual bubbles has been carried on by the use of pictures. The construction details, calibration and characteristics of these simples equipment are showed and discussed in this work.*

Introduction

Cavitation is a physical phenomenon associated with three aspects: formation, growth and collapse of bubbles within the body of a liquid due to the variations of local static pressure. However it is referred to as the collapse and release of energy. The bubbles form and grow in the regions of low pressure, and after collapse in the regions of high pressure. The objective of this work was to construct a tube of cavitation with didatic proposition for to show and analyze this formation, growing and collapse.

This specific type of water tube of cavitation was chose in this work because the pressure, velocity, and temperature of the liquid in the working section (water in the case) could be controlled accurately at any desired set of values within the range necessary in the experiment to produce or eliminate cavitation on a wide variety of situations.

The experimental investigations of the formation and collapse of bubbles present the problem that the individual bubbles or voids form and collapse continously with great velocity. The cavitation is generally caused by fast-moving bodies in liquid, or in closed conduits how pumps, so that even the study of simpler cases with a stationary object and fast-moving liquid to attain the same relative speed is very difficult. As a consequence of this a great number of experimental observations have been restricted to the study of the effect of cavitation is a cavitation damage. The objective of this paper is to make a quantitative, physical interpretation of the mechanism of cavitation, to formulate some elementary analytical descriptions of the phenomenon and to shown a construction of the equipment for visualization of cavitation in a very simple and didatic laboratory.

The Tube of Cavitation

The construction of this tube of cavitation was decided upon as the best way of meeting the following objectives:

1. Very low cost for our construction.
2. The dispositive should be able to accommodate a wide variety of experiments with a respective visualization of tests.
3. The dispositive should accommodate multiple users, with relatively fast changeovers between variables and experiments.
4. The students should be opportunity of to see and to measure phenomenons simultaneously.

Really the theory cavitation can also be used in combination with experiment in studying cavitation problems. A simple early example is the application of a visualization and controll of a cavitation in test. The theory, in this case, is simply that by the controll of pressures valve operating both input/output provides a correction in the bubbles of cavitation and his mechanism.

The principal value of a dispositive such as this is to provide the opportunity for studies in cavitation wich will improve theoretical flow modeling of the bubbles formation, growth and collapse. For this we show on figure 1 the schematic tube of cavitation by us constructed

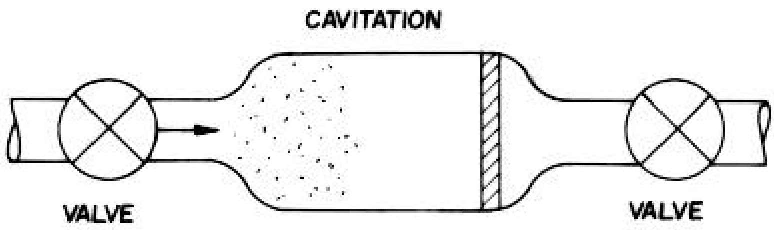

Figure 1 - The cavitation tube

Cavitation Theory

The phenomenon is clearly showed in the tube of cavitation in figure 1. There, water in high pressure flow by the left valve, by regulation of the right valve, release the liquid in atmosphere. When we open slowly the regulator valve are low velocity and flow, perhaps we not have cavitation. Opening the valve regulator, are velocity increase of water and the absolute pressure fall. The cavitation appear in the tube because it is induced by the rapid flow of liquid.

Cavitation number

The cavitation number C is the most useful parameter for defining cavitation flow in a fluid flow system and is given by

$$c = \frac{p - p_v}{\frac{1}{2}\rho v^2}$$

Where p is the free stream pressure, p_v, the vapour pressure, v the velocity, and p, correspond to the bulk temperature of the fluid.

Another type of cavitation appears at the point of incipient pressure p_i, when the pressure is decreased in a constant velocity. This is a cavitation incipient number σ_i, defined as

$$c_i = \frac{p_i - p_v}{\frac{1}{2}\rho v^2}$$

This cavitation incipient number c_i, is significantly affected by the content dissolued gases in water.

If p_c is the corrected gas pressure resulting from the quantity of dissolved gases, the experimental evidence showed (Naylor and Millward, 1984).

$$c_i = \frac{p - (p_v + p_c)}{\frac{1}{2}\rho v^2}$$

If we have a noncavitating flow the minimum pressure p_m is given by the minimum pressure coefficient (Holl, 1970), in the expression

$$c_{pm} = \frac{p - p_m}{\frac{1}{2}\rho v^2}$$

the vapourous cavitation occurs even when $p_m = p_v$ and, in this case usually we may write

$$c_i = cp_m$$

Gas bubble

The gas inside the bubble is foreign and thus not a directly part of the surrounding liquid medium when the cavitation occurs. The terminal velocity, V_t, is given by (Liberman, 1957)

$$V_t = \frac{2}{9} R^2 \left(\frac{\rho_i - \rho_e}{\mu} \right) g$$

Where ρ is the specific mass of the gas (ρ_i = internal gas, ρ_e =external gas), μ is the gas viscosity, g is the acceleration due to gravity, and R, the radius of the bubble.

Critical Radius

A complete study and discussion of the dynamic bubble growth was represented by the Rayleigh-Plesset equation (Knapp et al., 1970), in this equation the partial pressure of gas p_g is given by

$$p_g = \frac{GT}{R^3}$$

and

$$G = \frac{3m.}{4\pi}.E$$

Where T, is the absolute temperature, G, is the gas content factor, R, the bubble radius, m, the mass of gas, and E, is the specific constant of gas.

If A is the surface area of the wall, for different phases of bubble growth, the critical radius of the bubble can be write as

$$R_c = \sqrt{3GT / 2A}$$

Bubble Collapse

The collapse of the bubble is an very important phenomenon to be observed.

Measurements, Comparisons and Simplifications

In the present case, in various applications by the measure the pressure in input and output of the tube of cavitation we have the graphic in figure 2.

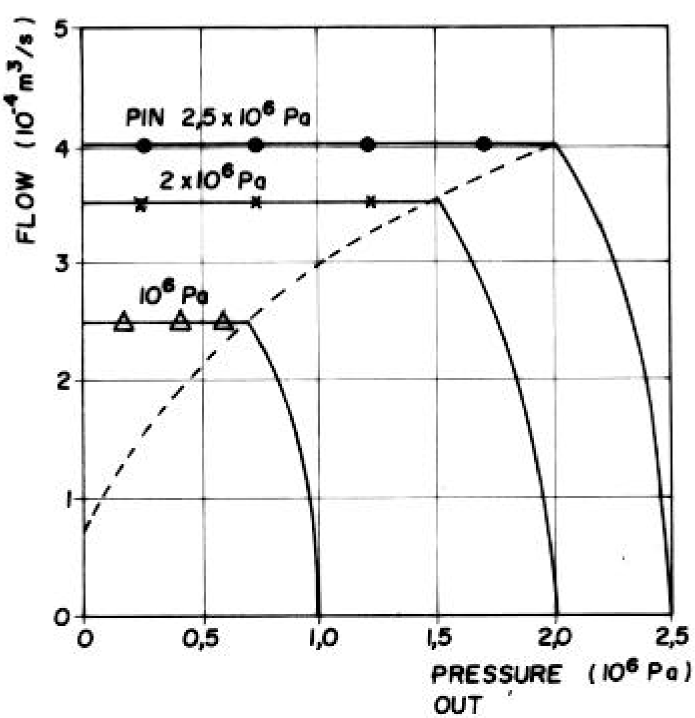

Figure 2 - Pressure out and flow relation

The pressure amplitude by the bubble collapse at the solid wall surface, acoording to silver (1942) is given as:

$$p_s = \sqrt{KP\left(\frac{V_s}{V_w}\right)^{\frac{1}{3}}}$$, for large bubbles ($R \rightarrow \infty$)

and

$$p_s = \frac{1}{\sqrt{R}}\sqrt{3KA\left(\frac{V_s}{V_w}\right)^{\frac{1}{3}}}$$,

for small bubbles ($R \rightarrow o$)

Where, p_s is the pressure exerted on solid surface, p, is the pressure rise, K, is the bulk modulus of liquid, A, the surface area of the wall, V_s, the specific volume of vapour, V_w, the specific volume of liquid, and R, the bubble radius.

by the application the Bernoulli equation and utilizing any simplifications we have for the pressure reason $\frac{p_0}{p_i} = 1 - \frac{t_r + t_d}{1 + t_r}$

where the unknown and values of constant are

p_0 = pressure out

p_i = pressure in

t_r = resistance coefficient of the tube = 0,07

t_d = resistance coefficient of the diffusion = 0,22

The values of constant are characteristics of experimental bottle neck, thus

$$\frac{\rho_0}{\rho_i} = 1 - \frac{0{,}07 + 0{,}22}{1{,}07} = 0{,}73$$

This way looking at picture 3 it is possible to verify the correlation between the experimental values found and the approximations adopted.

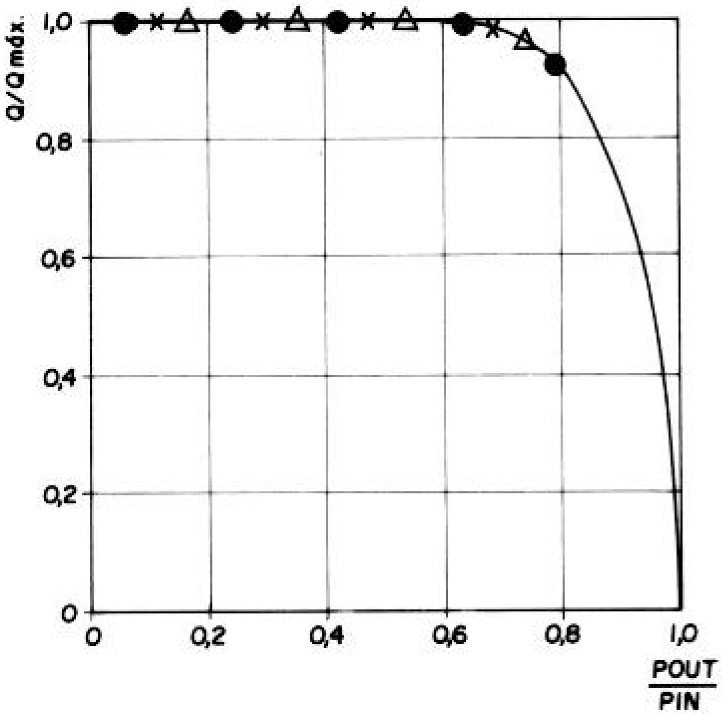

FIGURE 3. FLOW AND PRESSURE RELATION

CONCLUSIONS

In situ measurements of pressure and flow, the values founded by calculations are initially consistent with experimental observations in flow effects in cavitation occurrence.

The tube of cavitation constructed is a good machine for didatic applications in cavitation phenomenon mainly for its visual possibility.

It is possible to apply the tube of cavitation to analysis other formulations and equations in future works.

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