Determination of the flow regime using the experimental hydrodynamic stand

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Abstract. The article describes the approach to determining the flow regime using the experimental hydrodynamic stand for researching the cavitation processes. A series of experiments with technical tap water was performed, which allowed to confirm the reliability of the results obtained by comparing them with theoretical values. The researched values include mean flow rate, Reynolds number and cavitation numbers. Conclusions about the type of cavitation flow was made.

The emergence and development of cavitation in the industrial equipment and the transportation routes significantly affects the reliability of their work and operating conditions. The issues of identifying the beginning of cavitation and critical parameters of fluid flow depending on the geometry of the object, the type of fluid and flow parameters have great practical importance.

The research of cavitation processes is a difficult task. The reason of that is there is a lack of a general theory of cavitation phenomena and a disadvantage of reliable ideas about the mechanisms of origin of cavitation. The decisive factor influencing the occurrence of cavitation in a moving stream is its dynamic strength, in fact, a cavitation is a violation of the integrity of the flow.

It is common to associate the discontinuity of a fluid with the presence of so-called cavitation embryos in a liquid (any inhomogeneities in the liquid). Such inhomogeneities are solid or gas inclusions in a liquid. The total gas content of the liquid is determined by the amount of dissolved and free gas. The presence of free gas violates the homogeneity of the structure of the liquid, helping to reduce the resistance to tensile stresses, i.e., current rip.

The free gas, enclosed in the smallest voids inside the liquid – microbubbles, forms a kind of stably existing bubble ensemble. It is considered that the total amount of such gas is negligible and therefore cannot play a noticeable role even in such liquid processes, where the factor of discontinuity of the medium, it would seem, should come first. According to the existing estimates, the share of free gas in distilled water is less than 10–10 [1]. At the same time, it was proved that in reality the share of the relative free gas content of water is much higher [2–4]. Even in long-duration distilled water under equilibrium conditions, it can be exceeded 10–6, and for settled tap water under the same conditions it can be an order of magnitude higher, i.e. more than 10–5. The concentration of dissolved gases (the air in particular) can vary due to the displacement of individual volumes of liquid relative to each other or due to diffusion processes of substance transfer from one microvolume of liquid to another [5].

Ensuring the absolute absence of air in experimental setup is a difficult task, so most researchers rely on methods that presuppose its presence [6].

For the experimental study in Siberian Federal University, an experimental setup of the closed hydrodynamic contour [7] was created. The movement of the fluid is created by the centrifugal pump, the flow is measured, passing through a 300 mm long honeycomb. Then fluid is entering the working section and then goes again into the pump. The working section have the confuser and the transparent cylindrical tube with a truncated cone resistance installed in it. At the base of the cone there is a hole for measuring the pressure in the cavity.

The experiment starts with the system filled with tap water, then part of the dissolved air is removed through the air valves. The water flow rate in the experiments was 20 m^3 per hour, the cavity had a developed character. The appearance of the cavity is shown in Figure 1.

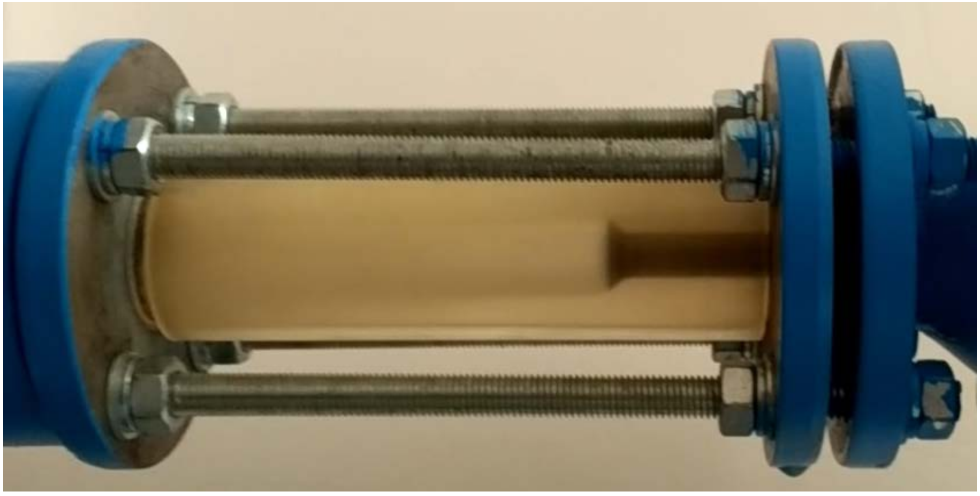

Figure 1. The appearance of the cavity.

The internal profile of the flow part of the working section with the cone installed in the flow, which acts as a hydraulic resistance, behind which a cavitation cavity is formed and the profile of the cavity are shown in Figure 2.

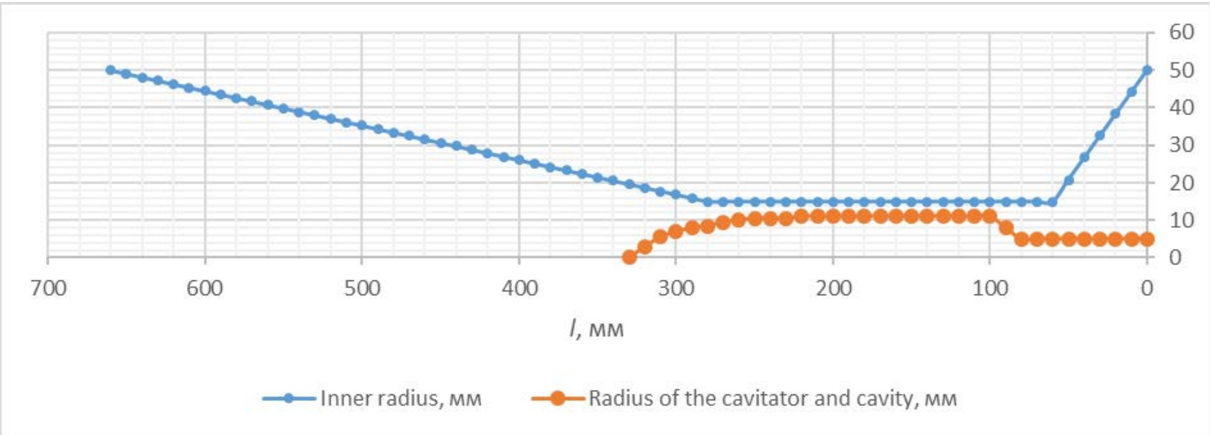

Figure 2. The internal profile of the flow part of the working section and the profile of the cavity.

The flow rates and Reynolds numbers averaged over the cross section for the flow rate of 20 m^3 per hour are shown in Figure 3.

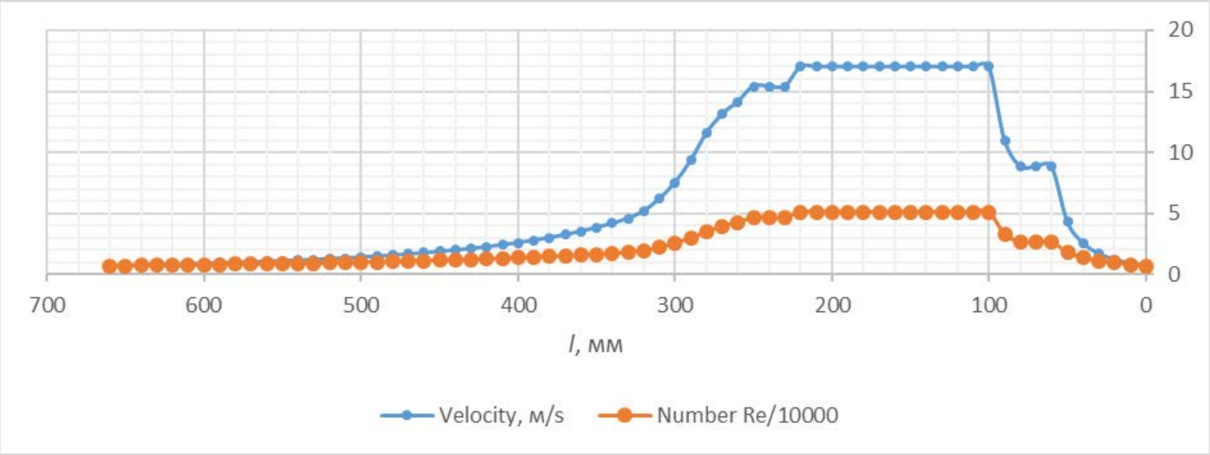

Figure 3. The flow rates and Reynolds numbers averaged over the cross section.

The measurements allow to calculate the cavitation numbers using the following formula:

$$\chi = \frac{2(p_1 - p_2)}{\rho V^2},$$

where p_1 is the pressure measured in the cavity, p_2 is the value of the saturated vapor pressure, V is the flow velocity average over the cross section. The obtained values for different flow temperatures are shown in Figure 4.

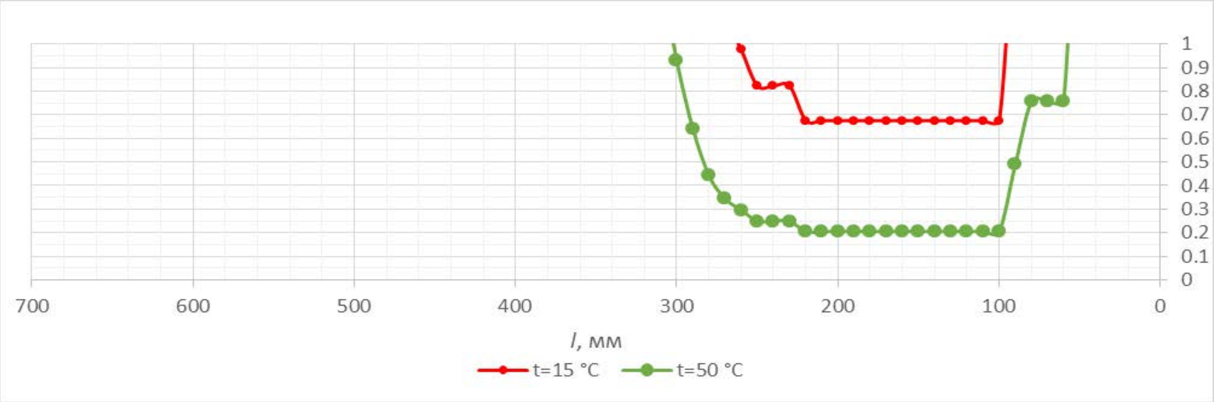

Figure 4. The obtained values for different flow temperatures.

The accuracy of the experimental results is confirmed by comparing the pressure measured in the cavity with the saturation pressure. Figure 5 shows the theoretical and experimental values of the pressure of saturated water vapor in the operating temperature range.

Over the entire temperature range, the measured pressure is higher than the saturation pressure at the same temperature, which is explained by the presence of a large amount of free air in the stream. The equalization of pressure values with increasing temperature is due to the process of deaeration of the flow, since the temperature rise is directly proportional to the time of water circulation in the experimental setup.

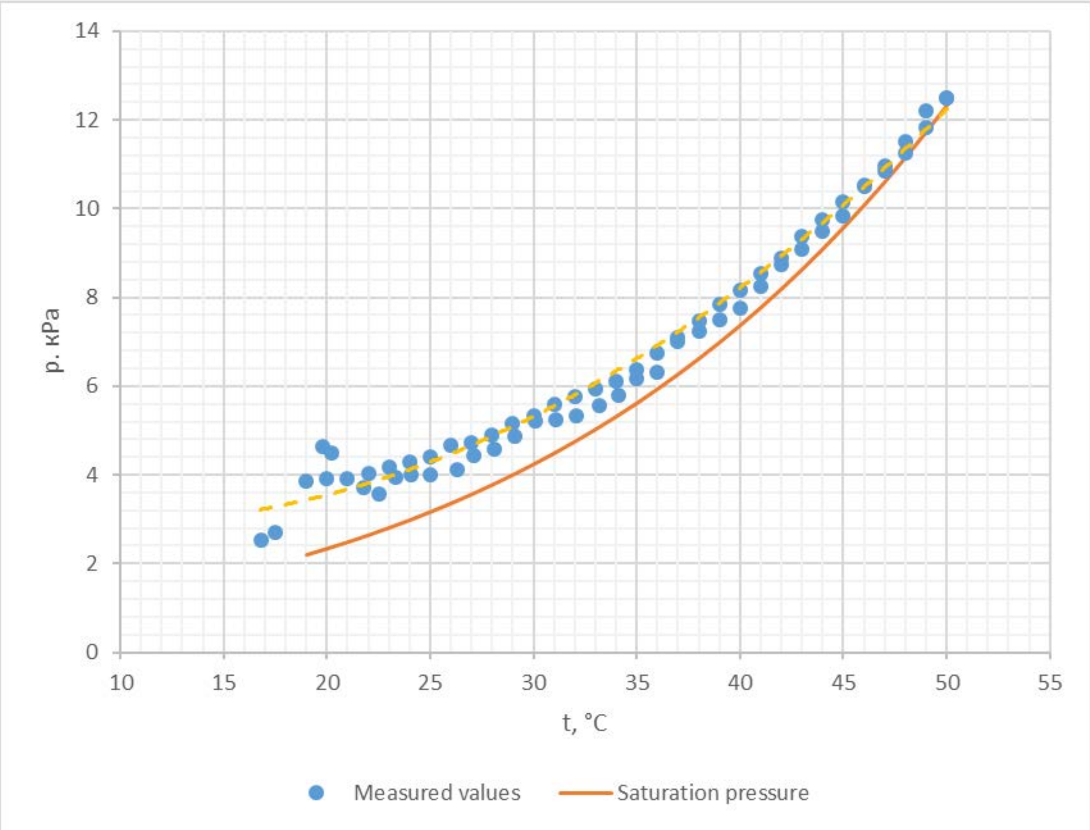

Figure 5. The theoretical and experimental values of the pressure of saturated water vapor in the operating temperature range.

Cavitational phenomena occurring in the hydraulic systems of technological equipment of various industries, affects the efficiency of their work, which determines the interest of the experimental researches. The reliable results of influence of such factors as a temperature of the liquid, a pressure of saturated vapor, a geometry of the system (a presence of local resistances) can be obtained with the presented experimental setup.

The obtained results and the described research methods can be used to select the operational parameters and geometric characteristics of industrial equipment.

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