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STUDY OF HYDRODYNAMIC LUMINESCENCE IN A CAVITATION LIQUID MEDIUM

The article presents the results of experimental studies of hydrodynamic processes in a cavitation generator. To study the mechanisms of cavitation and hydrodynamic luminescence, a basic hydraulic circuit of a test bench was developed and a bench was created that allows one to study the flow rate characteristic of a cavitator and visualize the flow in the working chambers. The analysis of literature and informational data made it possible to determine the basic conditions and factors affecting the process of hydroluminescence and showed that the interpretation of the nature of the occurrence of sonoluminescence and hydroluminescence is not unambiguous. The processes considered have two main theories of their occurrence - "thermal" and "electrical", but, as shown in modern scientific papers, this position cannot be considered satisfactory. Thorough experimental verification is required. It is concluded that the phenomenon of hydroluminescence (triboluminescence) can be used as a method for visualizing cavitation. As a result of the application of the experimental-analytical method and technical visualization, it was found that for this nozzle (configuration and flow part of the throttle) at a flow velocity of more than 40 m / s, a hydroluminescence process observed in the form of a pulsed-flickering spark of blue color on the periphery and white in the middle at the input edge of the valve. At the same time, the management of the work processes that accompany the phenomenon of cavitation is very relevant, because it allows you to deal with the undesirable consequences of cavitation. Based on the results obtained, it was proposed to use a temperature-sensitive drive for automatic correction of the throttle bore, which will allow maintaining a predetermined calculated value of the cavitation number in changing operating conditions, for example, depending on temperature and viscosity.

Keywords: *cavitation, visualization, hydrodynamic luminescence, throttle, triboluminescence, cavitator, visualization of fluid flow, temperature, viscosity, cavitation number, sonoluminescence, fluid flow rate.*

Introduction. Modern hydraulic equipment operates at significant working pressures, which can reach 400 bar. In hydraulic devices, hydro systems as shutoff and regulating elements are widely used different types of chokes, nozzles, throttles, etc. [1, 2]. In the diaphragm and cylindrical chokes, the flow of the working fluid has a pronounced turbulent character, and in the compressed section, high speed causes cavitation and the active allocation of bubbles of undissolved air and steam [2-5] associated with it. The phenomenon of cavitation is often harmful to the operation of hydraulic systems.

Since the appearance of cavitation is observed in a stream only under certain conditions, and it may be unstable when changing, it becomes necessary to create systems that will provide a stable cavitation regime [2-7].

Cavitation leads to the appearance of a number of physicochemical processes, may be accompanied by cavitation chemical reactions, oxidation, destruction and luminescence.

State of the problem. The urgency of studying the phenomena of hydroluminescence is due to the widespread use of dielectric pipelines and local resistance. In addition to simulation, the study of the flow of fluid in the cavitator can be carried out by involving experimental methods of research. Experimental methods help visualize the movement of the fluid in the nozzle to further analyze the processes of the medium [5]. Observation of the origin of cavitation processes can be accomplished by visualizing a fluid stream with a highspeed video recording of the work process in a cavitator with a transparent material casing [10-12]. Thus, in the indicated way, it is possible to analyze the process of occurrence of cavitation bubbles and the emission of light, as well as to obtain empirical calculations of dependence.

After passing through the rarefaction zone, in the zone of high pressure formed bubbles are instantly locked up, which causes the emergence of powerful spherical waves and cumulative jets, which leads to erosive destruction of the material of the walls of the channel and the emergence of active acoustic processes (Fig. 1).

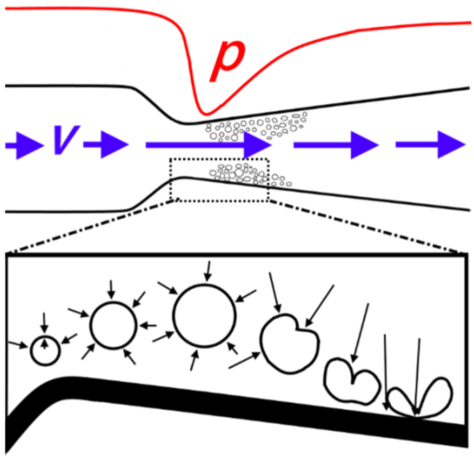

Fig. 1. The emergence of cavitation in the contraction region of the flows

Problem statement. The phenomenon of hydroluminescence is widely used as a method of visualization of cavitation. With the help of hydrolumnescence, ionize nanoparticles and electrify liquids, for example, varnishes or paints in order to achieve a more uniform coating of parts with paint. In this case, the liquid acquires a positive charge, and the walls of the channels are negative. In missile carriers, unauthorized cavitation with the appearance of hydrolumnescence in the fuel system (pump) may lead to an explosion of the fuel system of the rocket carrier [3-5]. The question remains of the physics of the process, which is due to the occurrence of hydroluminescence and its estimation in accordance with the theories proposed. To study cavitation processes and managing them it is necessary to: clarification of the discharge coefficient for the throttle of a hydrodynamic cavitator, determination of cavitation regimes in which hydroluminescence is observed, and factors influencing its intensity and managing them.

Purpose of the paper. The presented paper is aimed at is a study of the process of occurrence of cavitation phenomena and an experimental study of hydrodynamic cavitation accompanied by hydroluminescence.

Problem setting. In accordance with [12], for some processes it is necessary to determine the nature and conditions for the occurrence of cavitation processes, which are accompanied by hydroluminescence.

For study cavitation processes, a turbulent throttle model was created with the possibility of changing the channel cross sectional area. The screw is made from ebonite - a material with good cavitation emission of electrons.

Before the experiment, the temperature and pressure sensor were calibrated with a reference thermocouple and a manometer, and the digital flow meter calibrated with volumetric flow meter.

Cavitation intensity was estimated using a graphical editor, determining the weighted average brightness level of the image pixels obtained by multiplying each brightness level by the number of pixels of a given level, and then divided by the total number of brightness levels.

For an in-depth study of light emission, a schematic diagram of an experimental stand was developed (Fig. 2). The stand is built on the basis of a hydraulic station, and measuring equipment for recording the differential pressure on the model and the values of flow and temperature. The flow is fixed using a high-speed camera.

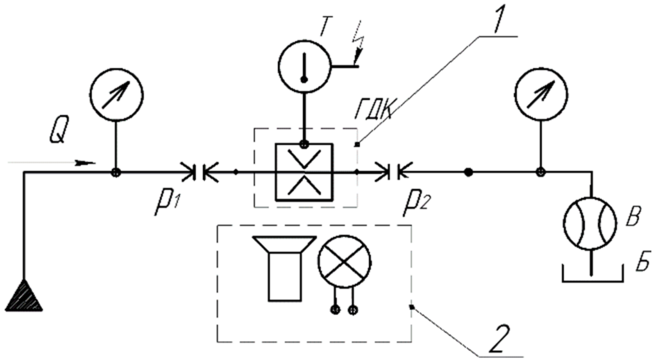

Fig. 2. Basic hydraulic diagram of the test bench (*1* – cavitation nozzle, *2* – speed camera)

For the study of cavitation processes, a model of a hydrodynamic cavitator with a regulated orifice was created. The element that controls the cross-section - the screw is made of brass. (Fig. 3).

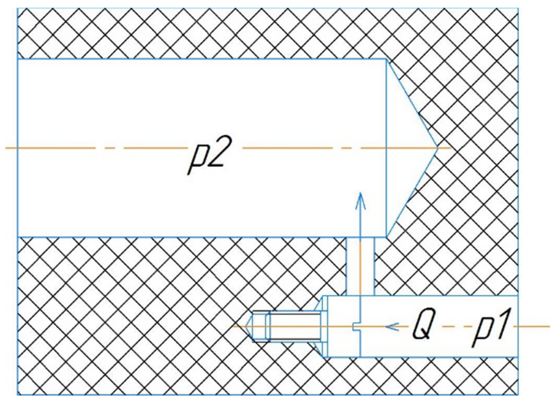

Fig. 3. Determination of the studied area of the cavitator nozzle

In the fluid moving in the stream, with the growth of the velocity vector, cavitation bubbles begin to appear (Fig. 4), the size of which increases with increasing pressure drop.

At a flow velocity of more than 40 m / s, visually the cavitation has a pronounced appearance with a well-formed cavitation torch and the appearance of light radiation (Fig. 4). In addition to the appearance of cavitation bubbles, it was observed that there were light effects in the narrow channel. The light emission was observed at a pressure drop of 1,8 MPa and was manifested in the form of sparks that slip along downstream in the central part of the canal.

The discharge coefficient of working fluid through the nozzle was determined:

$$\mu = \frac{Q_a}{Q_t} \quad (1)$$

where *Qa* – the actual flow rate, *Qt* – the theoretical flow rate.

Visually managed to trace the process of nucleation and development of the cavitational zone up to the moment of hydroluminescence [11; 12]. The study of the cavitation process was carried out for mineral oil of category H-LP and domestic mineral oil «Leol M20», in which the cavitation in the stream was more intense. No light emission was observed. It can be assumed that the dependence of light radiation on the properties of the base of mineral oil, the quantity and type of gas, water, the pressure of its saturated vapor and the composition of the additive package.

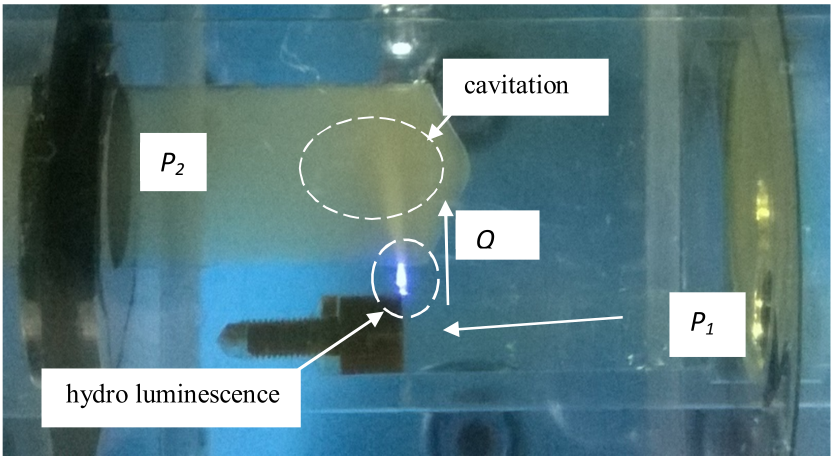

Fig. 4. Visualization of the occurrence of cavitation (t = 50°C, pressure drop, (P_1-P_2) = 4 MPa, flow rate, Q = 1,1 l/min, diameter of the throttle, d = 0,6 mm)

To prevent cavitation or its use at the certain level, it is proposed to create a design of a hydrodynamic cavitator, which will automatically adjust the flow rate in the throttles and maintain the required number of cavitation numbers to account for the use of a thermosensitive element.

Conclusions. Thus, a stand was developed that makes it possible to track the processes of hydrodynamic cavitation and take into account the following feature: in the presence of developed cavitation, hydroluminescence is observed. Experimental studies allowed to find that the temperature of the working fluid significantly influences on the flow characteristics of the throttle. The boundaries of the occurrence of hydroluminescence are established.

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ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ ГІДРОДИНАМІЧНОЇ ЛЮМІНЕСЦЕНЦІЇ В КАВІТУЮЧОМУ РІДИННОМУ СЕРЕДОВИЩІ

У статті представлено результати експериментальних досліджень гідродинамічних процесів у кавітаційному генераторі. Для дослідження механізмів виникнення кавітації та гідродинамічної люмінесценції було розроблено принципову гідравлічну схему випробувального стенду та створено стенд, що дозволяє дослідити витратну характеристику кавітатора і провести візуалізацію потоку в робочих камерах. Проведений аналіз літературних та інформаційних даних дозволив визначити основні умови та фактори, що впливають на процес гідролюмінесценції та виявив не однозначність трактування природи виникнення сонолюмінесценції і гідролюмінесценції. Розглянуті процеси мають дві основні теорії їх виникнення - «теплову» і «електричну», але, як показано у сучасних наукових роботах, це положення не можливо рахувати задовільним. Необхідна ретельна експериментальна перевірка. Зроблено висновок, що явище гідролюмінесценції (триболюмінесценції) може використовуватись як метод візуалізації кавітації. В результаті застосування експериментально-аналітичного методу та технічної візуалізації встановлено, що для даного насадку (конфігурації та проточної частини дроселю) при швидкості потоку більше 40 м/с в каліброваному отворі спостерігається процес гідролюмінесценції у вигляді імпульсно-мерехтливої іскри блакитного кольору по периферії та білого в середині на вхідний кромці золотника. У той же час керування робочими процесами, які супроводжують явище кавітації, є досить актуальним, оскільки дозволяє боротися з небажаними наслідками кавітації. На підставі отриманих результатів запропоновано застосувати термочутливий привід для автоматичної корекції прохідного каліброваного отвору дроселю, що дозволить підтримувати задану розрахункову величину числа кавітації в змінних умовах експлуатації, наприклад, в залежності від температури та в'язкості.

Ключові слова: кавітація, візуалізація, гідродинамічна люмінесценція, дросель, трибо-люмінесценція, кавітатор, візуалізація потоку рідини, температура, в'язкість, число кавітації, сонолюмінесценція, швидкість потоку рідини.

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