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RESEARCH OF THE PHENOMENON OF HYDRODYNAMIC LUMINESCENCE IN A TWO PHASE ENVIRONMENT

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ABSTRACT

The article presents the results of the study of the phenomenon of hydrodynamic luminescence in a two-phase medium during cavitation in hydraulic systems.

To conduct an experimental study, an analysis of the literature on the subject of the study was conducted, a stand based on a hydrodynamic cavitator with an ejector mixer at the inlet was developed.

The experiment was performed using mineral oil as a working fluid at an inlet pressure of up to 4 MPa and a flow rate of up to 10^{-5} m^3/s*. The main parameters that were monitored: inlet pressure level, inlet and outlet pressure drop of the sample, flow rate and outlet temperature. Shooting of the processes occurring inside the model was carried out by the camera at a speed of 120 ... 1000 frames per second. Cavitation areas were detected by high-speed video recording and the mechanism of its development in a two-phase medium was studied.*

As a result of the experiment, it was found that without saturation with inert gas, luminescence occurs when the pressure drops by 2 MPa, whereas with the help of a gas mixture (with a predominant inert gas content) when the pressure drops by 1 MPa.

It is concluded that the phenomenon of hydroluminescence can be used as a method for visualizing cavitation. It was found that the saturation of a liquid with an inert gas affects the rheological properties, namely: viscosity, density and physicochemical properties. The modes of the appearance of the glow were determined separately for each component of the experiment.

INTRODUCTION

The phenomenon of luminescence can be interpreted as the glow of substances, excess over their thermal radiation at a given temperature and excited by any source of energy. Such sources can be radioactive, X-ray or light radiation, chemical reactions, mechanical actions, electric fields, etc.

In the elements and devices of modern hydraulic systems, the working pressure can reach 400 bar [1, 2]. In the diaphragm and various throttles, the flow of working fluid has a pronounced turbulent nature. In a narrow section, the high velocity of the liquid causes cavitation and the associated active release of bubbles of undissolved air and steam [2-5].

The hydroluminescence effect was first discovered by Konstantinov in 1947 [6]. At a flat flow of water of a firm body (round cylinders) in the flat channel the luminescence behind cylinders, at strongly developed hydrodynamic cavitation was observed.

The information analysis of the sources showed that there is no unambiguous theory of hydroluminescence and unambiguous interpretation of its nature.

The largest number of results of experimental and theoretical works indicates that the processes of hydrodynamic luminescence have an electrical nature of origin, but there are also a number of works in which arguments are made in favor of thermal theory.

Electrical theory is based on electrical phenomena inside the bubble itself or its interaction with closely caviting bubbles. As a substantiation of this theory, the messages about the correspondence of the continuous spectrum observed during sonoluminescence to the radiation spectrum of an absolutely black body play a certain role [6].

The thermal theory is based on the assumption that when exposed to a cavitation bubble, high temperatures are formed inside it, which stimulate the emission of radiation by the bubble [7].

EXPOSITION

This paper presents the results of studies of the phenomenon of hydroluminescence, ie the emission of light by a liquid, which occurs during the cavitation of bubbles caused by hydrodynamic effects in a gas-liquid medium.

Hydroluminescence is the emission of light by a liquid in a narrow channel. We can say that hydroluminescence is caused by friction, so this is also a special case of mechanical luminescence, ie hydroluminescence is a triboluminescence of a liquid.

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Hydroluminescence spectroscopy gives us information about the conditions in the luminescent liquid. The hydroluminescence spectrum gives a clear indication of the nonequilibrium plasma in the bubbles.

Thus, the phenomenon of hydroluminescence has an electrical character. The insert material, in the zone of intense cavitation, emits electrons that are transferred by the flow, and a positive charge of high density is formed at the inlet edge of the holes.

Visualization and research. A stand was developed to visualize the experiment (Fig. 1)

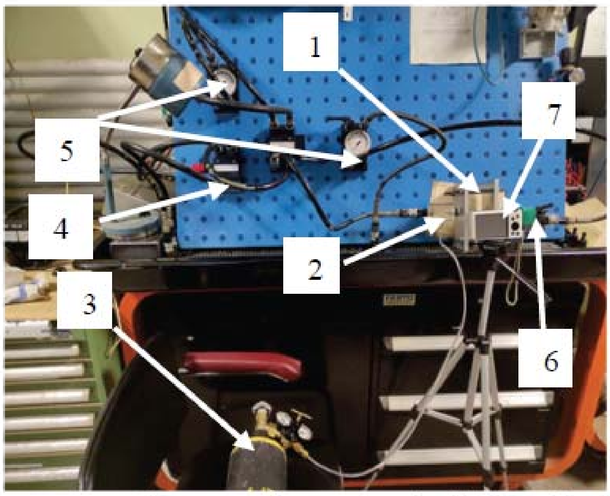

Fig. 1. Schematic diagram of a hydraulic test bench (1-cavitator, 2-ejector, 3-system for saturation of liquid flow with noble gases, 4-safety valve, 5-manometers at the inlet and outlet, 6-temperature sensors, 7-speed chamber)

a model of a cavitator with an ejector mixer at the inlet in the form of a transparent plexiglass cylinder was used (Fig. 2)

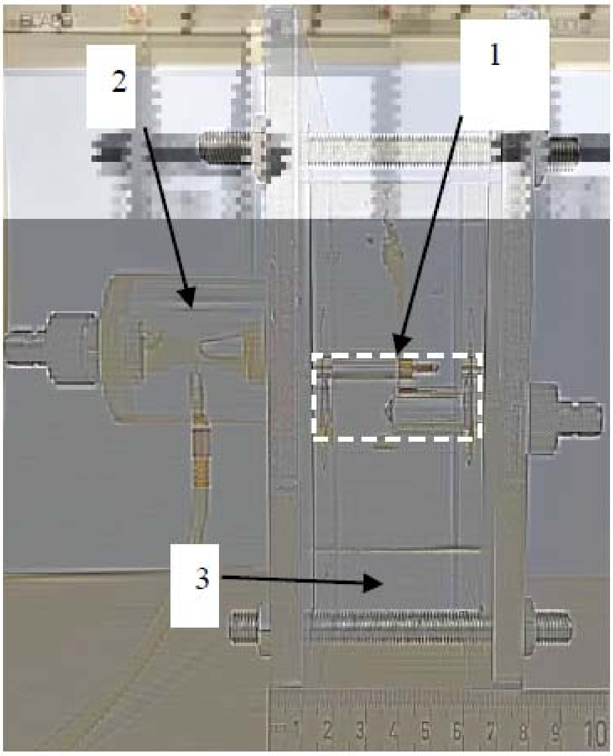

Fig. 2. The studied model of a hydrodynamic cavitator with an ejector mixer at the inlet (1 - reactor, 2 - ejector mixer, 3 - housing)

the sample was connected to the hydraulic system according to the scheme (fig. 3)

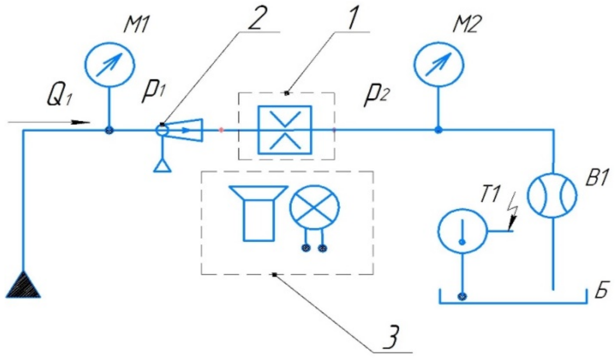

Fig. 3. Schematic hydraulic diagram of the test bench (1 - hydrodynamic cavitator with ejector mixer at the inlet, 2 - high-speed chamber)

The method of experimental research consisted of the following actions. Setting the required pressure drop on the device, the temperature of the working fluid was controlled by a reference thermocouple and measured the volume flow

The experiments were performed using mineral oil as a working fluid at an inlet pressure of up to 5 MPa and a flow rate of up to 10^{-5} m^3/s.

As a result of the experiment it was found that without saturation with inert gas luminescence occurs at a pressure drop of 2 MPa, whereas with a gas mixture (with a predominant content of inert gas) can achieve luminescence even at a pressure drop of 1 MPa.

Thus, observations show that the least intense luminescence was observed without additional saturation of the liquid with inert gases (Table 1).

Table 1 *Conditions for experiments*

Experiment conditions	**Parameters**	**Figure**
Without saturation	Δp = 4 MPa, oil temperature t = 33°C, Q = 0.0000004 m^3/s, throttle area 0.00003 m^2, v_{thr} = 100 m/s	Fig.4 (a)
Nitrogen saturation	Δp = 4 MPa, oil temperature t = 33°C, Q = 0.0000004 m^3/s, throttle area 0.00003 m^2, v_{thr} = 100 m/s	Fig.4 (b)
Argon saturation	Δp = 4 MPa, oil temperature t = 33°C, Q = 0.0000004 m^3/s, throttle area 0.00003 m^2, v_{thr} = 100 m/s	Fig.4 (c)
A mixture of gases Nitrogen + Argon	Δp = 4 MPa, oil temperature t = 33°C, Q = 0.0000004 m^3/s, throttle area 0.00003 m^2, v_{thr} = 100 m/s	Fig.4 (d)

The amount of gases in the bubbles depends on the number of cavitation. The critical parameters of the flow and depending on the height and velocity of the pressure, indicating the beginning of the cavitation of the flow, can be calculated [1]:

$$\chi = \frac{2(p_1 - p_2)}{\rho \cdot V_1^2},$$

where, p_1, V_1 - pressure and flow rate, for example, at the inlet of the valve p_2 - vapor pressure; ρ - fluid density.

The digital magnification of the image of the flash glow showed that in its conditional center of symmetry the color of light radiation is pure white, and on the periphery - bright blue and resembles an electric discharge (Fig. 4) [7].

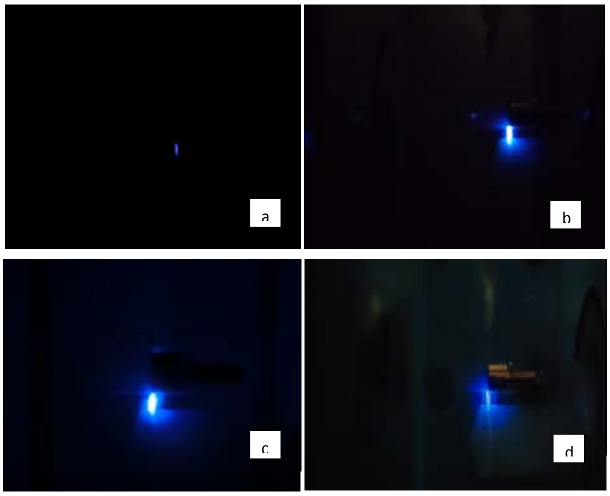

Fig. 4. Light radiation in the cavitation flow of mineral oil $\chi = 0.7$

According to our observations, with increasing flow velocity in the narrowing zone, first cavitation occurs, then, with further increase in flow velocity, single sparks begin to appear, then a flickering flame, and at some point there is a "breakdown" and stable glow.

Based on the results of elaboration and analysis of the conducted experimental researches, a conceptual model of the stages of origin and development of the cavitation process and accompanying effects is constructed (Fig. 5).

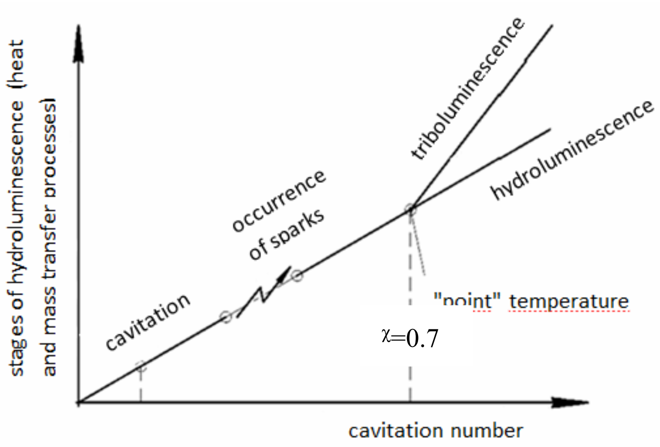

Fig. 5. Occurrence of cavitation and accompanying physical processes in the fluid flow

The study of the nature of hydrodynamic luminescence can be compared to fire: first it is a weak spark, then a flickering flame, and then a powerful flame endowed with speed and strength.

It can be assumed that the process of cavitation in the flow of mineral oil in narrow slits can cause electrical resistance of the oil base and channels, as well as lead to the burning of corrective additives to the oil. The main source of light radiation is the emission of gas into vapor bubbles, such as hydrogen. For example, water present in the working fluid under the action of cavitation can decompose into hydrogen and oxygen, which are then ignited with a discharge.

CONCLUSION

The conducted researches allowed to reveal the cavitation zones arising in the cavitator. With the help of high-speed video recording, cavitation zones were identified and the mechanism of its development was investigated. In addition, the characteristics of the visualization of the closed volume to some extent clarify the existing ideas about the behavior of the liquid in the nozzle.

The results of the study are valid for Newtonian fluids, which include the oil used during the experiment. For non-Newtonian fluids, the cavitation process can be more complex, which requires further research. In addition, the purpose of further research is to study in detail the effect of hydroluminescence on cavitation processes.

The cavitators that have been studied in this article can work with a variety of liquids. Some of them are sensitive to cavitation, which can change their physical, chemical and rheological properties. Thus, the study of the conditions of cavitation phenomena and their development will allow to choose rational modes of operation of the cavitator: the diameter of the valve, the pressure drop, flow rate and temperature of the working fluid.

The use of hydrodynamic cavitation with hydrodynamic luminescence to obtain energy under certain conditions is rational, due to the compactness and cheapness of the installation as a whole. Cavitation energy storage can be one of the most innovative and effective ways to achieve high energy density today.

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