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LUMINESCENCE PHENOMENON AND ITS FEATURES DURING HYDRODYNAMIC CAVITATION

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Abstract
The article discusses the types of luminescence and the mechanisms of its occurrence. The model of Stokes–Lommel and S. Vavilov law is presented, Kashi's rule. The analysis of literary sources shows that the sources of excitation of a luminescent substance can differ depending on the source of particle excitation. In scientific research, hydrodynamic luminescence is used to study various physical phenomena, such as turbulence, dynamics of fluid movement, and flow structure.
The work is devoted to the analysis of hydrodynamic luminescence, when studying the dynamics of fluid movement in turbulent flows.
In cavitation processes, hydrodynamic luminescence can indicate the conditions of formation and collapse of bubbles, which is essential in marine engineering and energy.

Keywords: hydrodynamic luminescence, hydrodynamic cavitation,

INTRODUCTION

Hydrodynamic luminescence is the phenomenon of light emission by liquids during their movement under certain conditions. This phenomenon occurs when particles in a liquid pass through a medium at a sufficiently high speed or undergo sudden changes in pressure and speed, resulting in the formation of short-lived light pulses [1-6].

This phenomenon is most often observed during phenomena accompanied by turbulence, when microscopic bubbles or cavitation processes occur, which create local high temperatures and pressures. After the collapse of such bubbles, energy is released in the form of a flash of light [8].

This effect is being studied for applications in areas such as: Marine Environments, Hydraulic Systems in Pumps and Turbines, Acoustic Cavitation, Microfluidics, Biomedical Applications, Industrial Processes and Nuclear Fusion Research. Let us consider in more detail the mechanism of excitation of molecular luminescence and its types.

The molecule can lose the received energy in various ways, including radiation according to the scheme (See Figure 1).

Thermal radiation is the most common in nature. It is carried out due to the energy of thermal motion of atoms and molecules of matter, that is, due to internal energy, and therefore depends on the substance's temperature. Some substances glow even without heating - at room temperature, it called cold glow or luminescence.

A certain amount of energy must be supplied to substance from the outside to cause the luminescence.

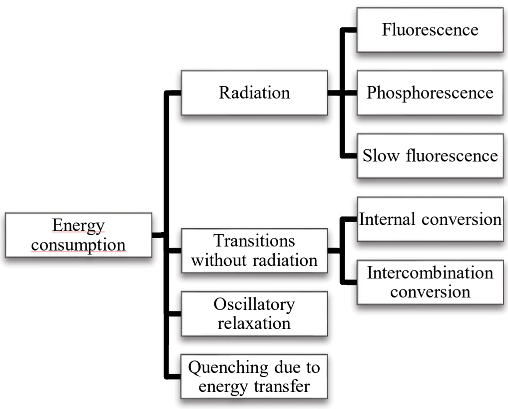

Fig. 1. *Scheme of the ways losing energy by molecules*

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The sources of excitation of the luminescent substance can be different. Depending on the source of particle excitation, the following types of luminescence are distinguished:

Source of excitation, Light flux (UV, visible light), Energy of chemical reactions, Energy of chemical reactions occurring in living organisms, X-ray radiation, Mechanical action, Electrical action;

Type of luminescence are: Photoluminescence, Chemoluminescence, Bioluminescence, X-ray luminescence, Triboluminescence, and Electroluminescence.

The study of fluid dynamics is necessary for a better understanding of processes in turbulent flows where cavitation occurs.

Cavitation — hydrodynamic luminescence can indicate the conditions of bubble formation and collapse, which is important in marine engineering and energy.

Sonoluminescence — when such light emission occurs under the influence of sound waves in liquids, as part of a broader study of acoustic phenomena.

Physicists and engineers study the phenomenon to gain a deeper understanding of the interaction of liquids with solid bodies, waves, and other factors affecting the movement of liquids.

In scientific research, hydrodynamic luminescence is used to study various physical phenomena, such as turbulence, dynamics of fluid movement, and flow structure. It can also be useful for solving practical problems related to the study of hydrodynamic properties of liquids, such as increasing the efficiency of oil production and optimizing the operation of hydrodynamic pumps.

The energy (BE) and quantum (Bq) yields of luminescence reflect the efficiency of converting energy absorbed by a substance into radiation energy. The energy output of luminescence is the ratio of emitted energy (Elum) to absorbed energy (Eabs):

$$B_E = \frac{E_{lum}}{E_{abs}} = \frac{N_{lum}}{N_{ex}} \cdot \frac{h\nu_{lum}}{h\nu_{ex}} = \frac{N_{lum}}{N_{ex}} \cdot \frac{\nu_{lum}}{\nu_{ex}},$$

where N_{lum}, ν_{lum}, N_{ex}, ν_{ex}, is the number of quanta, the luminescence frequency, and the number of absorbed quanta with the corresponding frequency

EXPOSITION

For experimental research, a model of a hydrodynamic cavitator was made, with a nozzle in the form of a transparent plexiglass cylinder, Fig. 2 [1]. The flowing part of the cavitator contains an ejector at the entrance, which allows introducing into the flow of liquid, for example, air or another phase in the appropriate concentration, which is calculated. The main part of the reactor consists of an adjustable channel in the form of a throttle of variable cross-section (the active passage area is set by turning the screw) [8-11].

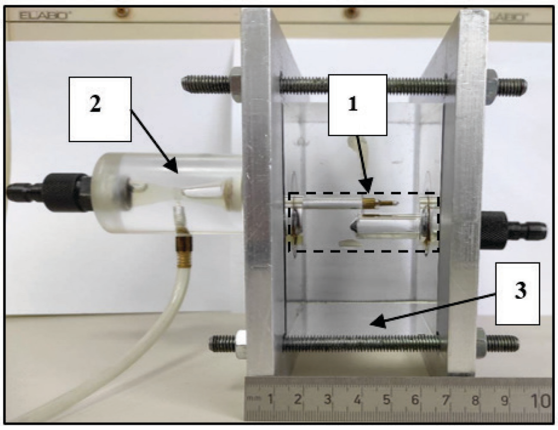

***Fig. 2.** Hydrodynamic cavitator with a cylindrical nozzle and an ejector at the entrance (1 - Reactor, 2 – ejector, 3 – body)*

Also, the basic hydraulic scheme of the test bench was developed, Fig. 3. and the experimental setup of Fig. 4.

The principle of operation of the experimental setup is as follows. The liquid under study passes through a rough oil filter and enters the high-pressure pump. A three-phase asynchronous electric motor drives the high-pressure pump through a belt drive. A small vector frequency converter was used to regulate the frequency of rotation of the three-phase asynchronous motor and, as a result, the gear pump's rotation frequency, which in turn made it possible to create different pressures of the investigated liquid.

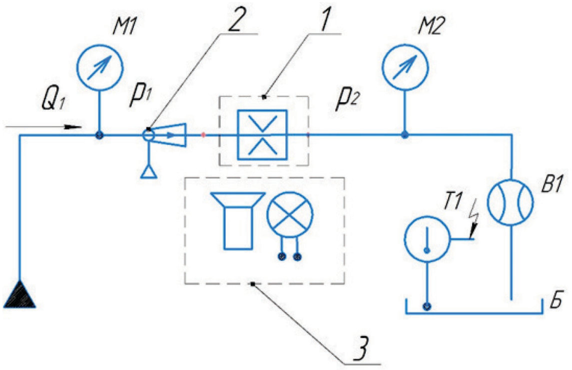

Fig. 3. *Basic hydraulic diagram of the test bench (1-cavitator, 2-ejector, 3- high-speed video camera)*

At the output of the gear pump, the liquid enters the working area through a high-pressure hose, after the working area, the liquid flows back into the filling tank-reservoir. The temperature and pressure sensors are calibrated with a reference thermocouple and pressure gauge, and the digital flow meter is calibrated with a reference volumetric flow meter. The appearance of the experimental stand is shown in fig. 4.

The experiment was conducted at a pressure drop of up to 5 MPa and a flow rate of up to 10^{-5} m^3/s. The temperature of the working fluid was maintained at 33°C, the velocity of the fluid in the narrow channel of the cavitator at the specified flow rate reached up to 100 m/s.

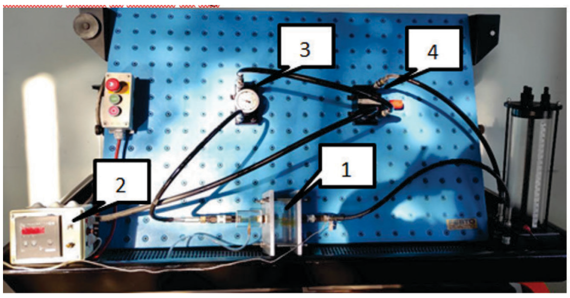

Fig. 4. *Experimental setup (1-cavitator, 2- temperature sensors, 3- manometer 4- safety valve)*

As the pressure increases to 2,5 MPa, the frequency of hydroluminescence flashes increases, and upon reaching a pressure of 3...3,5 MPa, the hydroluminescence glow becomes continuous, and stable (see Figure 5), and a further increase in pressure only slightly increases its intensity.

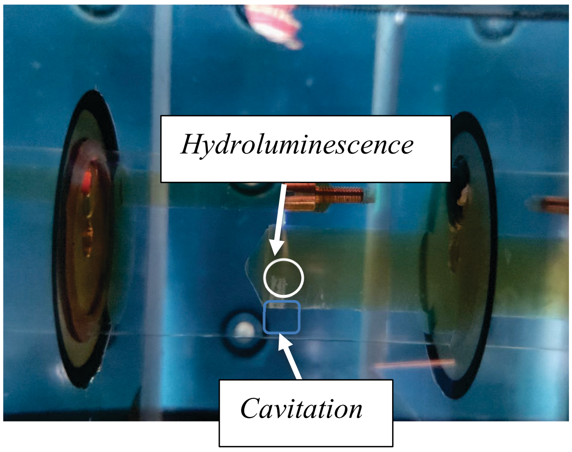

Fig. 5. *Hydrodynamic cavitation with short-term flashes of hydroluminescence*

When observing the process in slow motion (images obtained during high-speed video recording), it can be seen that hydroluminescence is not a continuous light but occurs with a certain frequency in frequent, unsynchronized, random flashes. A problem often encountered when using luminescence in quantitative analysis is its quenching by many substances. The luminescent substance itself can cause quenching.

CONCLUSION

The phenomenon of luminescence accompanying hydrodynamic cavitation can be observed in systems in various fields of technology and industry. Radiation is associated with the loss of energy by molecules, which can occur in different ways. To study the luminescence that occurs in the hydraulic system, a stand was created that allowed to detect the appearance of luminescence and determine the parameters of its occurrence.

Increasing the luminescence intensity can be achieved by optimizing the outlet pressure and measuring the acoustic power at the collapse of the cavitation bubble and luminescence as a function of pressure.

The generation of luminescence induced by hydrodynamic cavitation was also shown to depend on the gas and ambient pressure.

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