EFFECT OF POLYMER ADDITIVES ON CAVITATION

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It is found in experiments on pulsed cavitation equipment that, relative to water, the critical cavitation number is diminished 15% for a 0.1% polyox solution and 8% for a 0.47% butyl alcohol solution.

Research outside the Soviet Union on the influence of high-molecular additives on cavitation is analyzed in detail in [1]. Investigations in the United States, Britain, and Canada have shown that the use of various kinds of surface-active agents makes it possible to alter significantly the conditions for the formation of cavities, to reduce cavitation noise, to protract the time of cavitation inception, and to diminish cavitation erosion. The authors have declined, however, to submit any hypothesis to explain the effect of polymer additives on cavitation.

The first such attempt must be attributed to Fogler and Goddard [2]. They have analyzed the collapse of a spherical cavity in a viscoelastic liquid, derived an integrodifferential equation describing the motion of the cavity, and formulated some numerical solutions. The most interesting conclusion is that the elasticity of the liquid can strongly affect the collapse of a cavity and induce a prolonged vibrational motion of the cavity boundary if the relaxation time of the liquid is much greater than the Rayleigh collapse time.

The foregoing effect stands in sharp contrast with the rapid collapse that always occurs for cavities in purely viscous liquids. Unfortunately, the authors did not apply their conclusions to a concrete rheological model of a liquid, because to do so incurs difficulties in the analysis and calculations.

The most recent publication on the use of polymer additives in cavitations is a paper by Hoyt [3], who has investigated jet cavitation and shown that the critical number for the onset of cavitation can be decreased by the introduction of high-molecular additives in the liquid stream. Hoyt is of the opinion that the action of polymers on the inception of cavitation is one manifestation of the influence of those substances on the overall flow regime. Using a special hydrophone and associated instrumentation to pinpoint the inception of cavitation, Hoyt showed that the critical cavitation number is decreased 35 to 40% when polymer additives are introduced. Secondarily, he established the fact that with the use of polymers nozzle swirling vanes do not affect the flow characteristics, whereas in the nozzle flow of water the presence of such vanes considerably increases the critical cavitation number.

We have endeavored to study the action of polymer additives on cavitation, using pulsed-mode cavitation equipment. Prior to the experiment we carefully determined the viscosity and surface tension of the solutions. The data of surface-tension measurements of Polyox WSR-301 solutions by means of a Jobin and Vion tensiometer are in good agreement with the results given in [3, 4] for concentrations in the range from 0 to 0.1%.

The pulsed cavitation equipment makes it possible to study cavitation phenomena in various liquids. It has the following patent advantages over conventional equipment:

1) steady-state conditions in the working section in combination with small overall equipment dimensions, the volume of test liquid not exceeding 30 liters;

2) capability for varying the static pressure in the system, i.e., obtaining different forms of cavitation;

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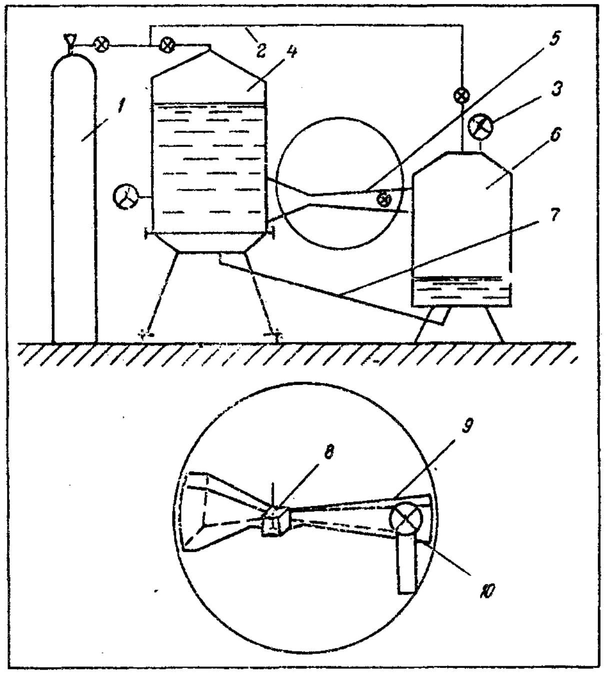

Fig. 1. Schematic of pulsed cavitation equipment. 1) Pressurized tank; 2) compressed-air line; 3) manometers; 4) delivery tank; 5) working section; 6) receptacle; 7) return channel; 8) cell with hydrophone; 9) working section; 10) shutoff valve.

3) open-cycle operation, precluding the accumulation of bubbles as cavitation nuclei.

A diagram of the experimental setup is given in Fig. 1. The pressure P_d in the delivery tank can be altered by the injection of compressed air from a pressurized tank. The pressure P_r in the receptacle tank is varied by means of a bleeder valve mounted on it.

We denote the cavitation number by

$$k = \frac{1 + P_r}{\rho \frac{v^2}{2}} = \frac{1 + P_r}{P_d - P_r}.$$

The onset of cavitation was determined with a hydrophone placed in a water-filled cell set up in the working section of the system. The hydrophone readings were delivered through an amplifier to a recording unit. The time of cavitation noise inception was recorded, being indicated by an abrupt jump on the tape plot. Comparative tests were made with water and solutions of polyethylene oxide (Polyox WSR-301).

The results, which are presented in Fig. 2, indicate, on the average, a 15% reduction in the critical cavitation number for the polymer solution at 0.1% concentration.

The experimental data thus corroborate in principle Hoyt's results on the reduction of the critical cavitation number with the injection of polymer additives. The quantitative discrepancies may be attributed

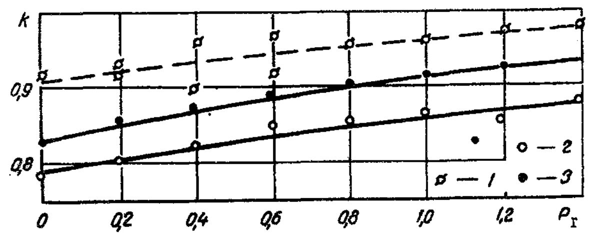

Fig. 2. Critical cavitation number versus pressure P_r, kg/cm^2, for special additives: 1) pure water; 2) 0.1% Polyox WSR-301; 3) butyl alcohol, C = 0.47%.

to the fact that Hoyt investigated jet cavitation, whereas the cavitation in our experiment described above took place in the slotted section of the pulsed cavitation system.

In addition to polymer additives, we also investigated the influence of other surface-active agents on the protraction of the cavitation inception time. For example, an aqueous solution of butyl alcohol at a concentration $C = 4.7 \cdot 10^{-3}$ has the same surface tension as a Polyox solution at a concentration of $1 \cdot 10^{-3}$ (σ = 60 dyn/cm). As Fig. 2 indicates, the addition of butyl alcohol to water decreases the cavitation number by 6 to 8%.

NOTATION

P_r is the receptacle pressure;
P_d is the delivery tank pressure;
ρ is the density of the liquid;
v is the liquid flow velocity;
C is the additive concentration.

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