CAPACITY AND ACOUSTIC-EMISSION METHODS OF STUDYING TURBULENT-CAVITATION FLOWS OF A FLUID IN POROUS PERMEABLE MATERIALS

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We present results from an investigation into the hydrodynamic flows of a fluid through porous materials; these investigations involve two developed methods and we have demonstrated their high sensitivity to the appearance of cavitation bubbles.

Porous permeable materials (PPM) are used extensively in liquid filtration and heat exchange in various branches of industry [1], and the forming flows [2] exert predominant influence on the efficiency of these processes. We presently have on hand a developed and tested range of various methods to study liquid flows in channels and these include mechanical [3], acoustic [4], electromagnetic (conductometric) [5], optical [6], and nuclear-physical [7]. However, the areas in which these methods can be employed to investigate the flows of a fluid in the microcapillaries of pores is extremely limited as a consequence of the specific nature of PPM structure. The goal of this study therefore involves the laying of a foundation for and the experimental verification of the capacity and acoustic-emission methods of examining turbulent-cavitation flows in PPM.

We know [8] that microcapillary channels in PPM are a form of a labyrinth with diversely distinct cross sections which are formed by the elements of the structure. The motion of a liquid about the curvilinear surface of the PPM channels is accompanied by deformation of the flow and the onset of turbulence [9], i.e., local fluctuations in velocity, pressure, and temperature; here we also find a reduction in the cavitational strength of the moving liquid [10]. When the local pressure is lower than the vapor saturation pressure, cavitation sets in [11] and this phenomenon is characterized by a pulsating vapor-gas phase which sends out acoustic waves into the surrounding medium. Consequently, having measured the cavitation index D, equal to the ratio of the component gas volumes $\Delta V_i$ of the phase in the liquid $V_0$ [12] and the amplitude-frequency characteristics (AFC) [2], we can qualitatively and quantitatively evaluate the turbulent-cavitation flows. On this basis, to achieve our stated goal, we have developed a PPM model to serve as a sensor, and this is a round disk of a sintered tantalum (niobium) powder. The structure of the formed materials pertains to the class of PPM and serves as an adequate analog of those materials used for filtration, heat exchange (Fig. 1). We know [1] that PPM exhibits large specific wetting areas, and the treatment of the tantalum (niobium) with $H_3PO_4$ acid forms thin current-insulating films on the material's surface. This makes it possible to come up with a high-capacity capacitor in which one of the plates is a PPM structure, while the current-conducting fluid (electrolyte) serves as the second. The capacitance here depends on the extent to which the PPM structure is completely filled, as well as on the uniformity of the liquid phase. Thus, we can make the assumption that with the onset of cavitation in the investigated PPM with a pore volume of $V_0$ the forming vapor-gas bubbles $\Delta V_i$ alter the initial capacitance $C_0$ of the capacitor by $\Delta C_i$, and the quantities $V_0 = C_0$, $\Delta V_i = \Delta C_i$ will be equivalent. Connecting this device (Fig. 2)
Fig. 1. Porous permeable materials: a) tantalum (niobium); b, c) FNS-5 and PNS-10 filtration materials. 2000 x.

Fig. 2. PPM model sensor device and circuitry of the metering control-recording equipment: 1) aqueous solution of sodium polyphosphate (dielectric fluid); 2, 11) flanged conduits; 3) coupling screws; 4) Teflon inserts; 5) LTZ-19 AE sensor; 6) coaxial cable; 7) signal amplifier; 8) AF-15 acoustic-emission instrumentation; 9) AF-4096A-90 pulse analyzer; 10) DPU digital printout unit; 12) model of porous permeable material, tantalum (niobium); 13) waveguide; 14) TESLA-M capacity meter; 15) K-12-22 loop oscillograph.

to capacitance metering systems and to a loop oscillograph enables us to determine the instantaneous value of $\Delta C_1$ and to calculate the cavitation index $D = \Delta C_1/C_0 = \Delta V_1/V_0$.

The second assumption is based on the fact that the acoustic waves of turbulent-cavitation flows are propagated through liquids and metals in analogy with [13]. As a consequence of this similarity we can conclude that the acoustic emission (AE) signals in the form of mechanical waves arising and propagating through the materials as their structures undergo local dynamic restructuring are characteristic of turbulent-cavitation flows and are found at the beginning of the megahertz range [14]. We have selected the following parameters to be recorded: $N$, the intensity of the AE signals, indicating the quantity of imploding cavitation bubbles; $A$, the amplitude of the AE signals, whose square characterizes the energy of the imploding cavitation bubbles; $\alpha$, the amplitude distribution of the AE signals, which provides information on the quantity of cavitation bubbles imploding with different energies, and which is determined by the expression [15]

$$\alpha = K/\ln N.$$

The AE signals generated by the turbulent-cavitation flows were received by the tantalum PPM and by means of a lead titanate-zirconate piezoceramic sensor (LTZ-19), these signals were then amplified and separated, to be analyzed by AE equipment [14] (Fig. 2).

The investigation followed a program which included determining the sensitivity of these methods to turbulent-cavitation flows and the establishment of an interconnection between the cavitation indices and the amplitude distribution of the AE signals.

For this purpose, in the first stage, the device (Fig. 2) was filled with a three percent aqueous solution of sodium polyphosphate and its original capacitance was measured. An ultrasonic dispersion vibrator (USDV-2M), positioned near the PPM model, was subsequently employed to generate a cavitation area at frequencies of 22 and 44 kHz, with a power of 0.1 kW. The