NOTATION

Here u denotes the velocity; m is the injection parameter $U_s\rho_s/U_\infty\rho_\infty$: Re_h and Re_s are the Reynolds numbers, for which the average parameters of the main flow were assumed to be the determining factors and the height of the working chamber at the inlet and the height of the slit for secondary-gas injection, respectively, were taken to be the characteristic dimensions; δ and δ^{**} are the boundary-layer and momentum thicknesses; R_w is the radius of surface curvature; x is the longitudinal curvilinear coordinate; $\eta=\frac{T_w^*-T_\infty}{T_s-T_\infty}$ is the efficiency of the gas blanket; and $K=\frac{\nu}{U_\infty^2}\frac{dU_\infty}{dx}$ is the acceleration parameter. Subscripts and superscripts: s pertains to the injection cross section; ∞ denotes parameters at the outer boundary of the boundary layer; w denotes parameters at the wall; 0 pertains to a flat plate; and * denotes parameters at an adiabatic wall.

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INFLUENCE OF SURFACTANT ADMIXTURES ON THE ACOUSTIC CHARACTERISTICS OF A CLOSED HYDRAULIC LOOP

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Results are presented of measurements of the friction drag, acoustic spectra of pipeline wall and pump pedestal vibrations as well as of the hydrodynamic noise during the motion of a fluid with surfactant admixtures of different nature in a closed hydraulic loop.

On the effective methods of reducing turbulent friction drag, diminishing the intensity of forced thermal and mass transfer and changing the acoustic characteristics of a stream is the injection of admixtures of high-molecular polymers, micelle-forming surfactants, and anisotropic particles into the fluid [1]. However, polymer admixtures cannot be used in systems having pumps and elements with high local drag because of the significant mechanical destruction [1]. As is shown in [2], surfactant admixtures possess high stability with respect to prolonged mechanical actions and their application is justified in closed hydraulic systems. Up to now a significant number of researches have been executed [1, 3, 4] to investigate the influence of polymer admixtures on different acoustic characteristics of a turbulent stream, however, there is no data on surfactant influence on flow acoustics yet.

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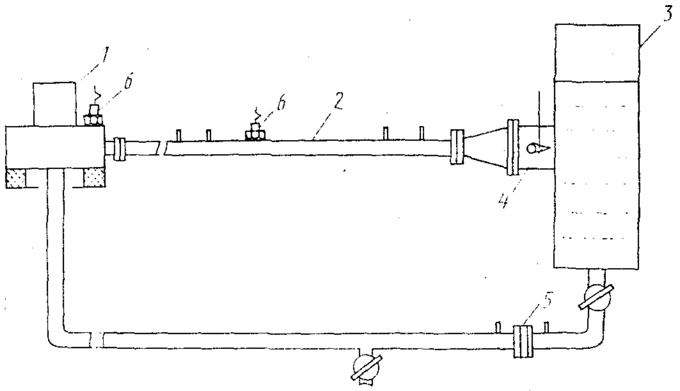

Fig. 1. Experimental hydraulic test stand.

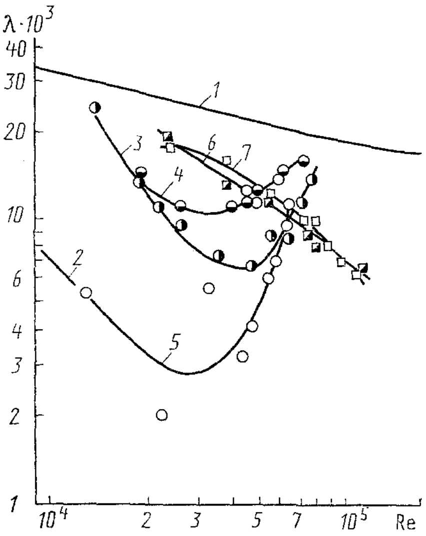

Fig. 2. Dependence of the friction drag coefficient λ on the Reynolds number: 1) Prandtl curve; 2) Hagen–Poiseuille law; 3 and 4) drag curves for flow with a ditalane OTS admixture; 5) flow with metaupon admixtures; 6 and 7) flows with CB-102 admixtures.

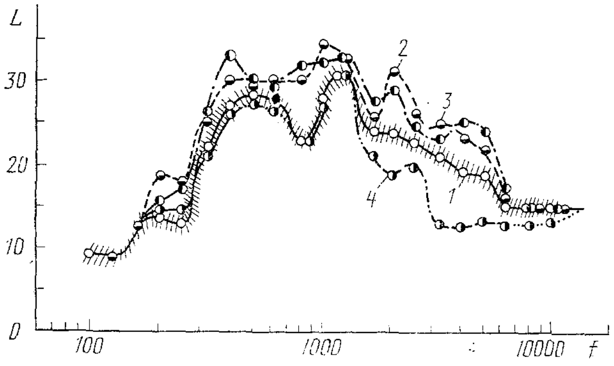

Fig. 3. Sound spectra recorded by a hydrophone during flows of ditalane TS (curve 2), metaupon (curve 3) and CB-102 (curve 4) solutions after 1 h from the beginning of installation operation. Curve 1 in the shaded domain is generalized sound-emission spectra for the mentioned surfactant flows at the initial measurement time. Flow velocity 6 m/sec, L, dB, f, Hz.

The purpose of this paper is to investigate the acoustic noise and vibrations during operation of a hydraulic circulation test stand with surfactant admixtures of a different nature and to estimate their stablity to destruction under significant shear stress conditions on the centrifugal pump vanes. The changes in the friction drag coefficient and the acoustic characteristic spectra that occur with the lapse of time were determined in different sections of the test stand.

The investigations were conducted on a closed hydraulic test stand whose block diagram is presented in Fig. 1. Fluid motion was produced by the centrifugal pump 1 of the brand NBTs 2.0/20. The velocity of fluid motion was regulated within the limits 0.5-6.0 m/sec by changing the voltage supplied to the electric motor collector winding. The water went from the pump to the pipeline 2 of $2 \cdot 10^{-2}$ m diameter and 6.2 m length. There were pressure samples at distances of 22 and 280 calibers from the input to measure the hydraulic friction drag. The pipeline was terminated by a diffusor with a $2\alpha = 6°$ aperture. The diffusor was installed in order to reduce the flow velocity ahead of the entrance to the receiving tank 3 performing the role of air bubble absorber, and also in order to place the hydrophone 4 in the steam. The hydrophone was in a fairing in the cylindrical part of the channel after the diffusor. Vibrations were measured by the vibrations sensor 6. The stream velocity was recorded by measuring the pressure drop on a throttling orifice plate 5. Calibration of the throttling plate was performed on an installation described in [5] to which a pipeline element with the measuring plate was connected, and the velocity was computed by a volume method. Water solutions of three different industrial surfactants, ditalane OTS, mataupone, and CB-102 (the chemical compositions of the surfactants are presented in [2, 7]) with an NaCl salt admixture, were used as working fluids in the present acoustic vibration investigations. The weight concentrations of the surfactant and electrolyte are presented below:

No.	Surfactant type	Concentration, %	
		surfactant	electrolyte
1	Ditalane	1	5
2	Metaupone	0,5	10
3	SB-102	0,5	2,0

There are supermolecular formations of different nature in all the surfactant solutions utilized. Plane crystalline structures [6] are contained in the ditalane OTS solutions, anisotropic micelles [2] in the metaupone solution, and the CB-102 solution forms an emulsion [7]. We present the characteristic values of the surfactant soltuion viscosities measured by using a VPZh-2 capillary viscosimeter with 0.56 m diameter: $\nu = 0.0124$ cm^2/sec for the ditalane OTS, $\nu = 0.022$ cm^2/sec for metaupone, and $\nu = 0.012$ cm^2/sec for CB-102.

The friction drag coefficient λ was determined for each surfactant solution prior to execution of the vibroacoustic measurements. The stream motion in the test stand was here produced only in the time needed to conduct the measurement (~20 sec). Dependences of λ on the Reynolds number are constructed from the test results. The curve 1 in Fig. 2 corresponds to a Prandtl dependence for the turbulent flow of pure water, the curve 2 to the Hagen-Poiseuille drag law for laminar flow. Curves 3 and 4 characterize the dependence of the drag in a turbulent fluid flow with ditalane OTS admixtures, curve 4 is obtained here during repeated start-up of the solution. It is seen that the effect of drag reduction drops at a certain critical value of the Reynolds number ($\mathrm{Re} = 4.6 \cdot 10^4$), which is associated with destruction of the surfactant supermolecular structure (crystals) [2]. The critical Reynolds number for curve 4 is shifted to the left as compared with curve 3, towards smaller shear stresses on the pipeline wall. This result indicates that the restoration period for the destroyed supermolecular structures in the ditalane OTS solutions is sufficiently prolonged. Curve 5 corresponds to the turbulent flow of a water solution of metaupone. It is seen that metaupone admixtures result in a significant (up to 80%) reduction in friction drag. However, even here destruction of the surfactant micelles starts for trhe Reynolds number $\mathrm{Re} = 2.5 \cdot 10^4$ and the influence of the admixture on the turbulence diminishes. Curves 6 and 7 in Fig. 2 denote the experimental data obtained during the flow of a CB-102 solution in the initial period after starting the installation and one hour after continuous test-stand operation, respectively. It is seen that curves 6 and 7 practically agree, which indicates stability of the emulsion solution to destruction. The flow velocity dropped approximatley 28% for ditalan OTS during pumping for one hour in the test stand at a maximal stream velocity (that corresponds to a 1500 time passage of the solution through the pump, where the drop was almost 10% after the first 10 min. The rate of metaupone pumping after one hour of operation dropped

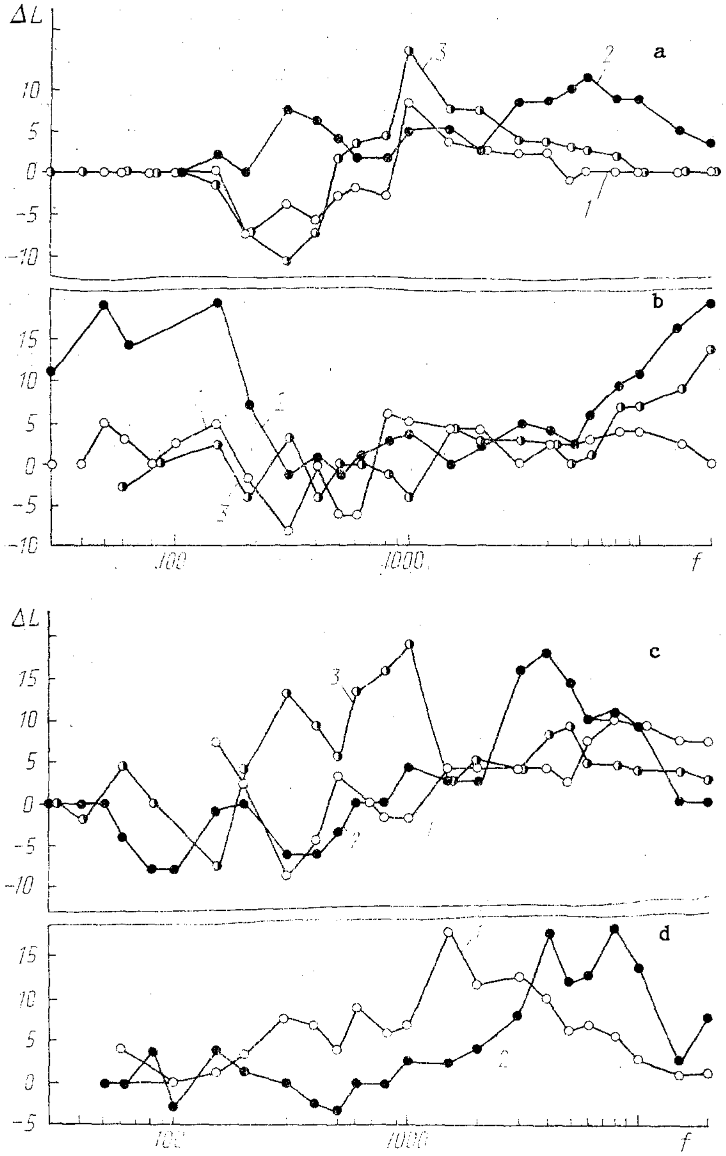

Fig. 4. Effect of the influence of ditalane OTS (curves 1), metaupone (curves 3) and CB-102 (curves 2) on the acoustic noise spectra (a), the vibrations of the pump pedestal (b), the transverse (c) and longitudinal (d) pipeline vibrations components. Flow velocity is 6 m/sec.

approximately 17%. After disconnection of the pump, the installation was started up again after one hour. The values of the friction drag magnitude in the metaupone and ditalane OTS solutions in the initial period of the second start-up agreed within the limits of error with those measured in the initial period of the first start-up. The results of these measurements indicates that a gradual drop in the efficiency of the influence of metaupone and ditalane OTS admixtures on turbulence during continuous test-stand operation is associated with the fact that the supermolecular structures existing in the solutions do not succeed in being restored completely after passing the pump.

The investigations of the vibroacoustic characteristics of a circulation hydraulic test-stands included measurement of the sound in the diffusor by using a hydrophone, measurement of pump pedestal vibrations, and also the longitudinal and transverse components of pipeline vibration 2. The vibrations and sound spectra were here compared for pure water and surfactant solution streams. A three-octave frequency analysis in the 20-12000 Hz range was used for processing the acoustic signals. The acoustic noise is measured by a spherical hydrophone of $1 \cdot 10^{-2}$ mm diameter placed in a fairing. The vibrations were recorded by a one-comonent vibration sensor of the 4333 type of Bruel and Kjer during its fastening to a magnetic plate in one of the two regular positions. As mentioned in [8], suppression here of the sensor sensitivity to the transverse component with respect to the main component is not less than 32 dB. The noise signal in the hydrophone can evidently be the sum of components $P = P_1 + P_2 + P_3$, where P_1 is the noise component being generated by pressure fluctuations on the pump and electric motor fan vanes that transfer pressure waves along the pipeline and fluid in the form of sound waves, P_2 is the noise component caused by pipeline vibrations and specified by the hydrophone vibration sensitivity, and P_3 is the hydrodynamic noise of the turbulent stream. The components P_1 and P_2 for this test stand are governing in the hydrophone signal and evidently due completely to structural features of the pump and the test stand as a whole. The results of acoustic noise measurements in the diffusor are represented in Fig. 3 for different surfactant solutions. The series of measurements performed during an hour of continuous test-stand operation showed that exactly as the magnitude of the friction drag, the acoustic characteristic spectra change somewhat with the lapse of time. Thus investigation of the acoustic noise in a diffusor showed that when ditalane OTS (curve 2) and metaupone (curve 3) solutions are injected, the noise spectra measured after an hour from the beginning of installation operation grew 4-7 dB in the $f \gtrsim 200$ frequency band as compared with that measured in the initial period after the beginning of the experiment (curve 1; the shaded domain includes values of the noise level in the initial period of test-stand oepration with ditalane OTS, metaupone, and CB-102 admixtures). On the other hand, the noise spectrum in the high-frequency domain was reduced 3-5 dB (curve 4) during fluid motion with CB-102 admixtures, which can be explained by additional mixing of the emulsion that tends to lamination while it is held at rest [7].

Furtheremore, let us consider the results of vibroacoustic experiments. Results of processing signals from the sensors during fluid flow with admixtures are presented in Fig. 4 and represented in the form of spectral increases with respect to measurements in pure water. The positive values of the spectral increases ΔL correspond to lowering the noise and vibrations levels (positive effect of the admixtures). The tests were performed with freshly prepared surfactant solutions during brief connections of the installation. The spectral noise increases recorded by the hydrophone are represented in Fig. 4a. It is seen that the ditalane OTS (curve 1), metaupone (curve 3) admixtures increase the noise in the medium frequency spectrum band $150 \text{ H} \lesssim f \lesssim 600$ Hz. Surfactant admixtures reduce the noise level at frequencies of $f \gtrsim 800$ Hz. It should be noted that CB-102 admixtures (curve 2) result in noise reduction in the whole frequency range investigated. Measurements of the centrifugal pump pedestal vibrations (Fig. 4b) showed that the ditalane OTS and metaupone admixtures do not influence the spectral characteristics at frequencies below 1 kHz while a significant positive effect is observed for the CB-102 solution even at low frequencies. A significant effect (up to 10-15 dB) of lowering the pedestal vibrations level at $f \gtrsim 5$ kHz frequencies is noted in metaupone and ditalane OTS solutions. The transverse and longitudinal pipeline vibrations components spectra, represented in Figs. 4c and d, respectively, change in a complex manner under the effect of the surfactant admixture. A certain rise in the transverse vibration component level is observed at frequencies below $f \sim 400$ Hz as is a 5-15 dB lowering of the vibration level in the high-frequency spectrum range (at frequencies above 1 kHz for ditalane OTS and CB-102 solutions and above $f \sim 250$ Hz for the metaupone solution). Only positive values of ΔL are characteristic for longitudinal pipeline vibrations in the presence of ditalane OTS and CB-102 mixtures, where the vibration levels are reduced by 10-15 dB at frequencies above $f \sim 1$ kHz.

The experimental investigations performed showed that solutions with different surfactant admixtures differ both with respect to stability to mechanical destruction and to the nature of the action on the acoustic parameters of the turbulent stream. According to modern conceptions, sound and vibration generation in near-wall turbulence is associated with fluctuations of the tangential forces acting from the stream onto the surface being streamlined [9]. The spectrum of the tangential force fluctuations is due to the nature of the turbulence of the whole stream and especially the processes occurring in the viscous sublayer and the buffer domain of the boundary layer. It was noted above that the surfactant admixtures under investigation form different supermolecular structures in solutions. Measurements performed earlier of the average velocity profiles and data about the turbulent heat transfer parameters [7, 10] indicate the different influence of the supermolecular formations on the turbulent fine structure of the stream. When crystals and anisotropic micelles are present in a fluid the suppression of turbulence occurs mainly in the core of the steam. Damping of turbulent fluctuations in both the stream core domain and in the viscous sublayer occurs in emulsions.

It is seen from the results obtained in this paper that the mentioned difference in the action of admixtures of distinct structure on turbulence appears even in the stream acoustic characteristics measurements.

NOTATION

α is the diffusor aperture angle, degrees; ν is the kinematic viscosity, cm^2/sec; λ is the friction drag coefficient; Re is the Reynolds number over the pipeline diameter; P is the acoustic noise signal level, dB, f is frequency, 1/sec; ΔL is the spectral increase determined as the ratio between the sighnal level in a three-octave frequency band in pure water flow and the acoustic signal level in a flow of solutions with surfactant admixtures, dB.

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LASER DIAGNOSTICS OF THE WORKING MEDIUM IN AN ELECTRICAL DISCHARGE CO_2-LASER WITH A CLOSED PUMPING LOOP

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Results are presented of an experimental investigation of the amplifier characteristics and temperature measurements of the upper laser level and the progressive tempeature of the working medium of a pumping electrical discharge CO_2 laser in the range of pumping power variation 18-65 kW. It is shown that growth of the progressive temperature of the active medium is the main reason for degradiation of laser operation efficiency at large (above 50 kW) values of the pumping power.

To a great extent the significant interest in flow-through laser systems with electrical excitation is due to the possibilities of their extensive utilization in various branches of science and engineering. Further perfection of electrical discharge laser apparatus to improve the energetic characteristics depends at this time on the solution of a number of particular problems, such as, say, the creation of a highly efficient system of working medium

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