EFFECT OF UNSTEADINESS ON REYNOLDS STRESSES OF ACCELERATED PIPE FLOWS

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With the development of computer science and appropriate methods of calculation a marked increase of numerical modeling of various applied hydrodynamic problems is being observed in world practice: unsteady fluid flow in pressure pipes, starting regimes of pump-storage stations, emergency hydraulic systems of nuclear power stations, lock chamber emptying and filling systems, etc. Coefficients found by the "quasisteady approach" based on characteristics of steady flows are usually used in numerical calculations of the aforementioned systems. However, the inertial forces occurring during unsteady flows cause marked changes both in the local characteristics and in the very structure of an unsteady flow [1].

A number of experimental investigations [1-4] explaining the change in the friction coefficient in accelerated flows were performed in the past decade. However, attempts to close the equations describing unsteady flow in pipes in accordance with the semiempirical theory or transport equations [5] run into difficulties related to the absence of experimental data of the temporal change of the unsteady process of Reynolds stresses \(-\nu'v'\). We conducted investigations for an experimental evaluation of the effect of unsteadiness on Reynolds stresses during acceleration of a fluid from a state of rest in pressure pipelines.

Experimental Device. The hydraulic part of the device [1], constructed at the hydraulics laboratory of the Tallin Polytechnical Institute (TPI), represents a closed system made of stainless steel, the working section of which is made of a seamless stainless steel horizontal pipe with length \(L = 20 \, \text{m}\) and diameter \(d = 0.061 \, \text{m}\). Approximately in the middle, at a distance \(L_1 = 100d\) from the pipe entrance, is a transparent measuring section (Fig. 1). The local characteristics of unsteady flow are measured in the indicated section by a laser Doppler anemometer (LDA). A quick-operating valve creating unsteady flows is in the lower end of the work-

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Fig. 1. Measuring section.
Fig. 2. Block diagram of measuring complex: 1) graphic display; 2) plotter; 3) SM-4 computer; 4) 16-bit controller; 5) 265-kilobyte storage; 6) 2.5-megabyte magnetic disk storages; 7) programmable clock; 8) control of laser beam scanning (three coordinates); 9) control of quick-acting valve; 10) flowmeter; 11) buffer interface; 12, 13) channels of the LDA; 14, 15) channels of the HZ; 16, 17) pressure channels.

Fig. 3. Racks with measuring units.

The experimental device is equipped with a measuring complex (Fig. 2) making it possible to automate the experiment and store and process the experimental data in real time. The measuring units are rack mounted in the laboratory (Fig. 3).

The standard Dantec apparatus (Denmark) is used as the LDA and hot-wire anemometer apparatus (HA). By means of the LDA the local characteristics of turbulence are measured along the three coordinate axes, and by means of the HA, the shear stresses on the pipe wall. The realizable frequency in the channel of this apparatus depends on the type of sensors used and reaches maximally 200 kHz. Strain-gauge transducers LKh415 with a measuring range from 0 to $10^4$ N/m² (with a frequency of 0-500 Hz) are used as the pressure transducers, the average instantaneous velocity over the cross section is determined by the "Moment" instrument made in the hydraulics laboratory of TPI with a frequency range up to 150 Hz. In addition to these quantities, the temperature of the fluid is measured at one point of the closed hydraulic system.

Software was also created in the laboratory for the measuring complex, which consists of two main program packages: the HDISA package makes it possible to select in real time the initial parameters for the experiment, to collect the experimental data, and to record them on the magnetic medium; the WORK package serves for working with the stored data: inspection of the codes of the data and instantaneous values of the quantities being measured and output of the initial and processed data to the printer, graphic display, or plotter.

The theoretical calculation basis of unsteady pipe flows are most completely substantiated in the work of Vasil'ev and Kvon [3] in the form