VIBRATION OF AN ELASTIC TUBE EXCITED BY A TURBULENT FLOW

V. G. Tkachenko, E. M. Greshilov,
and M. A. Mironov

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Results are presented of measurements of the vibrations of an elastic tube that is excited by a turbulent flow therein. It is shown that the longitudinal component of tube vibration exceeds the transverse component by 8-18 dB in the medium frequency range f ~ 300-3000 Hz.

Investigation of the vibrations of a tube subjected to a turbulent flow inside it is of interest both from the viewpoint of developing methods to produce and reduce the noise level and vibrations of different pipeline systems, particularly for blood flow in elastic vessels [1] and from the more general viewpoint of studying the mechanism of sound and vibration generation and sources of near-wall turbulence. A tube with a fluid flowing inside it is a relatively simple vibroacoustic system allowing sufficiently simple methods of converting the measured vibration or sound characteristics to vibration and sound source characteristics. Thus, in [2] by means of the measured sound spectrum generated by a turbulent flow in a hydraulic channel, the spectrum of the cources of this sound was computed and the velocity dependences of the levels were found. The data obtained in this manner were applied to estimate the sound spectrum emitted by a turbulent boundary layer above a rigid plane. In conformity with Newton's third law, tangential forces equal and opposite to the forces acting on the fluid from the wall act on the tube wall over which the fluid flows. Measurements of the longitudinal vibrations of the tube wall after appropriate processing can yield information about the tangential force parameters, the main sound sources of a turbulent boundary layer [3-5].

Longitudinal and transverse vibrations of an elastic polyurethane tube of $8 \cdot 10^{-3}$ m inner diameter with a $1 \cdot 10^{-3}$ m wall thickness and $E = 4 \cdot 10^8$ N/m^2 elastic Young's modulus excited by water flowing through it were measured in this paper. The purpose of the research is to verify the possibility noted above of investigating near-wall turbulence sound sources. The experimental set-up (Fig. 1) is a hydrodynamic channel of gravitation type. Water from the pressure tank 1 was delivered through a flow shaping and equilibrium section 2 into an elastic tube 3 lying on sheet porolon and fixed in massive holders 4. The spacing between the holders was $12 \cdot 10^{-1}$ m. The flow rate was regulated by the change in the shaping section 2 and varied between 1-3 m/sec limits. The vibrations were measured by a miniature accelerometer 5 that was fastened to the tube surface by a $4 \cdot 10^{-3}$ m high metal ring seated compactly on the tube. The vibrations spectrum was analyzed in a three-octave frequency band. Presented in Fig. 2 are typical spectra of the longitudinal and tranverse tube vibrations for a 3 m/sec flow velocity. It is seen that the longitudinal vibrations in the f ~ 300-3000 Hz frequency range are substantially greater than the transverse. Therefore, recording of the longitudinal vibrations is not related to a parasitic sensitivity of the accelerometer to the vibrations outside the direction of its axis of sensitivity.

Represented in Fig. 3 are velocity dependences of the longitudinal vibrations levels for different analysis frequencies. The slope of the curves is 9 dB for velocity doubling at the low frequencies (f = 200 Hz), which corresponds to approximation by the power-law dependence $|p(\omega)|^2 \sim U^n$ with exponent n = 3, while n = 4-5 at high frequencies (f = 1250 Hz). A similar regularity is observed also for velocity dependences of the tangential force levels in experiments in a hydraulic channel [2].

The investigastions performed show the possibility of investigating the sound generation mechanism of near-wall turbulence by measuring the wall vibrations of an elastic tube.

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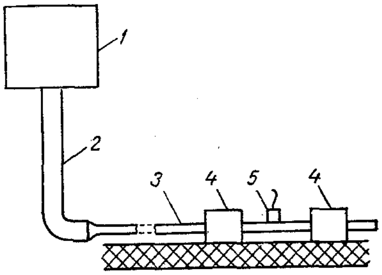

Fig. 1. Diagram of the experimental set-up.

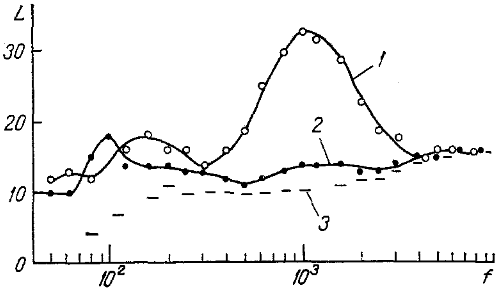

Fig. 2. Spectrum of the longitudinal (1) and transverse (2) vibrations modes of an elastic tube for a U = 3 m/sec flow velocity (3 is interference), f, Hz; L, dB.

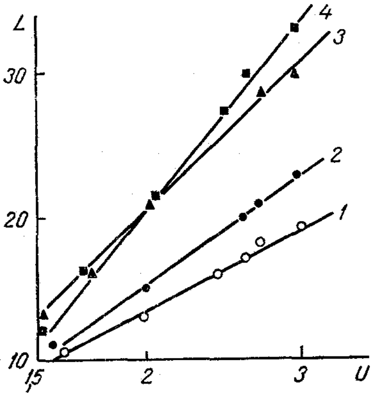

Fig. 3. Dependence of the tube longitudinal vibrations intensity on the flow velocity for different frequencies: 1) f = 200 Hz; 2) 630 Hz; 3) 1 kHz; 4) 1.25 kHz.

NOTATION

E, Young's modulus, N/m^2; L, vibration level, dB; f, frequency, 1/sec; $p(\omega)$, the sound power spectral density, W/m^2; U, mean flow velocity, m/sec; ω and $\omega = 2\pi f$, circular frequency, 1/sec.

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