Experimental studies of resonant nonlinear oscillations of a gas in an open and closed tube

R G Zaripov¹, L A Tkachenko¹,² and L R Shaidullin¹,²
¹Institute of Mechanics and Engineering, Federal Research Center KazSC, Russian Academy of Sciences, 2/31 Lobachevsky str., Kazan 420111, Russia
²Kazan (Volga Region) Federal University, 18 Kremlyovskaya str., Kazan 420111, Russia

E-mail: liqn@mail.ru

Abstract. Nonlinear oscillations of gas in an open and closed tube were researched experimentally. Dependencies of the of the pressure oscillation amplitude were obtained at the resonance frequencies of the gas excitation at a fixed amplitude of the tube displacement.

1. Introduction. The development of modern technology creates new challenges, among which one of the most urgent is the study of resonant vibrations of the environment in various apparatuses of power engineering and industry. Of special interest is the tube-resonator system, where one end of the tube is closed or communicates with the environment. Excitation of the gas produces highly nonlinear pressure waves and nonlinear effects are observed [1] near the resonances in these systems, for example, flow turbulence, secondary currents and acoustothermic processes. The results of these media were analyzed in a review [2, 3] in theoretical and experimental studies and considered transient regimes of gas flow at intense excitation amplitudes [4]. It seems necessary to experimentally studies and compares the nonlinear oscillations of the gas in an open and closed tube near its first basic frequency.

2. Experimental installation. The studies were carried out in an installation with a TIRAvib S 5220 / LS vibration generator 1 (Figure 1), which set in motion a flat tube 3. A tube with a diameter \( d = 0.1 \) m oscillated harmonically with a predetermined frequency \( \nu \) in Hz in a glass tube 4 of length \( L = 0.918 \) m for the open and \( L = 0.938 \) m for the closed pipe. The tube was opened or closed tightly with a lid 5.

The vibration table was controlled via a computer 7 by means of a piezoelectric IEPE accelerometer 2 of 4513 model by Bruel & Kjaer firm and a controller of VR9500 using specialized VibrationVIEW software. The pressure sensor 6 of the Bruel & Kjaer 6 model 8530C-15 was located next to the tube, the signal from which was fed through a three-channel bridge voltage amplifier 9 ENDEVCO model 136 of Bruel & Kjaer firm to a digital oscilloscope 8 of DSO 3062A model by Agilent Technologies firm, and then via an RS-232 interface to the computer, where the data for the gas pressure \( p \) in bar can be observed and saved using a specialized DSO3000 software.
3. Experimental results.

The dependencies are shown in Figure 2 for the range of gas pressure variations $\Delta p$ from the frequency $\nu$ at the amplitude of the tube stroke $l = 0.375$ mm. As can be seen, the pressure value exceeds in the closed pipe almost 2 times the pressure for the open pipe [7]. This is due to the

![Figure 2. Dependency of the span of the gas pressure oscillation $\Delta p$ on the excitation frequency $\nu$ at the amplitude of the tube stroke $l = 0.375$ mm, where ■ corresponds to an open ($\nu = 90.3$ Hz), and ● is closed tube ($\nu = 182$ Hz). Dots mark the experimental results, and the solid line is Lorentz approximation.](image-url)
boundary conditions at the end of the pipe. In a pipe with an open end, a continuous interaction between the gas in the pipe and air from adjacent to the open end of the external environment, as a result of which energy losses to acoustic radiation and vortex formation are observed [5, 8]. The front of the pressure wave has a strong distortion in the closed pipe, which leads to an increase in the average axial velocity [6] and the oscillations are close to discontinuous, in the open tube - the waveform is sinusoidal.

4. Conclusion.
The obtained data show that at a resonance frequency of gas oscillations at an equal amplitude of the tube stroke, the gas pressure variations in an open and closed pipe are distinguished, which is associated with losses at the open end. The waveform of the pressure wave has an asymmetrical leading and trailing edge, more pronounced for a closed pipe, as a result of which the pressure is higher.

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