The urgency of the problem of jet noise reduction has been rising again at the present stage of aircraft technology development. The main reasons are the following. The studies of attenuation of turbo-machine noise have demonstrated that the jet is one of the main noise sources even in engines with high by-pass ratios. Moreover, up-to-date passenger airplanes often use engines with low by-pass ratios where the jet noise contributes predominantly to the total noise of the power engine.

Hence, studies on development of efficient approaches to reduction of reactive jet noise are of great interest. For this purpose, the so-called passive and active methods of noise reduction are used. The former methods center around reduction of noise on its way from the source. The possibilities for passive methods implementation are rather limited due to engineer difficulties associated with the sound-absorbing unit mounting near the reactive jet. The attempts of jet noise reduction using screening capabilities of aircraft wing and fuselage or ejector noise silencers with the ejector sound-absorbing lining should also be noted.

The known active methods of reactive jet noise reduction are based on the change in aerodynamic characteristics of the mixing layer within the jet initial region, for which purpose, for instance, a coaxial jet with the high-speed central jet and the lower-speed annular jet is formed causing the shear stresses to decrease. The currently developed method of reactive jet noise reduction [8.9] based on the forming of a coaxial jet with the “reverse” velocity profile of the turbojet engine exhaust where the speed in the outer contour is larger than that in the inner one is very promising. The jet noise reduction by the change in the jet aerodynamic characteristics within the jet initial region is achieved in specific cases by means of thin transverse jet injections into the main jet near the nozzle outlet section [8.9]. These thin jets generate the flow circumferential nonuniformity ultimately attenuating the coherent structures that are the important source of jet noise.

The use of these methods provides in a number of cases the appropriate noise reduction of the reactive jet. However, one has to introduce important alterations in the operating scheme of the power plant gas generator or in the engine exhaust system structure. It should be also noted that the use of multi-nozzle and lobed noise silencers causes substantial thrust loss comprising, on average, 1% for 1 dB of noise reduction.
8.1. The Acoustical Silencer of Turbojet Noise

Studies performed in recent years [8.5, 8.14] directed radically new acoustical ways to turbulent jet noise reduction. Among other things it was established that noise excitation could considerably influence aerodynamic and acoustical characteristics of turbulent jets. For instance, low-frequency noise excitation of a jet with Strouhal number \( \text{St}_s = \frac{f_s d}{u_o} = 0.2 - 0.5 \) (here \( d \) is the nozzle outlet section diameter, \( u_o \) is the jet issue speed, and \( f_s \) is the exciting noise frequency) causes the intensification of the turbulent mixing in the initial region, and an increase in the characteristic turbulence scale in the mixing layer, resulting in an increase in the noise generation. The high-frequency noise excitation with \( \text{St}_s = 2 - 5 \) causes the reverse effect, i.e. attenuation of the turbulent mixing in the initial region, and a decrease in the characteristic turbulence scale in the mixing layer, resulting in a decrease in the jet broad-band noise.

Thus, the idea of the employment of jet sound excitation to decrease the jet noise is appealing. However, some difficulties emerge related to the necessity of mounting a high-frequency noise radiator on the engine.

The present chapter contains studies on acoustical characteristics of model and nature reactive jets under noise excitation generated by several parallel thin jets situated around the main jet. The nozzle diameters of the thin jets are one order of magnitude less than the main jet nozzle diameter and the outflow speed for the thin jets is equal to that for the main jet. Such a jet system could be realized for both the main jet and supplementary peripheral jets from the same receiver (Fig. 8.1, a).

The possibility of noise reduction in such a system with respect to the initial single jet noise is based on the following considerations. It is well known [8.5, 8.9, 8.14] that the maximum of the turbulent jet noise corresponds to Strouhal numbers \( \text{St} = \frac{f d}{u_o} = 0.2 - 0.5 \). This relation is valid equally for the main jet (subscript 1) and peripheral jets (subscript 2), i.e.

\[
\frac{f_1 d_1}{u_{01}} = \frac{f_2 d_2}{u_{02}} = 0.2 - 0.5. \tag{8.1}
\]

We have \( u_{01} = u_{02} \) for identical issue speeds of the main and peripheral jets, therefore \( f_2 = f_1 \frac{d_1}{d_2} \).

If the peripheral jet diameter is 10 times less than that of the main jet \( (d_2 = d_1 / 10) \) then \( f_2 = 10 f_1 \). Therefore, the Strouhal number determined from the diameter and speed of the main jet and from the exciting sound frequency \( f_2 \) equals

\[
\text{St}_s = \frac{f_2 d_1}{u_o} = 10 \frac{f_1 d_1}{u_o} = 2 - 5 \tag{8.2}
\]