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Acoustic Diagnostics of Instability Waves in Supersonic Jet

Victor F. Kopiev[1], *Mikhail Yu. Zaytsev*[2], *Sergey A. Chernyshev*[3]

Abstract

The aim of the paper is to analyze the correspondence of the existing ideas about instability waves as the main dynamic elements creating the noise of a supersonic jet M = 2 and acoustic measurements of this noise. The asymptotic theory of jet noise, in which the instability waves play a decisive role, was developed by C.K.W Tam. This theory proceeds from the fact that the source of the acoustic radiation of the supersonic jet (mixing noise) are packets of instability waves simulating large-scale turbulent perturbations propagating downstream in the jet mixing layer. For an ideally expanded supersonic jets, along with mixing noise, additional mechanisms of acoustic radiation-shock-associated noise and tonal noise (screech noise) also occur, which are also described in terms of waves of instability. Tam's theory made it possible to explain and calculate the main characteristics of sound emitted by a supersonic jet issued from a round nozzle. Tam's theory is based on two main hypotheses: (1) the bulk of the mixing noise is emitted by instability waves developing downstream of the nozzle edge; (2) the initial amplitudes of the instability waves of different azimuth numbers represent white noise. Thus, the unknown parameter of the theory is only one constant representing the power of white noise. In this paper we use an approach to measuring the sound field, based on the multichannel method of azimuthal decomposition of acoustic signals and measurement of the directivities of the individual azimuthal components of the field rather than the total signal. Since the main theses of the theory are formulated in the language of azimuthal modes, this method gives much more complete information about the source. Particular attention was paid to the shape of the nozzle and the flow regime in order to obtain a flow that is as close as possible to the design flow (in order to exclude the effect of shock waves and additional with respect to the mixing noise radiation mechanisms). This allowed us to compare not only the directions of individual azimuthal components (which in itself is much more informative than the total noise measurement), but also to compare the initial amplitudes of the instability waves (as noted above, in theory it is assumed that the instability waves are equidistributed in amplitude near the nozzle edge). It is shown that in the region of Strouhal numbers 0.03-0.35 for three azimuthal noise components, the theory satisfactorily describes the directivity of the radiation by individual harmonics, and the initial amplitudes of the instability waves are in qualitative agreement with the assumption of their equidistribution near the nozzle edge

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[1] *TsAGI, Zhukovsky, Russia*
[2] *TsAGI, Zhukovsky, Russia*
[3] *TsAGI, Zhukovsky, Russia*