Detection of quasiparticles in a turbulent mixing layer of a supersonic jet

S. A. Novopashin, A. L. Perepelkin, and V. N. Yarygin
Institute of Heat Physics, Siberian Branch of the Academy of Sciences of the USSR, Novosibirsk

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Experiments have shown that in a turbulent mixing layer a supersonic jet is carried by means of the exchange of quasiparticles. The typical size of the quasiparticles is determined.

In this letter we report a study of the flow of a supersonic N_2 jet in a mixing layer which flows out of a sonic nozzle with a throat diameter $d_* = 3$ mm. The stagnation temperature and ambient-gas temperature correspond to room temperature. The stagnation pressure is 3×10^5 Pa. The ratio of the pressure of the nozzle prechamber to the pressure of the ambient gas is 200. Under these conditions the flow in the mixing layer is turbulent in nature.[1]

For diagnostic purposes, we used the Rayleigh scattering method which allowed us to measure the concentration of molecules in a time 2×10^{-8} s. The spatial localization, determined by an optical arrangement, was varied in our experiments within the limits $(0.5\text{–}7)\times 10^{-6}$ cm^3.

Figure 1 is a cross-sectional profile of the average density at a distance $x/d_* = 7.6$. The density corresponds to the nozzle prechamber density and $\rho/\rho_0 = 5\times 10^{-3}$ corresponds to the ambient gas density $\bar{\rho}_\infty$. The coordinate y is reckoned from the position of the trailing shock wave. The characteristics of the turbulent flow were measured at the maximum density of the compressed layer $y = 2$ mm. Figure 2 shows the distribution functions of the readings obtained from series of measurements: in stationary gas (curve 1) and in the stream with various localized measurements: 7×10^{-6} cm^3 (curve 2), 2×10^{-6} cm^3 (curve 3), and 5×10^{-7} cm^3 (curve 4). The

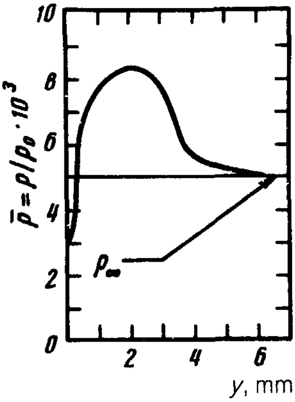

FIG. 1. Cross-sectional profile of the average density.

variance of the readings for curve 1 characterizes the single measurement error (~10%). In the gas stream, the turbulent density fluctuations affect the dispersion, causing a broadening of the distribution function (curve 2). As a result of the change in the spatial localization from 7×10^{-6} cm^3 to 2×10^{-6} cm^3, the reading distribution function transforms into a curve with two peaks. With further transforms into a curve with two peaks. With further decrease in the localization (curve 4), the effect becomes even more pronounced. This behavior of the distribution function shows that the region we are investigating has localized accumulations of gas molecules (moles) with characteristic densities $\bar{\rho}_1 = 5$ and $\bar{\rho}_2 = 13$. An important point here is that $\bar{\rho}_1$ corresponds to the ambient gas density $\bar{\rho}_\infty$. The mass is thus transferred to the surrounding medium by capturing a fraction of the flowing gas which carries a certain property of the medium: its density. In this respect, these accumulations of molecules have the properties of particles. The size of these quasiparticles can be determined from the transformation of the reading distribution function due to the change of the localization volume. Since the localization changes due to the change in the volume length from which the scattering is observed while holding the diameter of the focal spots constant (100 μm), we find the typical size of a quasiparticle $L \cong 1000$ μm. The

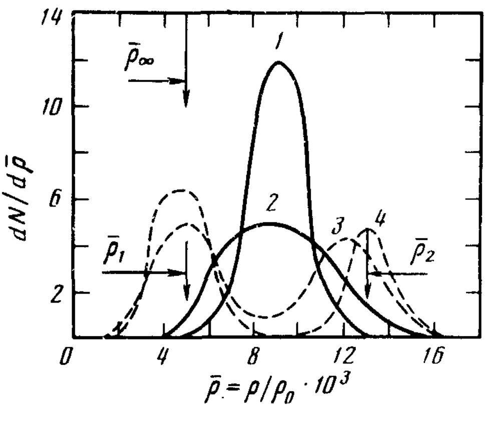

FIG. 2. The reading distribution function. 1—In the stationary gas with $\bar{\rho} = 9$; 2—in the jet with the localization 7×10^{-6} cm^3; 3—in the jet with the localization 2×10^{-6} cm^3; 4—in the jet with the localization 0.5×10^{-6} cm^3.

Knudsen number is $Kn_L = \lambda / L \cong 5 \times 10^{-3}$; i.e., the particle size amounts to approximately 200 mean free paths. The diffusion lifetime of such particles is estimated to be $t = L^2/(\lambda v) = \tau Kn^{-2} \cong 10^{-3}$ s (v is the thermal velocity, and τ is the time between the collisions, λ / v). If the supersonic jet is swept away in the mixing layer during the particle's lifetime, the particle will be displaced about 10 cm.

[1] V. S. Avduevskiĭ, A. V. Ivanov, I. M. Karpman, *et al.*, Dokl. Akad. Nauk SSSR **197**, 46 (1971) [Sov. Phys. Dokl. **16**, 186 (1971)].

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