EXPERIMENTAL STUDY OF RECEPTIVITY OF SUPERSONIC BOUNDARY LAYER ON SWEPT WING

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The paper is devoted to an experimental study of excitation and evolution of instability disturbances and laminar-turbulent transition in a three-dimensional supersonic boundary layer. This interest arises from the practical applications of this phenomenon, in particular, similar boundary layers are observed in the flow around a swept wing of an airplane. The problem of laminar turbulent transition in 3-D boundary layer is very complicated. In a 3–D case exist along with the well–known Tollmien–Schlichting waves, which development results to the turbulent transition in the 2–D boundary layers, stationary vortexes with axes directed along the outer streamlines and some traveling waves (not T–S waves). Excitation and evolution of all instability disturbances and their relative role in transition strongly depend on the environmental conditions.

Up to now receptivity of boundary layer on swept wing was studied experimentally only for the subsonic case. We performed experimental investigation of receptivity of supersonic boundary layer on swept wing to external vertical disturbances for the first time.

The experiments were made in a supersonic wind tunnel T-325 of the Institute of Theoretical and Applied Mechanics of the Russian Academy of Sciences with test section dimension 200×200×600 mm at Mach numbers M=2.0, 2.5 and unit Reynolds number $Re_1=5\times10^6$ m^{-1}. Model was a symmetrical wing with a 45° sweep angle, a 3-percent-thick circular-arc airfoil. The model length was 0.4 m, its width was 0.2 m, and the maximum thickness was 12 mm. The model was mounted at zero incidences in the central section of the test section of the wind tunnel. Edges of the model are with different bluntness. The radius of the edge bluntness was equal $r\approx1$ mm and another leading edge – approximately 0.1 mm. The disturbances are measured by constant temperature hot-wire anemometer. The frequency spectra of disturbances are determined by the discrete Fourier transformation.

Was designed and tested source of external disturbances (such sources are used at subsonic speeds). Vortex perturbations produced by a wire of various diameters, stretched in front of nozzle inserts. The experiments used a wire with a diameter d = 0.63 mm, 0.95 mm, 1.9 mm and 3 mm. The research of structure of the disturbances created by the source of external disturbances was made. It was well known method, proposed by Kovasznay, that was applied for the interpretation of the hot-wire measurements in the supersonic flows. It was found that the level of mass flux pulsation increases with the growth of wire diameter. Simultaneously decreasing of the stagnation temperature fluctuations was market.

A study of the receptivity of a supersonic boundary layer on a sharp and blunted swept wing to external disturbances at Mach M = 2 and 2.5 was made. The positions of the laminar-turbulent transition for all sources of external perturbations were determined. The effect of the wire diameter on the intensity of generated in the boundary layer disturbances and the transition location was obtained. Streamwise disturbances evolution at different sources of external disturbances is shown in fig. 1. Maxima in these dependences correspond to laminar-turbulent transition. The curves of disturbances growth, profiles of mass flux pulsations and mean voltage were measured, amplitude-frequency spectra were obtained and statistical analysis was conducted. Profiles of pulsation have two maxima, first corresponds to critical layer, second – subsonic layer.

It was found that the source of disturbances with wire diameter d = 0.6 mm does not affect the intensity of the perturbation generated in the boundary layer model and on the location of the laminar-turbulent transition. Increasing the diameter of the wire leads to the growth of the intensity of the excited disturbances and early appearance of non-linear processes, which in turn leads to the destabilization of the boundary layer. Factors of the receptivity were determined.

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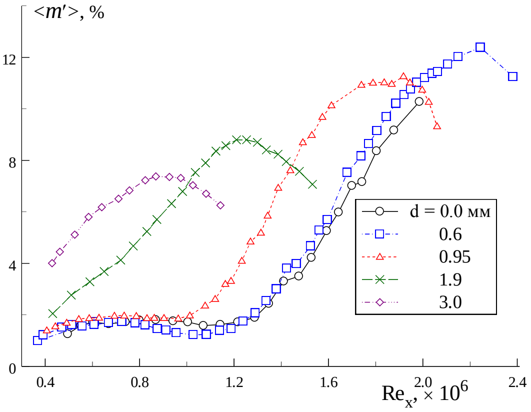

Figure1.