WAVE CHARACTERISTICS OF UNSTABLE DISTURBANCES IN 3D SUPERSONIC BOUNDARY LAYER

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Abstract Stability experiments of controlled disturbances in 3D supersonic boundary layer on the thin swept wing at low unit Reynolds numbers and at Mach 2 are considered in the paper. Spatial-wave structure of the artificial disturbances at the initial stage of laminar-turbulent transition was determined. Wave characteristics of the linear evolution of travelling disturbances in supersonic boundary layer on swept wing at controlled conditions are obtained.

The process of laminar-turbulent transition in subsonic flows is investigated in more detail than in the case of supersonic flow [1-3]. Moreover, we should note that the investigation of the problem of turbulence origin in 3D supersonic boundary layers is a very complicated task and there is no still satisfactory comparison with the linear stability theory. An attempt of direct quantitative comparison of LST data [4] with experimental results [5] has shown the necessity to extend the linear wave growth region in the boundary layer over swept wing. This work is possible to consider as the continuation of the previous investigations [6]. The main characteristics of unstable waves have been obtained that permit to conduct a more complete comparison with LST data.

EXPERIMENTAL SETUP

The experiments were conducted in T-325 low noise supersonic wind tunnel of ITAM SB RAS at Mach 2 and unit Reynolds number $Re_1=5\times10^6$ m^{-1}. The swept wing with swept angle of χ=45° were used. The model was specially designed for controlled disturbance experiments. The test surface of the model has radius of curvature R=4 m, the bottom surface was flat (3% profile, maximum thickness is 12 mm). Sketch of the swept wing model with dimensions in millimeters is presented in fig. 1. Source of artificial disturbances was built in the model. Controlled pulsations penetrated in boundary layer through an aperture of 0.4 mm in diameter and they were excited by high frequency glow discharge in chamber. Disturbances in the boundary layer were measured by using constant temperature hot-wire anemometer.

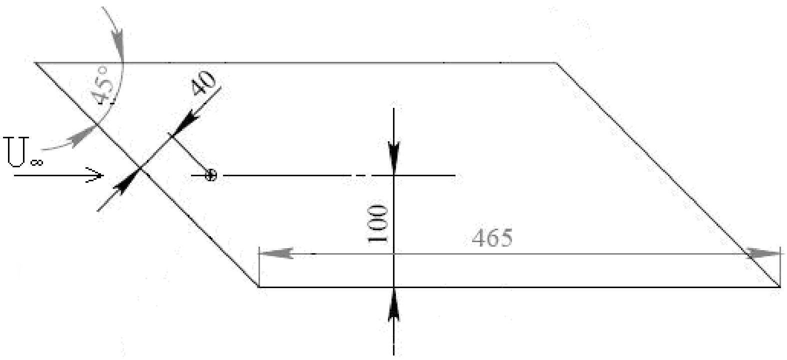

Figure 1. Sketch of the swept wing model.

RESULTS

The working frequency of the source of artificial disturbances was 20 kHz. In the boundary layer the excitation of a number of waves was observed, among which two waves had the largest amplitudes relative to others: the main wave train with frequency of 20 kHz and its unstable subharmonic wave train with frequency of 10 kHz. Both have a linear development and interaction between them wasn't observed. For specified wave trains the space-wave structure of the controlled disturbances were determined both on the area of introducing of the perturbations and on the region of the linear development of disturbances. For example, amplitude β-spectra are shown in fig. 2. The values of the transverse wave numbers at which the maximum amplitude is located are 0,9 and 1,1 rad/mm for waves with frequencies 10 and 20 kHz respectively.

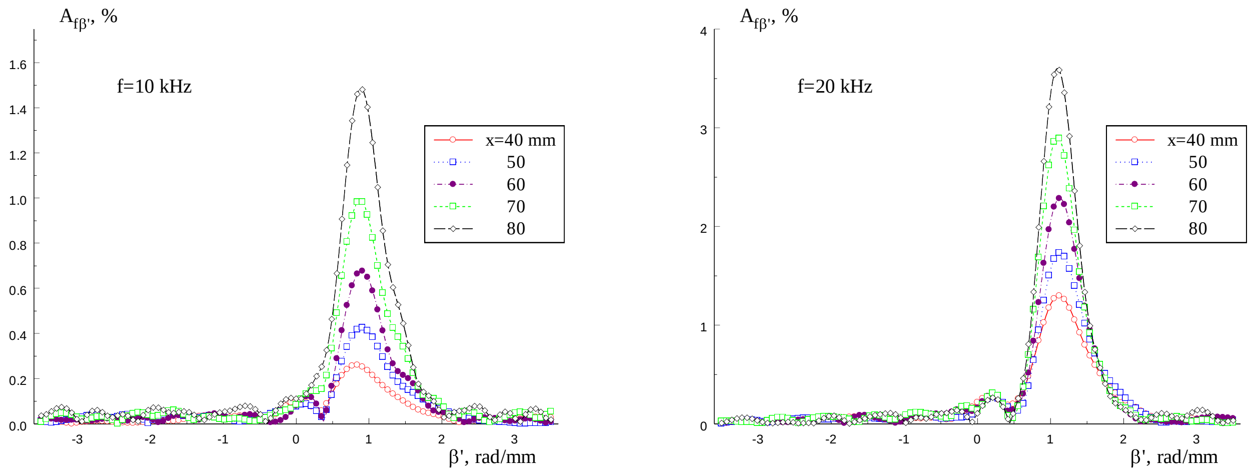

Figure 2. Amplitude β-spectra; f=10, 20 kHz.

Also the main wave characteristics of the linear development were obtained, namely estimations of longitudinal wave numbers α_r', inclination angles of a wave vector χ relatively a direction free stream, growth rates α_i. The inclination angle of a wave vector in a plane (x',z') was found to lie from 50° to 75° for the disturbances of the greatest amplitude for main wave. The growth rates comparison of two considered wave trains showed the more growth of disturbances with frequency of 10 kHz, but nevertheless, as stated, the nonlinearity was not observed and its absence can be explained by the failure of the subharmonic resonance condition, what can be obtained from the analysis of the dispersion relations (fig. 3).

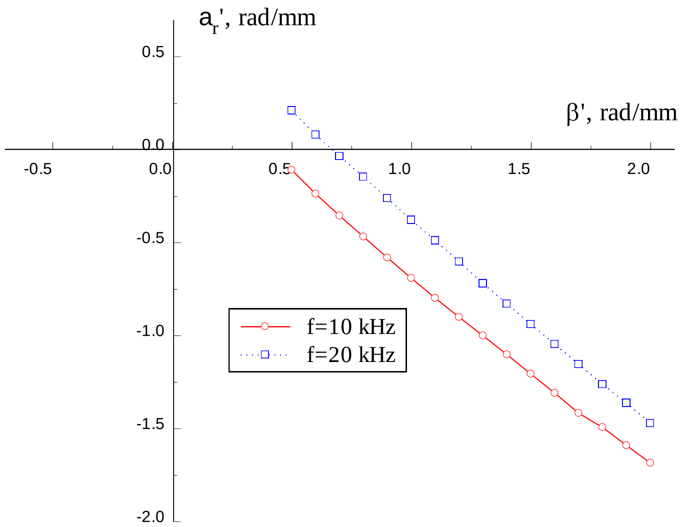

Figure 3. Dispersion relations $\alpha_r'(\beta')$; f=10, 20 kHz.

References

[1] W. S. Saric, H. L. Reed and E.B. White, Stability and transition of three-dimensional boundary layers, *Ann. Rev. Fluid Mech.,* Vol. 35, 2003, pp. 413-440.

[2] Gaponenko V.R, Ivanov A.V., Kachanov Y.S., Crouch J.D. Swept-wing boundary-layer receptivity to surface non-uniformities, JFM, **461**, 2002, P: 93-126.

[3] V. G. Chernoray, A. V. Dovgal, V. V. Kozlov, L. Löfdahl, Experiments on secondary instability of streamwise vortices in a swept-wing boundary layer. J. Fluid Mech., Vol. 534, 2005, pp. 295-325.

[4] Gaponov and Smorodskii, J. Applied Mechanics and Technical Physics, **49**, №2, 28, 2008.

[5] Semionov and Kosinov, EFMC6, 50, 2006.

[6] Alexander D Kosinov et al, J. Phys.: Conf. Ser. 318, 032011.