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THE FREE-STREAM TURBULENCE EFFECT ON THE LAMINAR-TURBULENT TRANSITION IN THE SWEPT WING BOUNDARY LAYER

Sergey L. Chernyshev[1], Alexander I. Ivanov[2], Andrey Ph. Kiselev[3], Vladimir A. Kuzminsky[4] and Dmitry S. Sboev[5]
Central Aerohydrodynamic Institute n.a. prof. N.E. Zhukovsky,
140180, Zhukovsky Moscow reg., Russia

E-mail: [1]slc@tsagi.ru, [2]ivanov_a_i@list.ru, [3]a-ph-kiselev@ya.ru, [4]vladimir.kuzminsy@ya.ru, [5]t124@inbox.ru, URL: www.tsagi.ru

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Problem of the laminar-turbulent transition description in the 3D boundary layer, such as the swept wing boundary layer, is of great applied importance. Tests of the advanced flying vehicles in the industrial wind tunnels (WT) are carried out, as a rule, at the high free-stream turbulence. In connection with this, the researchers should have in their possession methods, allowing to calculate with the enough precision the boundary layer stability characteristics and laminar-turbulent transition both in flight conditions and in different WT.

Boundary layer on the swept wing is subjected to many kinds of instabilities, the cross-flow instability representing the most interest for the researchers. This kind of instability reveals in the negative pressure gradient area near the wing leading edge as running and stationary disturbances (longitudinally-oriented vortexes). As it follows from the investigation of the turbulence effect on the laminar-turbulent transition [1, 2], at low turbulence level the stationary cross-flow disturbances dominate in the transition process, while the running disturbances begin to play the leading role with the turbulence level rise. Another transition mechanism was investigated in study [3], when under the influence of rather intensive external turbulence the low-frequency disturbances, stretched along the flow and localized in space and time are developed. These disturbances are called “streaky structures”. Laminar-turbulent transition in this case is realised through the appearence of turbulent spots as a result of the secondary instability of these structures.

The purpose of the experiments described in this report was further investigation of the free-stream turbulence effect on the laminar-turbulent transition parameters for the swept wing boundary layer. The proposed work continues the researches accomplished in TsAGI in the framework of the TELFONA Project (FP6), [4].

The laminar-turbulent transition caused by the cross-flow instability on the swept wing boundary layer was investigated. The influence of the external turbulence level on the transition location is determined. The results of the semi-empirical e^N-method and empirical criteria implementation to the transition location prediction are analyzed.

The comparison is made of the results obtained with the boundary layer transition data for the straight wing with the same airfoil at similar external condition. It was shown that at high free-stream turbulence the “streaky structures” localized in space and time, which transforms into turbulent spots, are observed in the boundary layer of the swept wing. The transition location on the swept wing in this case shifts downstream compared with the straight wing tests. This fact contrasts sharply with the available data concerning the sweep angle influence on the transition location at the low-turbulence external flow, but it confirms one of the theoretical mechanisms of the 3D boundary layer receptivity to the intensive external turbulence, [5].

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