EXPERIMENTAL APPROACH TO INVESTIGATION OF EXCITATION OF INSTABILITY MODES IN A SWEPT-WING BOUNDARY LAYER AT SCATTERING OF FREESTREAM VORTICES ON SURFACE NONUNIFORMITIES

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Receptivity is the very first stage of the laminar-turbulent transition which responsible for conversion of external environmental disturbances to initial eigen boundary-layer waves. In order to improve the understanding of this problem the project 'RECEPT' was initiated in 2011 under the 7[th] Framework Programme (FP7). According to the project it was planned to investigate the receptivity of a boundary layer on a 35° swept wing due to scattering of a free-stream vortices on an airfoil surface non-uniformities both experimentally and theoretically. For accurate quantitative measurements of receptivity characteristics, the experiments supposed to be performed at fully controlled experimental conditions including controlled surface non-uniformities and free-stream disturbances with spanwise orientation of the vorticity vector. The measurements planned to be performed at two angles of attack: −5 (experiments 'A' and 'C') and +1.5° (experiments 'B'). In the experiments 'A' and 'C' the cross-flow instability dominated in the flow, while in experiments 'B' the Tollmien-Schlichting instability was predominant.

The experimental set-up was adjusted in a way that the excited harmonic free-stream vortex street swept just above the boundary layer edge. At nondimensional chordwise coordinate $x/C = 0.15$ it scattered on (interacted with) a streamwise localized controlled surface non-uniformity that was either spanwise localized or spanwise periodic. This interaction leads to generation of instability waves at combination frequencies. For quantitative evaluation of the receptivity mechanism efficiency (i.e. for obtaining the receptivity coefficients), complex amplitudes of the exited instability waves were measured in the boundary layer downstream the surface non-uniformity and related properly to amplitudes of both the free-stream vortex and the surface non-uniformity.

Thus, in order to complete the experimental part WP1 of the 'RECEPT' project, it was necessary to design and manufacture the following equipment: (*i*) experimental models of a 35° swept wing (with static pressure taps) allowing variation of angle of attack, (*ii*) contoured wind-tunnel sidewalls for providing satisfaction of the infinite swept-wing condition in the finite-size test section of the MTL wind-tunnel of KTH (Stockholm), (*iii*) a disturbance source for mounting into the airfoil section surface simulating the surface non-uniformities of variable frequencies and spanwise spectrum, (*iv*) a vortex generator for installation in front of the wing model for excitation of fully controlled free-stream vortex street of resizable frequencies, (*v*) multi-component traversing mechanism adopted for precise positioning of the hot-wire probe in the vicinity of topologically complex surface of swept-wing airfoil and adjusted in particular for performing numerous boundary-layer spanwise scans at fixed wall-normal distances.

The task (*i*) was solved in the Institute of Aero- and Gasdynamics (IAG) of Stuttgart University. The high quality fiberglass airfoil section with chord length of 0.8 m (Fig. 1) was manufactured in a workshops of the IAG. The calculations of the sidewalls' shapes and their manufacture (task *ii*) were also performed successfully; the solution of this problem is reported in [1]. The surface disturbance source (task *iii*) was designed and manufactured in ITAM (Novosibirsk) and later was integrated into the airfoil model (see ref. [2]). The vortex generator (task *iv*) was also designed and manufactured by Novosibirsk group (Fig. 2). The key part of the generator was a thin gilded tungsten wire oscillating in the free-stream flow at desired amplitude and frequency. The wake behind the oscillating wire generated a spanwise-uniform vortex street with vorticity vector parallel to the airfoil leading edge. The amplitude of the velocity fluctuations within this street were of order of several tenth of a percent.

The problem of the hot-wire probe traversing (task *v*) was a challenging one. The matter is that the main traversing mechanism of the MTL wind-tunnel was mainly adopted for measurements on classical horizontally mounted flat plates. Moreover, due to its bulky design it could perturb the base flow. In order to traverse the hot-wire on a vertically mounted swept airfoil section it was suggested to equip the main MTL traverse with an additional smaller traverse providing additional degrees of freedom. The main technical demands to the additional traverse were the following: a) extremely small cross-section, in order to exclude any significant base-flow distortions, b) wall-normal positioning of hot-wire probes with accuracy of about ±5 microns or better, c) spanwise positioning of probes with accuracy of about ±20 microns (without displacement of the large main MTL traverse). The traverse fully satisfying these requirements was designed and manufactured in Novosibirsk and was called 'Komarik'. Later in Stockholm in collaboration with the KTH group, 'Komarik' was integrated with the main MTL traverse. The main function of the MTL traverse was to deliver 'Komarik' traverse to the position where serial y- or z'-scans were made, and to 'land' it accurately to the airfoil surface. Shown in Fig. 1 is the whole traversing system including the 'Komarik' traverse standing on the airfoil section surface.

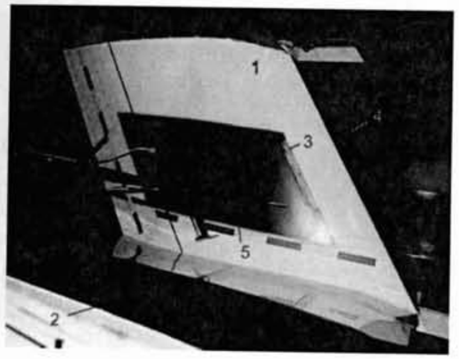

Fig. 1. Experiment setap.
1 – airfoil section, *2* – contoured sidewalls, *3* – controlled surface nonuniformity, *4* – oscillating wire, *5* – 'Komarik' traverse, *6* – sting of main traverse.

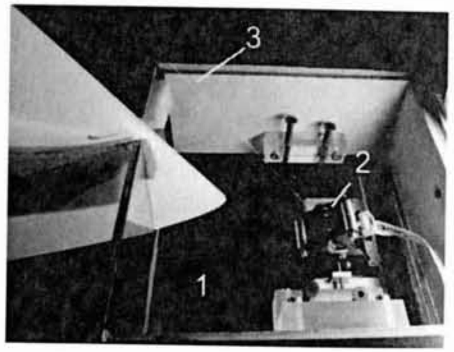

Fig. 2. Vortex generator.
1 – housing in sidewall, *2* – wire shaker, *3* – gilded tungsten wire (diameter is 50 microns).

This work is supported by the European Commission through the FP7 project 'RECEPT' (Grant Agreement no. ACPO-GA-2010-265094).

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