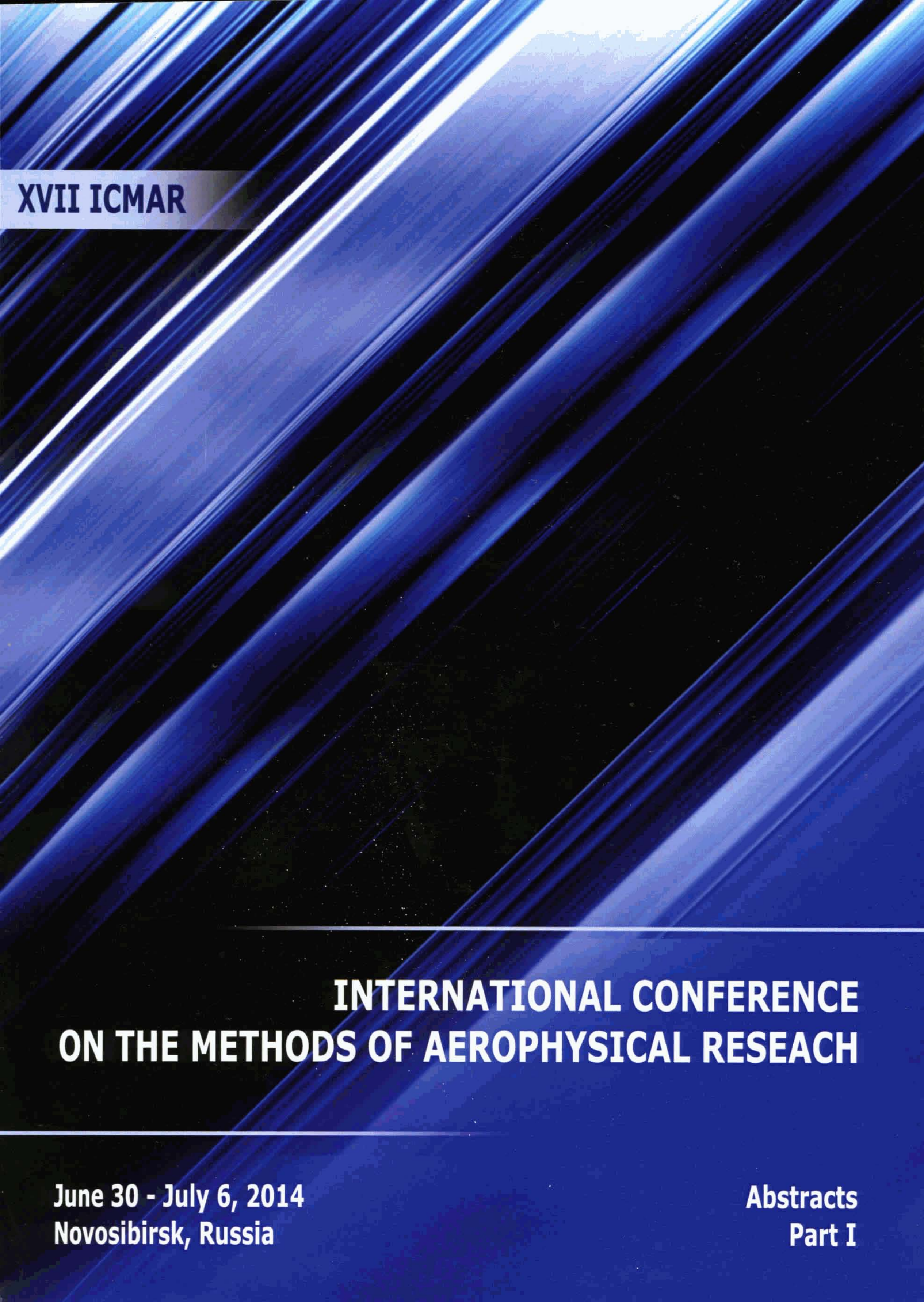

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Abstracts
Part I

NUMERICAL AND EXPERIMENTAL REALIZATION OF AN INFINITE-SWEPT-WING BOUNDARY-LAYER FLOW IN A WIND TUNNEL

A. Hanifi[1,2], P.H. Alfredsson[1], S. Imayama[1], R. Örlü[1], N. Tillmark[1], J. Vernet[1], S. Hein[3], D.G. Romano[4], M. Minervino[5], W. Würz[6], V.I. Borodulin[7], A.V.Ivanov[7], Y.S. Kachanov[7]

[1]Linné Flow Centre, KTH Mechanics, SE-100 44, Stockholm, Sweden
[2]Swedish Defence Research Agency, FOI, SE-164 90, Stockholm, Sweden
[3]DLR – Institute of Aerodynamics and Flow Technology, 37073, Göttingen, Germany
[4]Piaggio Aero Industries S.p.A., 34, Via Campi Flegrei, 80078, Pozzuoli (NA), Italy
[5]C.I.R.A., SNC via Maiorise, 81043, Capua (CE), Italy
[6]Institut für Aerodynamik und Gasdynamik, D-70550, Stuttgart, Germany
[7]Institute of Theoretical and Applied Mechanics, 630090, Novosibirsk, Russia

Transition to turbulence in boundary layer flows is a process involving several steps: receptivity to ambient disturbances, linear and non-linear disturbance growth, non-linear breakdown and turbulent spot or wedge formation and growth, and finally the establishment of the fully turbulent boundary layer. Ambient disturbances may be in the form of free stream turbulence or sound, but also vibrations of the surface as well as surface roughness may have a distinct role in setting up the initial conditions for further disturbance development. The details of the transition process depend on if the base flow is two- or three- dimensional, whether the flow is subjected to a pressure gradient (favorable or adverse) or not, and if the surface has a curvature (convex or concave) or is flat. Although many steps in the process of these different cases are fairly well understood, the receptivity is in all cases the least researched as well as least understood mechanism, despite the fact that it defines the starting point for the further development of the disturbance field.

The work reported here has been carried out within the EU-funded research project RECEPT (Grant Agreement no. ACPO-GA-2010-265094). It deals with receptivity of three-dimensional boundary layers on a swept wing at two different angles of attack. One is positive (where the instabilities are dominated by Tollmien – Schlichting type of disturbances) and the other negative (in this case cross-flow vortices dominate the transition process). In this paper we will describe the experimental set-up, design of contours of the wind-tunnel walls to establish flow resembling an infinite swept wing, and validation of measurements through comparison with numerical simulations.

The wind tunnel selected for the experimental study was the MTL (Minimum Turbulence Level) wind tunnel at KTH, Stockholm. The tunnel has a test chamber with a cross section of 1.2 m wide and 0.8 m high, with a total length of 7 m. The disturbance levels in terms of turbulence and noise are extremely low ($Tu \approx 0.02\%$ at 10 m/s) and the tunnel is therefore an excellent facility for stability and receptivity research. In addition the tunnel has excellent constancy characteristics, both in terms of speed and temperature. To guarantee the latter, the wind tunnel is equipped with a heat exchanger that allows keeping the temperature constant within 0.1°C even for measurements stretching for several days.

For the present measurements a standard wing profile with a sweep angle of 35° was chosen. The profile was modified to have the desired stability characteristics at both of the two different angles of attack and to avoid boundary-layer separation at the lower surface in the case of a negative angle of attack. The chord length was chosen to 0.8 m and the airfoil was mounted vertically in the test section. The chord length is large in comparison with the test section dimensions which required contoured test section walls (top and bottom) in order to ensure good spanwise homogeneity of the flow over the model, i.e. the flow should resemble that of an airfoil of infinite span. The preliminary design was based on RANS simulations including the test section and the boundary layers developing on the wind tunnel walls. In principle the design was based on the assumption that the shape of the wind-tunnel walls should resemble the streamlines in the potential flow for a spanwise infinite airfoil. However, two streamlines (one going to the suction side and one to the pressure side of the airfoil) next to each other far upstream would separate in the spanwise direction as they approach the wing. This would mean that walls had to have a step along the stagnation streamline that was not deemed to be satisfactory since it may create streamwise vorticity. Thus, the wall was made continuous in front of the wing. This gave rise to a small separation region near the wall but it was deemed to be acceptable. However at the trailing edge a rather large step from the pressure to the suction side was necessary in order to follow the correct shape of streamlines. From flow visualizations this step did not seem to generate any significant disturbances in form streamwise vorticity. The true shape of the streamlines and, hence, the sidewalls is, of course, three-dimensional. However, it is difficult to manufacture and use such walls in an experiment. Therefore, the sidewalls were made two-dimensional, i.e. uniform in the wall-normal direction and corresponded to the streamlines calculated for the potential flow just outside the boundary-layer edge. This approach turned out to be very successful.

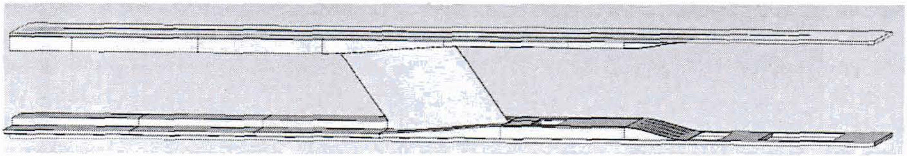

Fig. 1. Wall contours for the 1.5° angle of attack case. Flow is from right to left.

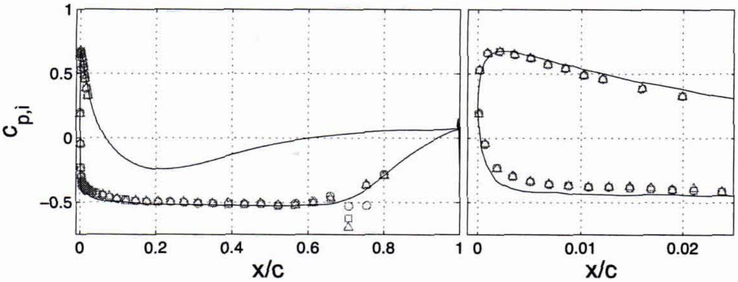

Fig. 2. Comparison of measured and computed pressure distributions at the 1.5° angle of attack case. Curves are from the RANS calculations and the symbols from the experiments. Blue symbols are from the suction side (front side of airfoil in Fig. 1), red from the pressure side.

The geometry for the 1.5° angle of attack is shown in figure 1. The total vertical height of the flow region after the initial contraction was about 65 cm. Despite this rather small distance as compared to the chord of the wing profile the measurements showed an excellent spanwise homogeneity as well as agreement with the calculated pressure distribution. As can be seen in figure 2, the comparison of measured and computed pressure coefficients shows a very good agreement.

In the presentation the calculation procedure will be outlined and also comparisons between the potential flow from simulations and experiments outside the boundary layer, streamline trajectories as well as the pressure distribution will be presented.