AN EXAMINATION OF FLOW BEHAVIOUR DOWNSTREAM OF VORTEX GENERATORS AT ZERO PRESSURE GRADIENT BY NUMERICAL SIMULATION

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Introduction

This research is a part of the project focusing on separation control by means of vortex generators, which started with implementing of the certain VGs configuration based on outcomes of the other authors on a model of NACA 63A421 airfoil with simple deflected flap of 20 degrees. The details about vortex generator designing and measurements are in [1] and here only the main conclusions will be mentioned. The results from several visualization methods and lift slope evaluation show differences in VG efficiency when the shape of VGs is changed as well as at modification of spacing between VG pairs. Moreover the efficiency corresponding to spacing change was opposite when the shape or size of VGs was altered, it means that large VGs with rectangular shape had greater efficiency for small spacing, VGs with triangular shape were more efficient with large spacing and the small rectangular VGs behave at the same way as the triangular ones. In contrary to the results of the other authors the efficiency of small VGs was negligible. Thus the decision to visualize and evaluate the behaviour of the vortices produced by VGs arose. Before the Particle Image Velocimetry (PIV) visualization with VGs will be carried out, the measurement of the straight channel without VGs called baseline case and the numerical simulation of the baseline case and also with VGs was performed and will be discuss in this paper.

Experiment

The experiment of baseline configuration were carried out in blow-down facility of cross section 250 mm x 100 mm and the flow was evaluated using Time-Resolve PIV technique. The flow condition was outer flow velocity of 4.6 m/s with less than 0.1% of turbulence intesity.

The basic characteristics of the boundary layer were evaluated at the distance 2 m dowstream of channel input: $\delta_{0.995}$ = 22.5mm, δ_2 = 2.32mm and H_{12} = 1.53. More details about measurement and results are in [2].

The results were used for comparison with numerical simulation of baseline case performed at the same conditions.

Numerical Simulation

Based on dimensions of the channel in the experiment the same geometry and computational mesh for the numerical simulation of the baseline case was created by commercial sofware Gambit. After validation of the baseline case three other geometries and meshes with implementation of vortex generators in the middle of the channel were made. The single VG pair, two VG pairs with small spacing (3h) and with large spacing (5h) were designed. The structural mesh consisted of hexahedral cells was used for all cases.

The numerical simulations were performed by commercial code Fluent 13.0.0. Solutions were obtained under the assumptions of steady, three-dimensional, incompressible viscous flow. Turbulence was modelled by two-equation k-ω Shear-Stress Transport (SST) model. The inlet boundary conditions correspond to those in experiment. Wall conditions were set on all sides of the channel and on vortex generators, the pressure-outlet boundary condition was defined at the outlet of the channel, and velocity-inlet boundary condition was used for the inlet part. A second-order, upwind discretization scheme was selected with respect to the mesh used.
The VGs influence on the flow was determined at 13 planes located downstream of vortex generators position, namely at non-dimensional distance x/h 2, 6, 8, 10, 20, 30, 40, 50, 60, 70, 80, 90 by means of the evaluation of the contours of the mean velocity U, V, W, turbulent kinetic energy (TKE) and circulation decay for all cases.

Results

One VG pair produced two counter-rotating vortices as it was expected. All velocity components are symetric, for V and W there is the same magnitude of negative and positive velocitites. When two VG pairs with 3h spacing is implemented, there is interaction between neighbouring vortices, which leads to redistribution of TKE, increasing of TKE level and faster up motion of interacting vortices at downstream motion. With increasing the spacing the vortices on the inside are at the beginning further apart, nevertheless they have approached so close, that they begun to interact as well. But this happend much further downstream.
The V component of velocity persists the longest dowstream for two VG pairs with spacing 3h, however the W component holds out the longest dowstream for two VG pairs with spacing 5h. With the single VG pair both components decay the fastest. These results are in an agreement with the observations in [3] as well as the results of circulation decay, see following paragraph.
The comparison of the circulation decay shows, that the lowest circulation values are observed for single VG pair. Close to the VG trailing edge the largest circulation is achieved for two VG pairs with spacing 3h, but this case has also the steepest circulation decay. The circulation at the end of the channel is the largest for VG pairs with spacing 5h and the lowest for single VG pair.

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References

[1] Souckova N., Kuklova J., Popelka L., Matejka M.: Visualization of flow separation and control by vortex generators on an single flap in flap configuration, *Experimental Fluid Mechanics 2010*, Liberec, Czech Republic, 2010, pp. 617-628.

[2] Uruba V., Hladík O.: On the structure of turbulent boundary layer on smooth and rough walls, 10th conference on Power System Engineering, Thermodynamics & Fluid Flow – ES 2011, Pilsen, Czech Republic, 2011, pp. 1-5.

[3] Lögdberg O.: Vortex generators and turbulent boundary layer separation control, Technical reports from Royal Institute of Technology, KTH Mechanics, Stockholm, Sweden, 2006, p. 106.