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DES SIMULATION OF SEPARATION CONTROL FOR FLOW OVER HUMP

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Abstract: *Article deals with numerical solution of the separation control using Detached Eddy Simulation turbulence model. Numerical computation was done using commercial code Fluent. Vortex structures was visualized from the numerical solution. The strong influence of side walls to the character of the flow field is visible. The effect of the flow control was observed. Computed flow field is compared with experimental data obtained from hot wire measurement in the traversing plane. Significant deviations between numerical simulation and hot wire measurement are found. Numerical simulation of the three dimmensional flow controlled flow field is still challenge for present CFD.*

Keywords: ***Detached Eddy Simulation, Flow Control, Hump, Vortex Structures***

1. Introduction

Separation occurs in the wide range of application in the engineering practice. Separated flow has negative impact on performance because it reduces pressure loss, increase noise etc.

Control of turbulent flow by using oscillatory perturbation generated by synthetic jet actuator can be effective in influencing flow separation (Gatski & Rumsey, 2004). The main advantage of flow control by using synthetic jet actuators against steady suction or blowing is their energy consumption and not least they do not require piping system. Oscillatory flow control is effective mainly in the case when introduced two dimensionally because there are generated vortex structures which are responsible for the momentum transfer across the shear layer.

Our geometrical configuration is inspired by the work of Seifert & Pack (2002) which also forms the basis for few CFD validation workshops (Gatski & Rumsey, 2004) but the numerical simulation of flow controlled separation is still an open problem. Our previous works were focused to visualization and identification of vortex structures, pressure measurement, constant temperature anemometry measurement and to the methods of flow control (Matějka et al., 2011, Matějka et al. 2009, Matějka & Popelka 2010).

2. Experimental Setup

Experiments were conducted in low speed Eiffel type wind tunnel with *300 mm x 200 mm* test section. The dimension of hump is *400 mm x 300 mm x 50 mm (l x w x h)*. The hump has built in a synthetic jet generator to control flow field behind it. The position of output slot is marked in the figure 1.

Data acquisition was carried out by using constant temperature anemometry. Measurement was done by using a single sensor probe in the traversing plane behind the hump. Traversing plane is marked by red colour in the figure 2a.

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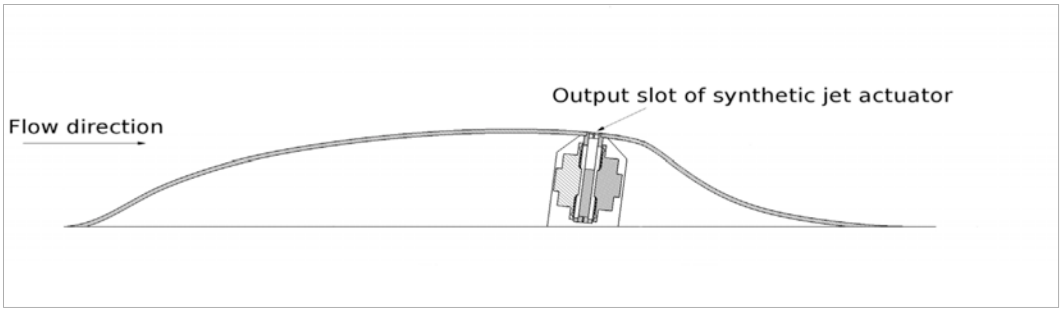


Fig. 1: Hump with synthetic jet actuator

The design of synthetic jet generator is based on requirement to obtain maximum intensity of the synthetic jet with minimum input energy (Kordík et al. 2010). Therefore, the exciting frequency of synthetic jet generator should correspond to its resonant frequency. Two loudspeakers arranged by two in one cavity and 9 cavities in one line were used. The synthetic jet actuators were excited by using amplitude frequency modulation. Carrying frequency *fc = 370 Hz* is the resonant frequency of synthetic jet actuator. The value of modulation frequency $f_{AM} = 60$ *Hz* was chosen with respect to the Strouhal number

$$\boxed{F^+ = \frac{fx}{U_\infty}} \quad , \tag{1}$$

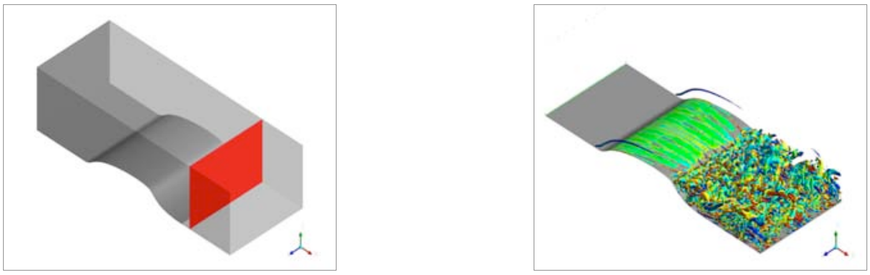
Stokes number of output orifice

$$\boxed{St_o = \frac{fh^2}{\nu}} \tag{2}$$

and oscillatory momentum coefficient

$$\boxed{c_\mu = \frac{\rho_0 u_0'^2 h}{1/2 \rho_\infty U_\infty^2 l}} \quad . \tag{3}$$

The value of Strouhal number was $F^+ = 1.2$, Stokes number of output orifice was $St_o = 6.6$ and oscillatory momentum coefficient was $c_\mu = 0.0047$.



(a) Location of traversing plane behind the hump *(b) Visualized vortex structures behind the hump*

Fig. 2: Computational domain

3. Numerical Simulation

Unsteady numerical simulation of the flow field with influence of synthetic jet was done by using commercial code Fluent. In this case half of the channel is simulated on 14.5 million cells by using non iterative time advancement method with second order implicit scheme. Fractional step scheme is used for pressure velocity coupling. Convective terms are discretized by using bounded central differencing scheme in momentum equations otherwise second order upwind scheme is used. Turbulence modelling is based on Delayed Detached Eddy Simulation variant of SST *k-ω* model

(Menter et al. 2003). The inflow velocity of $8\ ms^{-1}$ was set up, i.e. $Re = 215000$. Velocity boundary condition close to the synthetic jet actuator slot exit was set with carrying frequency $fc = 370\ Hz$ and modulation frequency $f_{AM} = 60\ Hz$ and with amplitude $17\ ms^{-1}$.

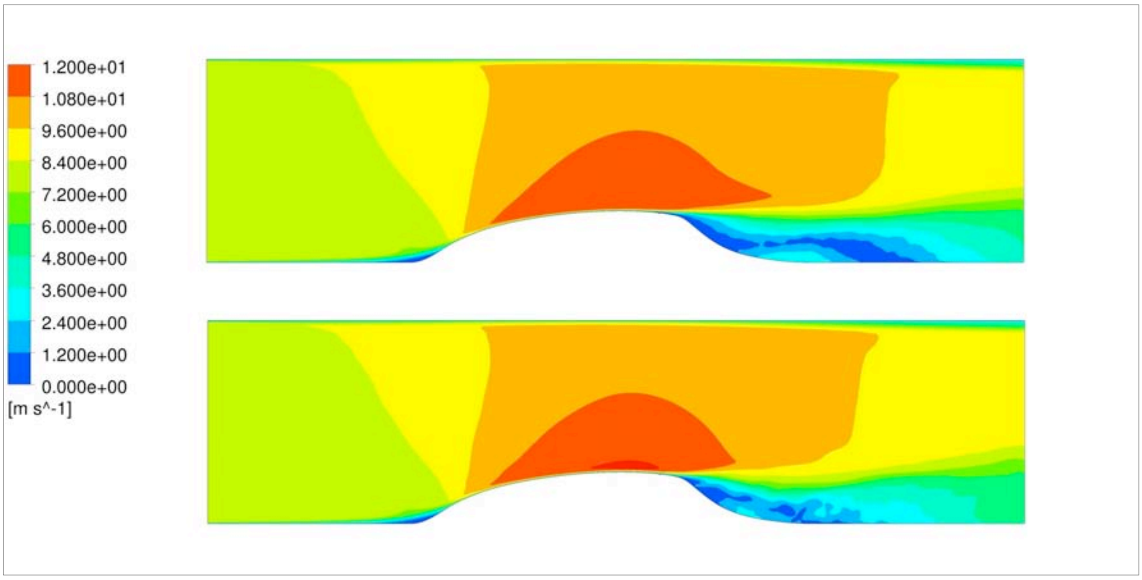


Fig. 3: Contours of mean velocity in the symmetry plane, upper without influence of synthetic jet, lower with influence of synthetic jet

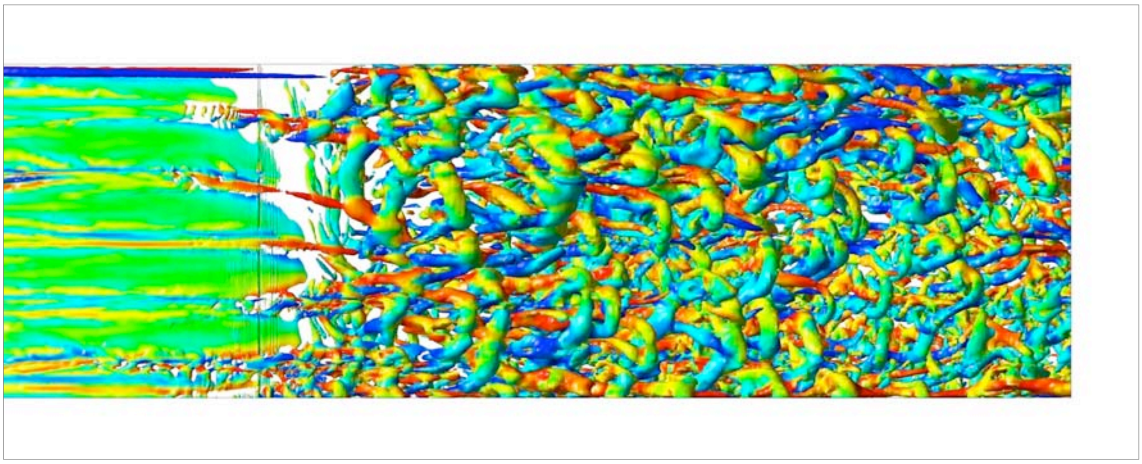


Fig. 4: Vortex structures behind the hump without influence of synthetic jet visualized using swirling strength criterion; only half of the channel in visible

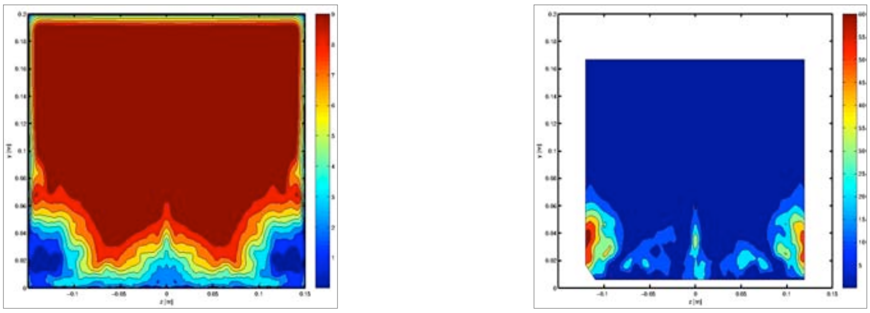
4. Results

The figure 2b shows complex three dimensional vortex structures behind the hump. Vortexes are visualized by using swirling strength method where colour is based on component of swirling velocity in the direction of the main flow. The influence of synthetic jet generator can be observed on the creation of downstream traveling vortex packs. Observed vortex packs are present through the whole width of the channel.

There are complex vortex structure behind the hump for both cases, i.e. synthetic jet controlled and uncontrolled flow field. Figure 4 shows vortex structures for the case without influence of synthetic jet. It is very interested in that there are not big dominant secondary vortexes close to the upper side wall but instead of it there are few small vortexes.

The effect of synthetic jet flow control is clearly visible on figure 3 where contours of mean velocity in the symmetry plane are shown for both the case without influence of synthetic jet and with influence of synthetic jet. Flow control in this case significantly reduce size of separation zone.

Velocity profile from the numerical computation in the traversing plane is presented in the figure 5a and deviation of measured and computed mean velocity normalized by inflow velocity is in the figure 5b. Significant deviation in the regions close to the side walls can be seen. Maximum observed deviation close to the left side wall is very close to *60 %.*

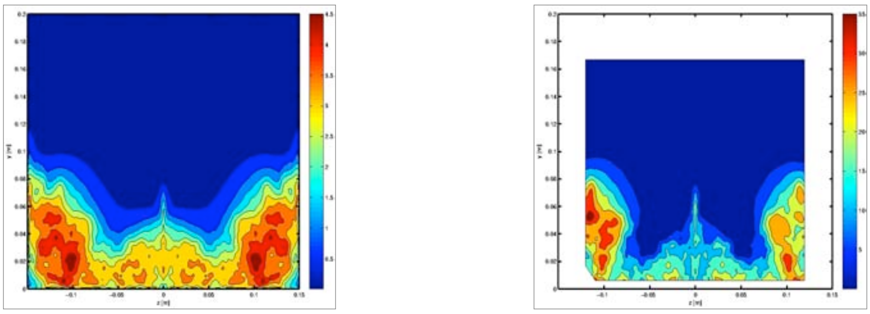


(a) Velocity profile from the numerical computation in [ms^{-1}]

(b) Normalized deviation of the measured and computed mean velocity in [%]

Fig. 5: Mean velocity profile in the traversing plane

RMS velocity profile from the numerical computationn is presented in the figure 6a and deviation of measured and computed RMS velocity normalized by inflow velocity is in the figure 6b. Maximum deviations are present close to the side walls and maximally reach 35 % close to the left side wall.



(a) RMS velocity profile from the numerical computation in [ms^{-1}]

(b) Normalized deviation of measured and computed RMS velocity in [%]

Fig. 6: RMS velocity profile in the traversing plane

5. Conclusion

Investigation of the flow field in the channel with wall hump which is affected by the synthetic jet generator has been made. The focus was placed both on the comparison of measured and computed velocity data in the traversing plane and on the identification of vortex structures influencing the flow field. It was shown that there are significant deviations of mean velocity and RMS velocity in the regions near the side walls. In the middle part of the channel, where the side walls do not affect strongly flow field good agreement is obtained between hot wire anemometry data and computation. The significant deviations close to the side wall can be caused by the influence of traversing probe to the flow field and mainly by lack of knowledge about boundary conditions in the slot exits which are based on synthetic jet characteristic measured as a synthetic jet into quiscent air and approximated by harmonic function.

Acknowledgement

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