DETECTION OF ORGANISED STRUCTURES IN THE TURBULENT BOUNDARY LAYER BY VITA TECHNIQUE

Artur Drozdz, Witold Elsner, Stanislaw Drobniak
Technical University of Czestochowa, Czestochowa, Poland

Turbulent flow is the phenomenon characterised by the chaotic, random changes of velocity, however one may find there some repetitive patterns called eddies or coherent structures. These organised structures create stress and intensify the transport of energy. The paper concerns experimental investigations of turbulent boundary layer developing on a flat plate under the adverse pressure gradient corresponding to the case of pressure variation at axial compressor blading. The pressure gradient was generated by a proper curvature of the upper wall. The fully developed turbulence structure was achieved by appropriate triggering of the boundary layer and as a result the adverse pressure gradient turbulent boundary layer (denoted t.b.l herein) at Re_θ = 3000÷6000 was achieved. The paper deals with the analysis of bursting phenomena in the t.b.l., for which the large coherent structures are responsible (Kline & Robinson, 1989). The VITA technique developed by Blackwelder and Kaplan (1976) was used to detect the structures containing most of energy in the flow. In the paper, the results of VITA detection process, based on X hot-wire signal, is presented. For interpretation of structures behaviour the shape of conditionally averaged <*u*> and <*v*> velocity traces recorded by X-wire was analysed. The applied quadrant analysis of time signals allowed to identify events occurring not only during bursting but also before and after the occurrence of burst.

The VITA detection scheme is based on the analysis of running variance *var*(*t*,*T*) of detection parameter *a*(*t*) given by equation:

$$\mathrm{var}(t,T) = \frac{1}{T}\int_{t-T/2}^{t+T/2} a(t)^2\,dt - \left[\frac{1}{T}\int_{t-T/2}^{t+T/2} a(t)\,dt\right]^2 \qquad (1)$$

Parameters of the detection process have to be properly tuned in order to obtain the best possible efficiency of this procedure. The instantaneous time derivative of streamwise *u* velocity component was selected as a basic detection parameter "*a*(*t*)" and either positive $\frac{\partial u}{\partial t}$ (+) or negative $\frac{\partial u}{\partial t}$ (-) values were used to differentiate between the particular phases of bursting event. Detection of the structures has been based on streamwise *u* velocity signal which gives higher amplitudes of velocity fluctuations in comparison with *v* velocity component normal to the wall. In order to select the appropriate time averaging window *T*, which is the next important detection parameter of VITA, the criterion of the maximum number of positive structures (N^+) detected was used. Fig. 1 presents the number of positive (N^+) and

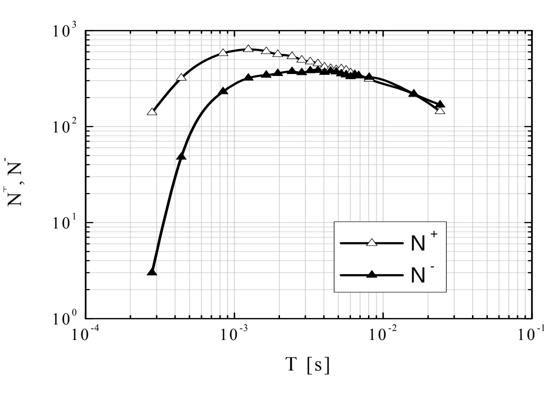

Fig. 1 Amount of structures N^+, N^- versus time averaging window T.

negative (N^-) structures detected for particular values of time averaging window *T*. One may notice that the number of (N^+) structures is significantly larger in comparison with (N^-) ones and furthermore the peak in (N^+) distribution is more pronounced, that allows to select the optimum *T* with less ambiguity. The next important parameter of VITA technique is threshold value *k* of detection function *D*(*t*,*T*). Previous investigations (Materny, 2009) revealed that it was very difficult to define its optimum and following the literature sources (Ichimiya et. al.1998) this value was set as *k* = 1. One may expect (Materny, 2009) that for *k* = 1 the VITA technique detects only the strongest structures which are responsible for the production of turbulence kinetic energy. The sample time traces of phase averaged velocities <*u*> and <*v*> are presented at Fig. 2 for positive (a) and negative (b) structures. Distributions of the <*u*> and <*v*> are approximately 180° out of phase which confirms the earlier findings of Wallace et al. (1977). One can see also that <*v*> distribution has much lower amplitude in comparison with <*u*> time-trace and this confirms that detections based on the *u* signal is more realiable, due to much larger amplitude of the analysed signal.

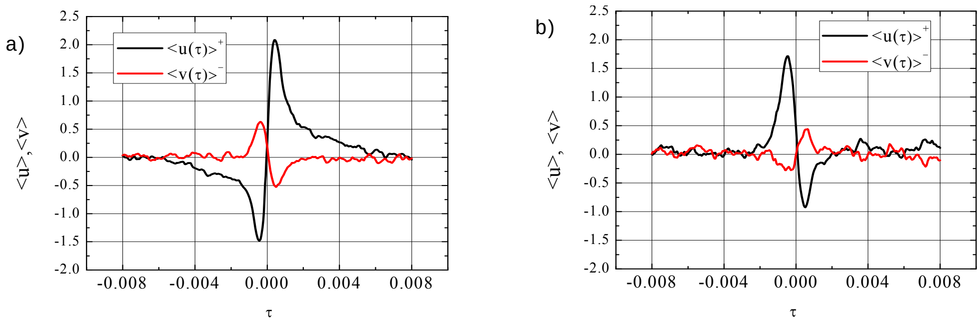

Fig 2. Phased averaged velocities during structures passage: positive (a), negative (b).

The simultaneous analysis of phase-averaged <*u*> and <*v*> time traces allows to apply the quadrant analysis and detect two characteristic features associated with the presence of large coherent structure in t.b.l. i.e. ejection and sweep (Wallace). Ejection event (with <*u*> < 0 and <*v*> > 0 dominates) before positive structure comes to the measuring point and the same event but weaker when negative structure exits measuring point. Sweep event (with <*u*> > 0 and <*v*> < 0) occurs when positive structure exits measuring point and the same event but also weaker when negative structure comes to the measuring point. This interpretation is consistent with the analysis presented by Adrian et al. (2000).

Acknowledgement The research was supported by COST/258/2006 „Opracowanie reguł efektywnego wykorzystania metody LES w wybranych typach przepływów turbulentnych" 2006-2009

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