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INVESTIGATION OF THE NEGATIVE AND POSITIVE JETS IN THE INDUCED BY WAKES TRANSITION

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ABSTRACT

Experimental investigation of the wake boundary layer interaction is important for many technical applications, especially for turbomachinery. It should also deepen our understanding of this phenomenon giving an insight into its physics and can be also useful for numerical modelling of flow in turbomachinery.

This investigation was carried out in the subsonic wind tunnel of low turbulence intensity, Tu<0.08%. The low level of turbulence was deliberately chosen to avoid the influence of the turbulence which can darken our insight into this phenomenon. In this place it is probably reasonably to recall the case of Tollmien-Schlichting waves which many years could not be revealed because of enhanced turbulence level. To generate the wake and especially the negative and positive jet of the wake the harmonic motion (of the frequency equal to 4 Hz) of a single rod in flow of was used. The measurement was made for different incidence angle of a plate for acceleration coefficient $K= 0 \div 3.5\cdot10^{-7}$ and oncoming velocity U_o=15 m/s. For this investigation the thermoanemometry (single hot-wire) with ensemble averaging and wavelet analysis were used. The aim of the investigation is to reveal the difference between the positive and negative jets when the wake is passed over the boundary layer. The positive jet of the wake is impinging the plate surface whereas the negative jet sucked the medium from the boundary layer. In turbomachinery relating to compressor or turbine blades we have to differentiate between the interaction of negative and positive jet with the boundary layer on the pressure and suction sides of the blade, appropriately. Additionally, an evolution of the mean boundary layer characteristics in the wake period was determined using the ensemble averaging technique which also enabled the separation of the stochastic and periodic velocity fluctuations, especially the C_f, δ, δ^*, δ^{**} and H values at different Reynolds numbers showing changes from the laminar to turbulent flow. Fig. 1 shows the ensemble averaged velocity across the boundary with the negative (first from left) and positive jets. After the negative jet more disturbances can be seen than after the positive jet. $C_f(\tau, Re_x)$ values (three figures on the left side and one in the right lower corner) in three different Reynolds numbers shown in red in the figure with time averaged results for $C_f=f(Re_x)$ (in the right upper corner). The C_f coefficient as a function of the time period of wakes generated by the rode shows great changes which lie between the laminar and turbulent lines. The same great changes are also shown for other characteristics of boundary layer induced by wakes.

In Fig. 2 the non-dimensional velocity $u^+ = f(y^+)$ in wall coordinates is shown for the time period τ at point marked as a red line lying at the begin of the negative jet. It can be seen that it is possible that in the range of the wake in boundary layer the relation of the viscous sublayer $u^+ = k\, y^+$, where k = 1 is probably not more valid. Next the result of wavelet analysis is shown for Reynolds number $Re_x = 168843$ and the value $y^+ = 10{,}25$ so near to the plate surface, Fig. 3.

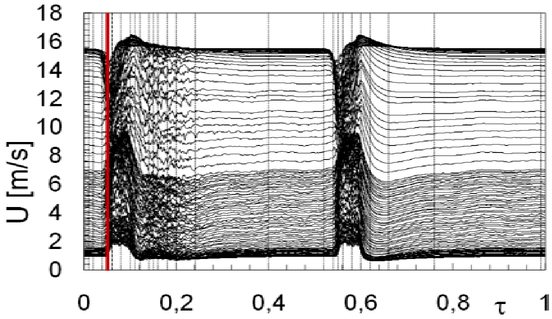

Fig. 1 velocity across BL layer versus time

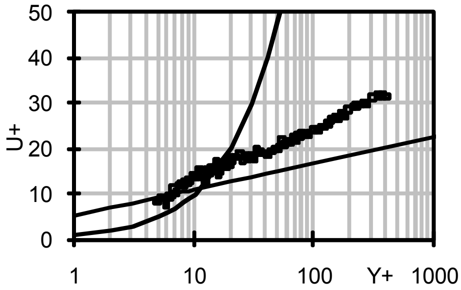

Fig. 2 $u^+ = f(y^+)$ at wake

In Fig. 3 three diagrams are shown, in the upper – the velocity fluctuations versus time are shown for three subsequent wake periods. As in Fig. 1 the negative jet is placed as the first from the left, then consequently, positive, negative etc. In the second - the results of wavelet analysis are shown as coefficients a=a(f,t). The third – presents the result of section across the wavelet analysis for the frequency f= 1150 Hz. In the first and third diagram the strong disturbances (probably the turbulent spots) are clearly seen behind the negative jets at the point of local velocity minimum, such disturbances are absent behind the positive jets. Additionally, in Diag. 1 and 2 two different wavetrains can be seen for $f_1 = 190$ Hz and $f_2 = 40$ Hz, both behind the negative and positive jets.

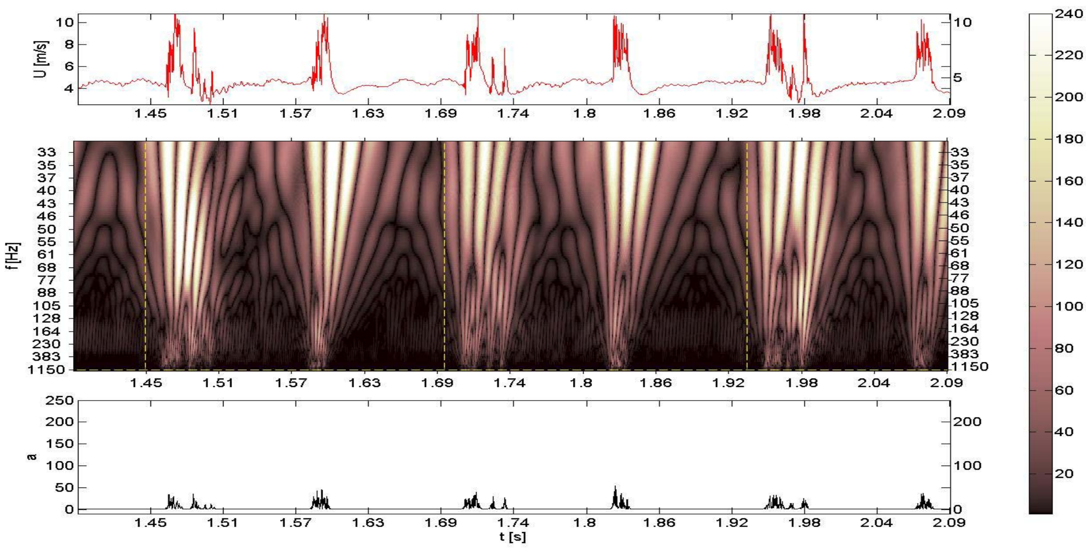

Fig. 3 Results of wavelet analysis

For the growing Reynolds number the number of strong disturbances behind the negative jet is steadily growing . It is supposed that behind the negative jet the becalming region is rather absent, while the becalming region behind positive jets are seen almost until the end of transition region.

Concluding it can be said that the investigation of the negative and positive jets and its impact on the boundary layer can give us the instruments to develop the modeling of l-t transition in the boundary layer.