TURBULENT SPOTS DURING BOUNDARY LAYER BY-PASS TRANSITION

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ABSTRACT

The effect of the free stream turbulence (FST) level *Tu* on the location of transition onset is known long ago. The authors clearly proved (Jonáš et al. [1, 2]) that the length scale L_e of the FST also influences the start of boundary layer by-pass transition. Roach and Brierley [3] and Brandt et al. [4] confirmed the importance of both FST scales too. But a clear physical notion on the role of the FST length scale in transition process is not elaborated yet. The investigation of the spots behaviour during transition at various FST scales can contribute to the problem explanation.

The flat plate boundary layer was investigated experimentally in the close circuit wind tunnel IT AS CR, Prague (0.5 x 0.9) m^2 on a smooth wooden plate 2.75 m in length. Plane grids of different geometry across the flow produce homogeneous nearly isotropic turbulence. Boundary conditions correspond to the ERCOFTAC Test Case T3A+: free stream velocity U_e = 5 m/s and the FST level *Tu* = 0.03 with various length parameters L_e = 3.8, 5.9 and 33.4 mm respectively in the leading edge plane (x = 0). The applied CTA measuring method and procedures [5] allow determine digital records (25 kHz, 750000 samples) of the instantaneous velocity $U(t, x, y)$ and wall-friction $\tau_w(t)$ rows and carry out relevant statistical analyses. Conditional analysis of $\tau_w(t)$ allows sorting the record in time intervals either with turbulent flow structure or with laminar/non-turbulent structure and thus determine the transitional intermittency factor $\gamma(x)$. Valuable information on turbulent spots role in transition process can be deduced with regard to Emmons ideas and Narasimha concept of transitional intermittency [7]. The transitional intermittency factor $\gamma(x)$ is interpolated by the formula

$$\gamma\left(Re_x\right) = 1 - exp\left[-\left(Re_x - Re_{x_{tr}}\right)^2 n^*\sigma\right]; \quad Re_x = xU_e/\upsilon; \quad n^*\sigma = n\sigma\upsilon^2/U_e^3$$

where the parameter $n^*\sigma$ stands for the dimensionless spot production rate. Next n denotes the spot production rate, σ is the Emmons's non-dimensional propagation parameter, ν and U_e denote kinematic viscosity and external mean flow velocity.

The application of wavelet transform of digital records $\tau_w(t, x)$ represents other approach to the investigation of turbulent spots during boundary layer transition. The wavelet transform is able to detect particular frequency components and localize the investigated event in time. Elsner et al. [6] developed an original detection procedure. Using the Morlet wavelet transform, they determine the dimensionless spot production rate $n^*\sigma$ and distributions of reduced number and mean length of the identified turbulent regions arising from turbulent spots. Results from the application of the Narasimha's intermittency concept and the results from the wavelet analysis are in a satisfactory accord mutually as shown in Figure 1. They correspond also with the results of Fransson et al. [8] and with the model of the spot production rate proposed by Mayle [9] above all if the local turbulence level at the location of transition start, x_{tr} is considered. Next it was ascertain that the spot occurrence is more numerous at larger *Le* at the beginning of transition ($\gamma = 0.1$). This phenomenon disappears farther downstream. The observed maximum of the spot occurrence was near $\gamma = 0.25$; later the spot production is effectively inhibited due to calming (see Ramesh and Hodson [10]); the mean length of turbulent regions arising from occurrence of turbulent spots initially slowly grows, regardless the L_e, up to the location where $\gamma > 0.7$.

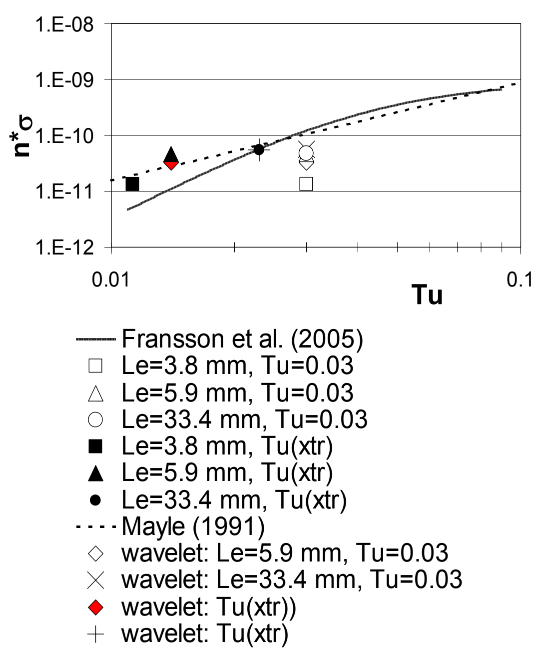

Figure 1 Dimensionless spot production rate versus turbulence level.

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