Laminar to turbulent transition in separated boundary layer at elevated turbulence level

Konrad Gumowski and Sławomir Kubacki

Institute of Aeronautics and Applied Mechanics, Warsaw University of Technology, ul. Nowowiejska 24, Warsaw, Poland
kgumowski@meil.pw.edu.pl

1 Abstract

Experimental investigation of separated boundary layer transition from laminar state to turbulent state, under a statistically steady mean flow are presented using CTA and PIV techniques. Elevated freestream turbulence levels are considered, effectively leading to bypass transition inside at the apex of separation bubble. The aim is to gain insight/at into the processes which are of particular importance in turbomachinery boundary layer flows.

The experiments were conducted in low-speed wind tunnel, which is an closed circuit wind tunnel with closed test section. It incorporates among others a settling chamber with a turbulence grid, and a rectangular test section of 0.25 m width, 0.45 m height, and 1 m length. The model is followed by a flap, which is used to control the small separation bubble at the leading edge of the plate. The flow over the plate is subjected to adverse-pressure gradient. The required pressure gradient is achieved by a contoured wall opposite the plate (Hourmouziadis case [1]). Experiment was performed for wide range of Reynolds number ($Re_x = 10^5 - 3*10^5$) and two levels of turbulence intensity ($Tu = 3.5 - 6\%$).

Figure 1 shows the static pressure distribution (with isolines depicted by dashed lines) along the plate (x) for various Reynolds numbers. Separation region was verified by occurrence of plateau in static pressure distribution. As shown, the distance between the boundary layer separation point and flow reattachment becomes smaller and the under-pressure becomes stronger as the Reynolds number increases.

The analysis of velocity spectra allow to distinguish the Klebanoff distortions in the laminar and transitional boundary layer and show the energy transfer towards smaller scales approaching the turbulent flow region. The Klebanoff modes strongly perturb the separated boundary layer and lead to bypass transition inside the separated boundary layer. Some evidence of the Kelvin-Helmholtz instability mechanism is also revealed in transitional flow, suggesting that the bypass transition co-exists with the Kelvin-Helmholtz instability. These results confirm, therefore, the literature data on transition mechanism

in separated boundary layer at elevated/high turbulence level. CTA data allow to calculate the intermittency function which is used to make a distinction between laminar, transitional and turbulent flow regions. In particular, the intermittency function is used to determine the transition onset point. The intermittency factor, together with other parameters, are used for validation of well-known transition onset correlations (Mayle, Roberts [2]).

Detailed PIV results allow to trace the evolution of the mean and turbulent quantities in separated flow region, determine the skin friction coefficient and integral parameters. The analysis of PIV results combined, with analysis of CTA data, allow to formulate a unique conclusions on transition mechanism in separated boundary layer flow.

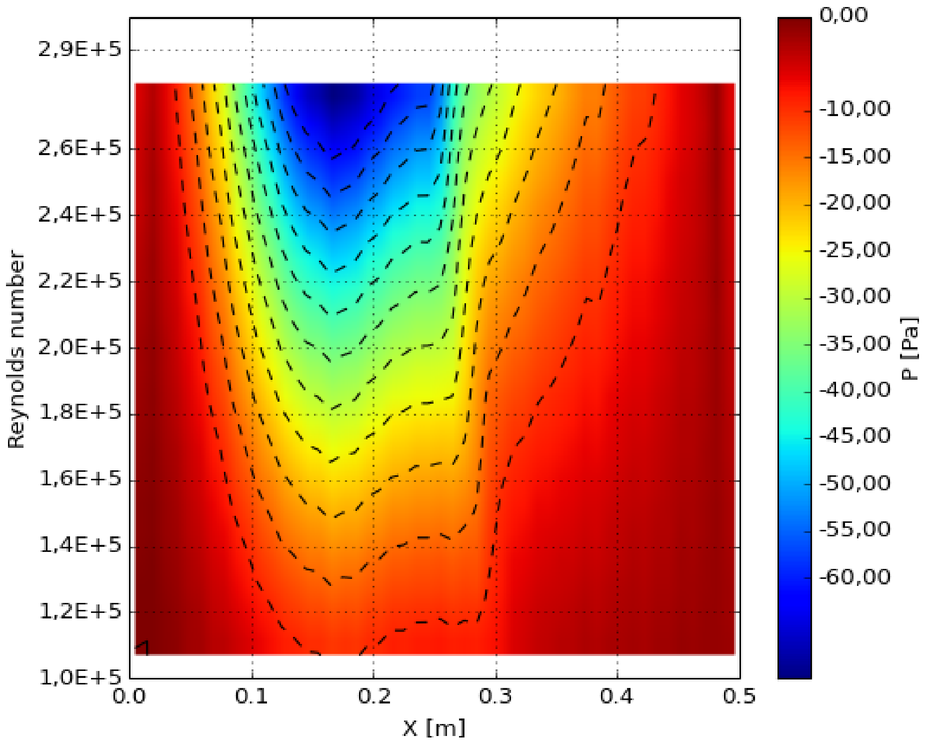

Figure 1: Pressure distribution on a surface of model in function of Reynolds number.

References

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[2] Mayle, R. E. *The Role of Laminar-Turbulent Transition in Gas Turbine Engines Journal of Turbomachinery* ASME International, 1991, 113, 509