Mitteilung

Projektgruppe/Fachkreis: Numerische Simulation

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Thema: Modification of the SSG/LRR-ω RSM for turbulent boundary layers at adverse pressure gradient with separation using the new DLR VicToria experiment

The prediction of turbulent boundary layer separation due to a smooth adverse pressure gradient (APG) in the low-speed regime using RANS-based CFD is still associated with significant uncertainties. Well-defined and documented validation test cases with a thin separation bubble and at high Reynolds numbers relevant for the flow around aircraft wings are rare in the literature. Therefore within the DLR project VicToria a new boundary layer experiment was designed. The goals are (i) to establish a data base for the mean velocity and the Reynolds stresses in the APG region and in the separation region, (ii) to extend a recently proposed wall-law at APG (see [1]) towards separation, (iii) to establish the test case as a validation case for RANS and scale-resolving simulations, and (iv) to extend the recently proposed modification of the ω-equation for the SST k-ω model (see [1]) to the SSG/LRR-ω model and to calibrate this modification for the situation that the flow approaches separation.
The experimental investigation was performed using the Atmospheric Windtunnel (AWM) at the UniBw in München. The measurements where performed at four reference velocities up to 35m/s. The geometry in the APG region is shown in figure 1.

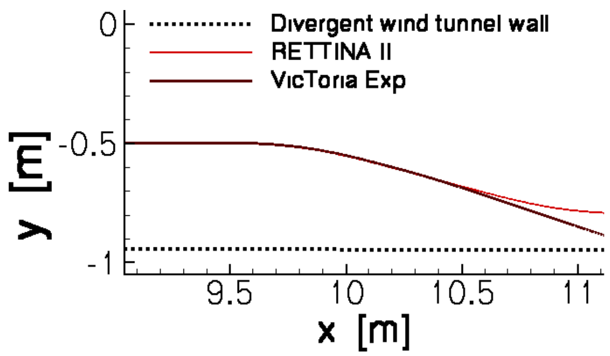

Fig. 1 – Left: Geometry for VicToria and RETTINA II experiment mounted to the wind tunnel wall in the AWM.

For a large-scale overview measurement, we used 8 cameras for a simultaneous 2D2C PIV measurement over a streamwise distance of more than 2m. The three most downstream located cameras provide a continuous measurement of the region where the flow approaches separation and the development of the separated shear layer. A 3D3C STB measurement was performed at two positions in the region just upstream of the separation line; STB with the multi-pulse approach was used at the more upstream position while a time-resolved approach was used at the more downstream position. The 3D3C measurements provide highly resolved data of the Reynolds stresses. The wall shear stress is determined by a fit of the STB data to the mean velocity profile by Nickels [3] in the region $y^+<20$ and by a fit to the DNS data at APG [4] for a similar value of Δp_x^+, see figure 2 (left). The underlying assumption is the existence of a universal wall law for $y^+<20$ which is parametrized by Δp_x^+ as proposed by [3], which is also indicated by the DNS data in [4]. In the future we plan to use oil film interferometry for the wall-shear stress during a repetition of the experiment.

Then we extend the work of [1], where we sensitize the SST model to adverse pressure gradients in attached boundary layers. The approach uses a square-root-law (sqrt-law) above the log-law, see figure 2 (left), and a variation of the slope parameter K in the log-law region as a function of Δp_x^+, see figure 2 (right). The APG sensitization of the ω-equation is applied here to the SSG/LRR-ω model. The calibration in [1] was based on data at mild APG. In the present work we use the new data at high values of Δp_x^+ to recalibrate the sensitivity terms when approaching separation, see figure 2 (right).

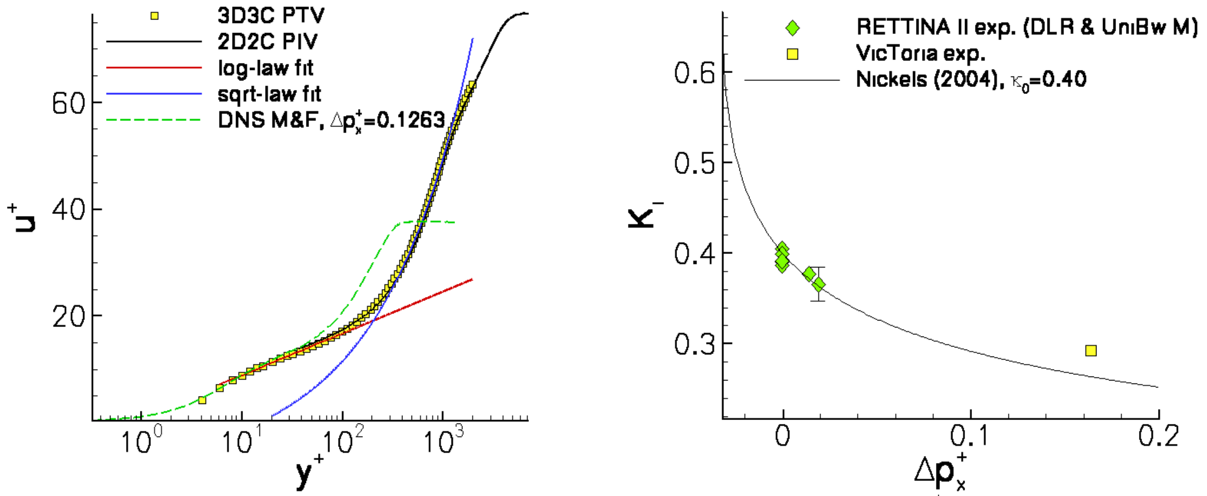

Fig. 2 – Left: Mean velocity in the APG region at U_{ref}=35m/s at a large value of Δp_x^+ =0.16 little upstream of incipient separation, including the DNS data by Manhart & Friedrich [4]. Right: Slope of the log-law fit for mild APG (RETTINA II exp.) and strong APG (VicToria exp.).

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References:

[1] Knopp, T.: „A new wall-law for adverse pressure gradient flows and modification of k-ω type turbulence models”. AIAA 2016-0588.

[2] Knopp, T., Reuther, N., Novara, M., Schülein, E., Schanz, D., Schröder, A., Kähler, J. C. “Investigation of a turbulent boundary layer flow at high Reynolds number using particle-imaging and implications for RANS modeling”. 10th International Symposium on Turbulence and Shear Flow Phenomena, 06.-09- Juli 2017, Chicago, USA, 2017.

[3] Nickels, T.B.: “Inner scaling for wall-bounded flows subject to large pressure gradients”, J. Fluid Mech., 521:217-239, 2004.

[4] Manhart, M. & Friedrich, R.: “DNS of a turbulent boundary layer with separation”, Int. J. Heat and Fluid Flow 23(5):572-581, 2002.

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