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CORRELATION BASED INLET BOUNDARY CONDITIONS FOR IMPROVED TURBULENCE AND TRANSITION PREDICTION IN TURBOMACHINERY FLOWS

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Laminar-turbulent transition plays a significant role in the boundary layer development of modern highly-loaded low-pressure turbine (LPT) profiles, and to a smaller degree for compressor profiles. The significance is even accentuated due to the drop of Reynolds numbers at high flight altitudes, that means at cruise conditions. Some turbine profiles operate at Reynolds numbers as low as $Re_{2th} \leq 1.0 \cdot 10^5$, showing a large laminar boundary layer patch with subsequent separation and turbulent reattachment, cf. Mayle [1] and Hourmouziadis [2]. This transition process is influenced by many parameters, e.g. turbulence intensity, Reynolds number, pressure gradient, etc.. Most transition models capture this influence by taking the corresponding parameters into account, in one way or another. In the present framework, the influence of the turbulence length scale (l_T) is also indirectly captured by the turbulence decay behaviour of the turbulence model. Depending on the prescribed turbulence length scale at the inflow boundary, different dissipation rates will arise, with significantly altered decay of turbulence intensity. This leads to a shift in transition prediction, since the transition model is coupled to the turbulence intensity, cf. for example Bode et al. [7], Babajee and Arts [8] and Moore and Moore [9]. Turbomachinery flows are very prone to this effect, due to high turbulence levels and corresponding sensitivity to dissipation rate (or length scale) prescription. As many experiments do not provide the turbulence length scale, the CFD users feel free to choose a value, often one that best fits the experimental data. Hence, an empirical correlation based on experimental data for estimation of the turbulence length scale at the inflow boundary is derived and presented (cf. Figure 1). This estimation yields reasonable turbulence decay, supporting the transition model in accurately predicting the laminar-turbulent transition location (cf. Figure 2) and development and also the turbulence model in accurately predicting the turbulence intensity (turbulent kinetic energy) in the boundary layer and freestream. As an additional element of the approach, the sensitivity of the turbulence model to free-stream values is suppressed by limiting the eddy viscosity in non-viscous regions. Therefore an approch is developed and presented to fullfill the realizabitiy constraint.

In this work, the combination of the k-ω turbulence model by Wilcox [3] and the γ-Re_θ transition model by Langtry and Menter [4] is applied. This transition model is developed and validated for several generic and turbomachinery testcases, cf. Langtry and Menter [4]. The turbulence model is modified to capture the streamline curvature effects (cf. Kožulović and Röber [5]) and to avoid excessive shear stress levels by implementing an upper limit of the turbulent shear stress in boundary layers (cf. Menter [6]). The improved model is tested and validated against generic and turbomachinery test cases.

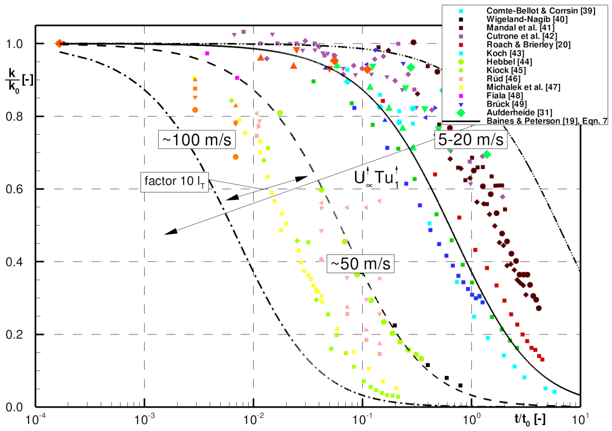

Figure 1: Turbulence decay for several experiments

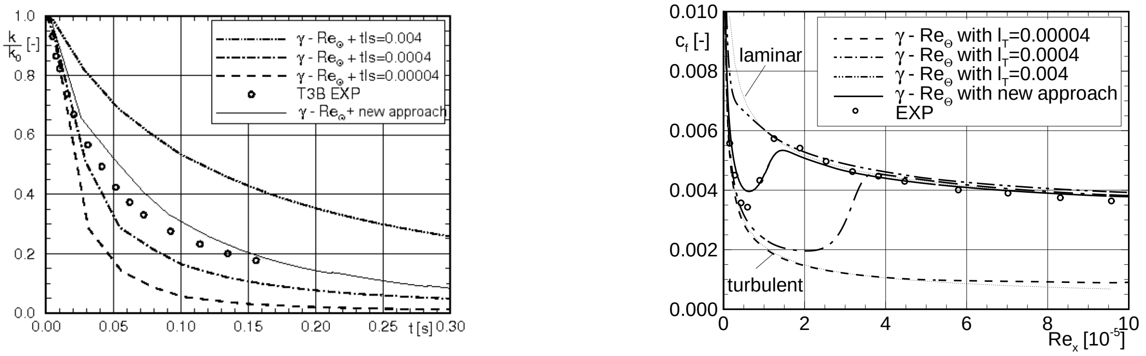

Figure 2: Turbulent decay and boundary layer behaviour of T3B flat plate

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