MODELLING AND ANALYSIS OF THE LAMINAR TO TURBULENT TRANSITION IN A LOW-PRESSURE TURBINE

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The current generation of civil aircraft engine design is characterized by high by-pass-ratio (10:1). In that case, one speaks about very large turbo fan engines where the main thrust is provided by the fan driven by the Low Pressure Turbine (LPT). This design implies an increase of the fan diameter and a decrease of the rotational speed of the driving shaft. The other design challenging issue concerns the weight reduction of the LPT. This component represents about 30% of the overall weight of the engine. Reducing the weight means diminishing the number of LPT blades. Consequently, this suggests that the loading per blade should be increased to meet the overall loading of the stage. The solution is to increase the aft diffusion on the new blade design and/or move further upstream the peak velocity.

The LPT blade flow might be prone to separation and in the worst cases to open separation due to the combination of the low Reynolds number working conditions, encountered during cruise, and the large aft diffusion that the LPT blades experience. This results in high losses and performance deterioration.

The purpose of this thesis is to analyse the laminar to turbulent transition mechanisms occurring in new LPT designs. To tackle this topic, one will focus on the assessment and the validation of the Langtry and Menter γ-$Re_{\theta t}$ correlation-based transition model, recently implemented in the RANS code elsA from ONERA. Two LPT rotor blades with the same compressible Zweifel loading coefficient but different load distributions are tested. The corresponding experimental results are provided by the von Karman Institute. The outlet isentropic Reynolds number ($Re_{2,is}$), based on blade chord and outlet isentropic velocity, ranges from 60000 to 250000 in order to investigate the complex separation-induced transition phenomenon occurring at low $Re_{2,is}$ cruise condition. The turbulence intensity is taken as the natural freestream turbulence of the facility (0.9%). The numerical test campaign gives good predictions, particularly when accurately tailoring the trailing edge and wake regions of the mesh. The numerical mass-averaged kinetic losses are in good agreement with the experimental ones. Moreover, the flow topology parameters (the transition onset, the transition end and the separation) show good agreement in comparison to the experimental results and correlations from the open literature. One is even able to detect separation-induced transition with reattachment before the trailing edge at the lowest $Re_{2,is}$. However, one stresses the turbulence Reynolds number (Re_t=(ρ.k)/(μ.ω)) effect on the prediction of separation-induced transition for strong diffusion LPT blades such as the T106C. Figure 1 illustrates this aspect by highlighting the viscosity ratio (μ_t/μ) contours coupled with the bubble streamtraces for Re_t=0.01 and Re_t=6.67 (which corresponds to the facility decay of turbulence). In addition, the isentropic Mach number (M_{is}) distributions are illustrated to point out this Re_t dependency.

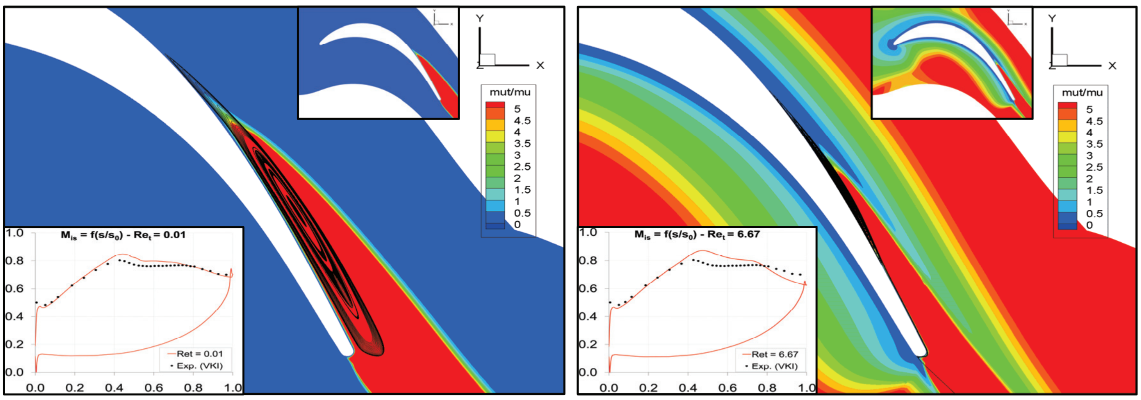

Figure 1: μ_t/μ contours and M_{is} distributions of T106C at $Re_{2,is}$=80000, $M_{2,is}$=0.65 and Tu=0.9% with the bubble streamtraces for Re_t=0.01 (left) and Re_t=6.67 (right)