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ASSESSMENT OF LAMINAR-TURBULENT TRANSITION MODELLING FOR ROTATING WING APPLICATIONS

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INTRODUCTION

Flows involved in industrial applications may sometimes exhibit large laminar regions which significantly affect the aerodynamics performance. In order to accurately simulate this kind of flows, the turbulence models need to be corrected by means of either empirical and theoretical criteria [1] or transport equations of new variables [2]. These two different methods of transition modelling have been assessed for several rotating wing applications where transition is expected to have a significant effect. The conclusions of these numerical studies are presented in this paper. For helicopter application, the effect of transition modelling has been investigated for a rotor in hover conditions and for the dynamic stall of 2D airfoil under pitch oscillations. In turbomachinery application, a high-lift low-pressure turbine is considered. At last, the influence of transition is numerically investigated for a contra-rotating open rotor application.

HELICOPTER APPLICATION

Rotor performance in hovering flight is mostly underestimated by numerical simulations, mainly because laminar regions on the lower side of the blades are not taken into account with fully turbulent simulations. The capabilities of transition methods based on criteria [1] and γ-Re_θ transport equations [2] have been evaluated and compared to fully turbulent simulations in order to quantify the effect of laminarity on the rotor performance. Results of the two transition prediction methodologies are in good agreement and give a rotor performance enhancement of 2.4 points compared to the fully turbulent results (Figure 1).

In the context of helicopter aerodynamics, transition modelling methods have also been applied to the dynamic stall of pitch oscillating airfoil. Simulations based on transition criteria and γ-Re_θ model have been investigated and compared to fully turbulent simulations and experimental data. Results show a noticeable improvement of the stall prediction although the discrepancy with experiments is still significant (Figure 2).

TURBOMACHINE APPLICATION

At altitude cruise conditions, the Low Pressure Turbine (LPT) of modern bypass turbofan engines works at relative low Reynolds numbers, which result in a laminar boundary layer forming on the suction side of the blades. The γ-Re_θ transition modelling has been applied to simulate the flow around the T106C blade [3]. The flow is characterized by a separated flow region which expands as the Reynolds number decreases. This separation is visible on the plateau region of the isentropic Mach number (Mis) distributions represented in Figure 3. The experimental data and the numerical results are in very good agreement, except for the lowest

Reynolds number case, where the bursting of the separation bubble is not well captured by the simulation.

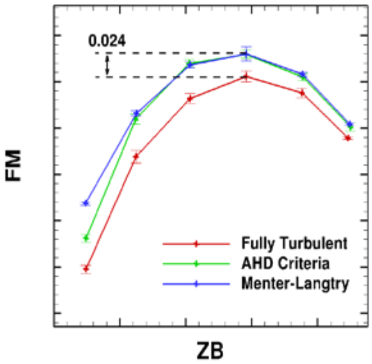


Figure 1: Figure of Merit (FM) as a function of the thrust coefficient ZB (EC1 rotor in hovering flight).

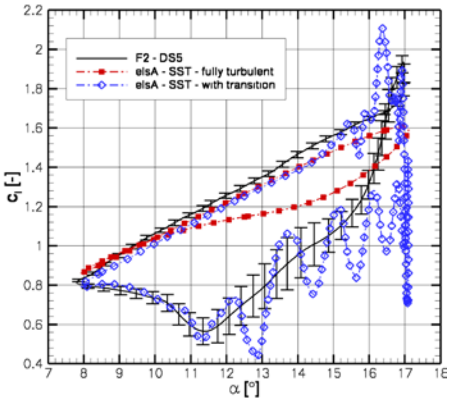
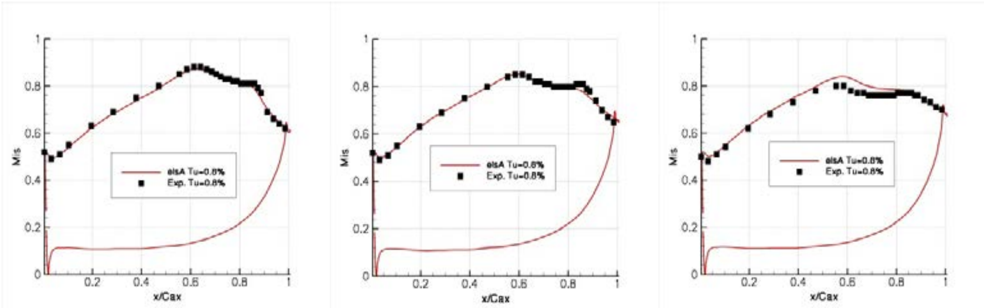


Figure 2: Lift coefficient Cl as a function of the angle of attack (pitch oscillating OA209 airfoil)



(a) Re2is=160 000 (b) Re2is=100 000 (b) Re2is=80 000

Figure 3 : Comparison between experimental and numerical values of Mis for the T106C cascade.

OPEN ROTOR APPLICATION

The γ-Re_θ transition model has been applied to the chorochronic simulations of the Airbus Clean Sky generic open rotor configuration, in both low-speed and high-speed conditions. Results are compared to fully turbulent simulations of the same configurations in order to highlight the effect of transition. For low speed conditions, transition has no significant influence on the thrust of the front propeller, while it slightly reduces the thrust on the rear one. A small benefit effect is also observed on the efficiency on the front propeller. For high speed conditions, the influence of transition is much more noticeable on both thrust and efficiency, mainly because of large laminar regions on the front blade. This also leads to a lower momentum deficit in the wake of the front blade. The interaction noise is thus reduced, as shown by the acoustic analysis.

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