AERODYNAMICS OF LOW PRESSURE TURBINE BLADES

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The actual aero-engine design is oriented toward a reduction of the blade count in low pressure (LP) turbines, in order to save weight and to lower manufacturing and operating costs for modern jet engines. This trend implies an increase of the aerodynamic load on each single blade and led to the development of very-high-lift airfoils, characterised by a higher velocity peak on the suction side followed by a relevant diffusion. The resulting strong adverse pressure gradient may induce boundary layer separation, particularly during high altitude cruise flight, when Reynolds number in LP turbines usually ranges between 4x104 and 5x105 and transition of the boundary layer is delayed until the diffusing rear part of the suction side. Since this may lead to very high losses, it is of primary importance to analyse the evolution of the separation bubble with the flow conditions, evaluating how it affects the blade performance.

This project deals with the experimental investigation of the boundary layer development on the suction side of the T106 very-high-lift, mid-loaded, LP turbine blade. Focus is posed on how the Reynolds number and the freestream turbulence intensity affect transition and separation. The main goal is to provide a prediction model for the evolution of the separation bubble in function of the flow parameters, identifying bursting conditions for which the bubble passes from short to long causing a strong increase of the losses.

The experimental measurement campaign was carried out in the VKI S-1/C high-speed, closed-loop, variable density cascade wind tunnel, which allows to set up the flow regime varying the Reynolds number independently of the Mach number. Tests were performed at low density for a constant highly subsonic Mach number, ranging the Reynolds number between 80000 and 160000 to match the typical flow conditions found in real engines during high altitude flight. A static grid, placed in different positions upstream of the cascade, was used as passive turbulence generator to obtain different values for the freestream turbulence intensity.

Suction side measurements were performed by means of two alternative instrumented blades: one provided with pressure taps, to acquire the pressure distribution, the other with an array of surface-mounted hot-films, used to investigate the wall shear stress evolution. The inlet flow angle was measured traversing a 3-hole probe in pitchwise direction, while the outlet flow angle and the kinetic losses were acquired traversing a 5-hole probe downstream of the cascade. A single hot-wire anemometer was employed to evaluate the freestream turbulence intensity generated by the grid.

The different sets of acquired data allowed to evaluate the main features of the separation bubble and to locate the onset of transition. Bubble bursting conditions were identified and elaborated into a prediction model. Correlations to predict bubble characteristics in function of the flow parameters were also obtained, showing a good agreement with results found in literature. This work constitutes an improvement over previous studies, since it takes into account the effect of the freestream turbulence intensity and presents a better reliability, resulting from the comparison between a large amount of data acquired with different measurement techniques.

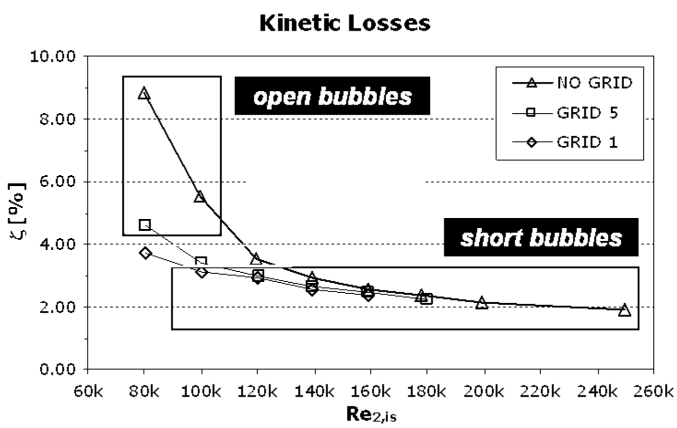

Figure 1: Left: kinetic losses against Reynolds number and classification for the separation bubbles
Right: VKI S1/C cascade wind tunnel test section: T106 linear cascade and turbulence generator grid