UNSTEADY WAKE-BOUNDARY LAYER INTERACTION ON ADVANCED HIGH LIFT LOW PRESSURE TURBINE AIRFOILS

Thomas Coton, Belgium
Supervisor: Prof. T. Arts
Promoter: Prof. 0. Leonard (ULg)

High lift profiles constitute the new trend for the low pressure (LP) turbines design as they allow substantial reduction of costs and weight. Given the importance of the LP turbine efficiency for the engine performance, the suction surface boundary layer characteristics must be carefully assessed. Indeed, it is submitted to stronger diffusion and a resulting laminar separation could compromise the reliability of the concept. However, the wakes shed by the upstream blade-row constitute an effective tool to maintain the losses at an acceptable level as shown by Howell et al., Brunner et al. or Schulte & Hodson.

In spite of the huge research efforts already made, a full comprehension of the unsteady transition phenomena is not yet achieved. The designers can hardly consider the wake-induced transition in a very practical way. Numerical predictions of transitional or separated flows suffer from the lack of quantitative databases while their validation is still mainly grounded on HP profile data (e.g. Steelant & Dick or Pecnik et al.). Moreover, the related experimental investigations generally do not reproduce all the working conditions (mainly compressibility, flow coefficient and freestream turbulence) of the LP turbines.

The objective of the present contribution is precisely to provide a reliable and quantitative test case for this environment. A very high lift profile (g/c=1.05 and theoretical load coefficient ~ 1.6) has been designed. Experiments have been performed at an exit Mach number of 0.7, for two Reynolds numbers (130,000 and 300,000) and for two inlet turbulence levels (0.8 and 3.5 %). A rotating disk wake generator type allowed to reproduce correctly the dynamics of the wakes. These were created by cylindrical bars of 1.5 or 2 mm diameter (figure 1). The measurements provide principally the airfoil performance and the boundary layer status via the unsteady wall heat flux (by means of thin film gages).

The positive effect of the wakes by suppressing the separation bubble can lead to a reduction of the profile loss coefficient by more than 35 % (figure 2). The mean heat transfer distributions confirmed the wake impact and showed the change of the predominant transition mode from separation to bypass. The high resolution of the heat transfer signals allowed to follow the wake events in space-time diagrams illustrating the path of the diverse induced phenomena. The intermittency factor has been computed by an adapted conditional sampling technique. In presence of passing wakes, the existing models failed to reproduced the intermittency evolution. They have been considerably improved by considering the effect of the velocity gradient on the wake disturbances.

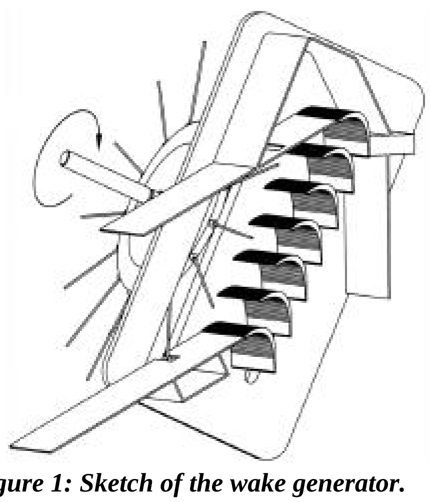

Figure 1: Sketch of the wake generator.

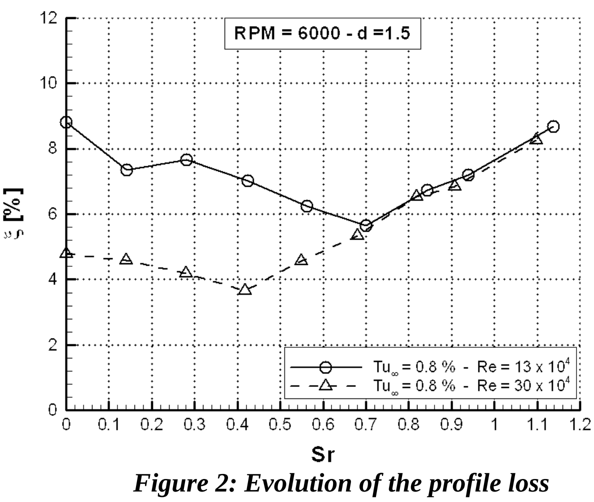

Figure 2: Evolution of the profile loss coefficient as a function of the Strouhal number.