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Prediction of the transitional flow of turbine blades with DDES and LES

***Franco Magagnato[1] and Martin Gabi[2]**

[1] FSM,University of Karlsruhe
Karlsruhe, Germany,
magagnato@ism.uka.de
www.ism.uni-karlsruhe.de

[2] FSM, University of Karlsruhe
Karlsruhe, Germany,
gabi@ism.uka.de
www.ism.uni-karlsruhe.de

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ABSTRACT

The prediction of the laminar to turbulence transition is essential in the calculation of turbine blades, compressor blades or airfoils of airplanes since a non negligible part of the flow field is laminar or transitional. In this paper we compare the prediction capability of the Delayed Detached Eddy Simulation (DDES) with the Large Eddy Simulation (LES) when applied to the calculation of transitional flows on turbine blades. Detailed measurements from Canepa et al. of the well known VKI-turbine blade served to compare our results with the experiments. The calculations have been made on a fraction of the blade (20%) using non-reflective boundary conditions of Freund at the inlet and outlet plane in combination with the Synthetic Eddy Method (SEM) proposed by Jarrin et al.. The calculations have been conducted with 10^6 grid points with a resolution of $y^+<1$, $x^+\approx 20$ and $z^+\approx15$ at the suction side. The LES using the dynamical Smagorinsky model and the MILES approach both predict a satisfactory transition location. In fact Canepa et al. found for the Re-Number = 590 000 that transition starts at tr_{st}=0.5 and ends at tr_{end}=0.6 while the computation with the Dynamical Smagorinsky model gave tr_{st}=0.5 and tr_{end}=0.56 and the MILES approach slightly shift the transition onset upstream to tr_{st}=0.48 and tr_{end}=0.53. In contrast to the relatively poor agreement of the LES with experiments with respect to velocity profiles and turbulent stresses published at the first DESider conference [1] the agreement is now considerably better as can be seen on figure 1. This is mainly due to the non-reflecting boundary conditions applied both at inlet and outlet plane.

With reflecting BC's pressure waves generated at the trailing edge moves up and down the calculation domain and are unrealistically reflected at the boundaries. This in turn interacts with the boundary layer in the rear part of the blade. For the DDES the improved Spalart/Allmaras model has been used. The results obtained on a coarse mesh with DDES showed that the three-dimensional structures at the suction side as well as the trailing edge are somewhat suppressed as expected by the high value of eddy viscosity level predicted by the model in the boundary layer. The prediction of the boundary layer characteristics have been found do agree quit well with the experimental findings. But for a good prediction a correct transition location is necessary. In our case the Abu-Ghanam and Shaw correlation was used for the DDES. On figure 2 the velocity distribution is shown. The agreement is surprisingly good. Even the insipient separation around the transition location is predicted. It appears that the prediction of transitional flows which prevails in modern turbine blade design is a little better predicted by LES than DDES. But the surprisingly good prediction of the DDES, in combination with a transition model or correlation, is very encouraging.

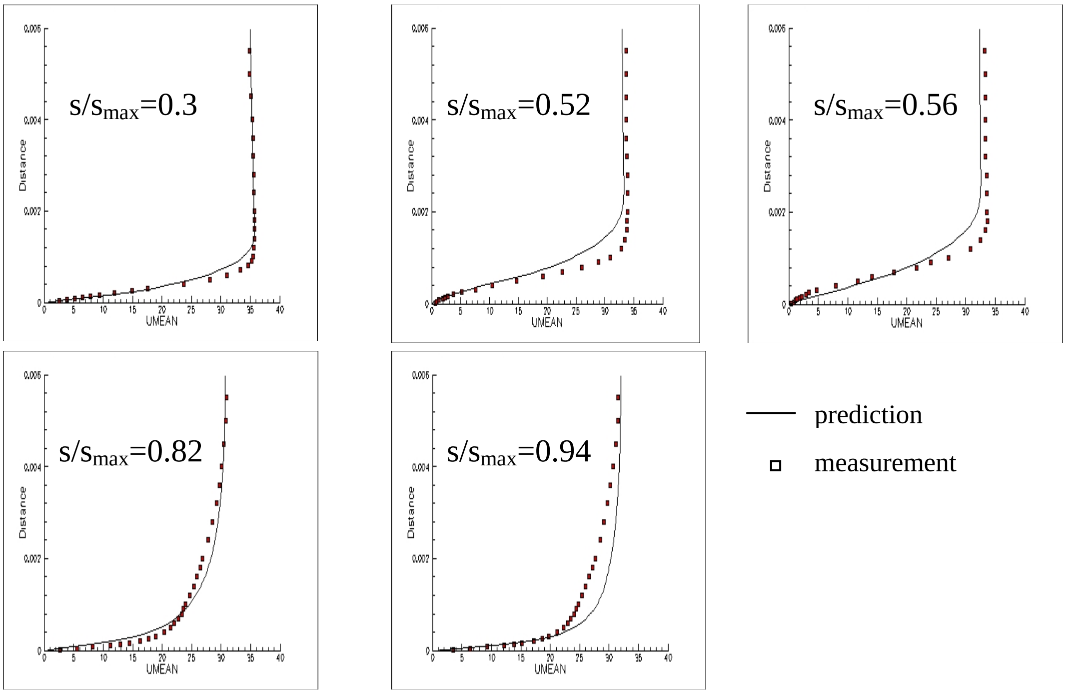

Figure 1:Velocity profiles at different stations calculated with DDES

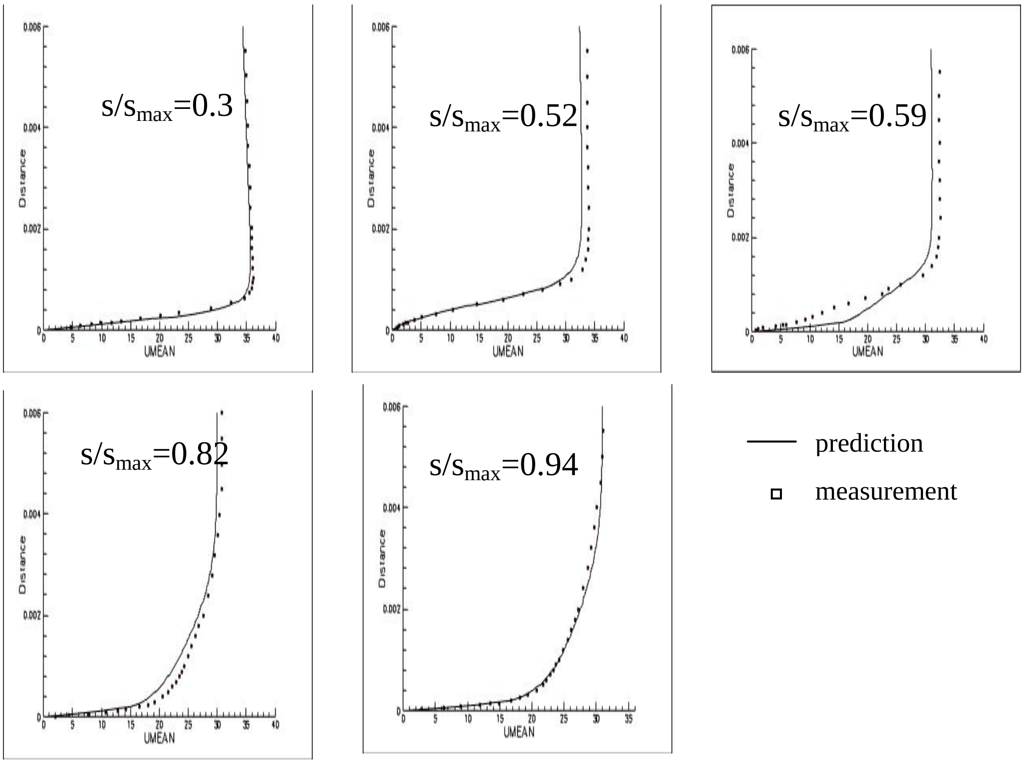

Figure 2: Velocity profiles at different stations calculated with LES

REFERENCES

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