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An integral boundary layer method for modelling the effects of vortex generators

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In this work, the measured modulated integral boundary layer (IBL) characteristics of low-profile vortex generators (VGs) are used to validate new developments in a viscous-inviscid interaction code which is modified to incorporate the effect of the passive mixing devices. The motivations are laid out and sample validation data is presented within this abstract.

I. PROBLEM STATEMENT

An imperative part of every wind turbine design process concerns the integrated design of the airfoil/blade sections. Despite the increased use of Computational Fluid Dynamics (CFD) for airfoil performance evaluation, the cost of capturing the influence of blade add-ons remains prohibitively high. A more efficient, robust approach is thus sought using an integral boundary layer approach.

II. BACKGROUND

In recent years, increased experimental research has shed light on the flow physics of vortex generators i.e. the interplay between the stream-wise vortices and the encompassing boundary layer. Modelling work has been mainly limited to the modification of CFD based codes to incorporate the effect of VGs. However, recent findings by Velte et al. [1,2], also seen in Baldacchino et al. [3] show that embedded stream-wise vortices may exhibit useful analytical and self-symmetric properties, as shown in Fig. 1. It remains to be seen though how these new physical insights can be coupled with existing numerical codes or formulated in such a fashion so as to practically improve airfoil design codes and routines.

III. METHODS

An initial approach is to modify the formulation of the turbulent shear stress production at the location of the VG trailing edges in the boundary layer formulation, according to

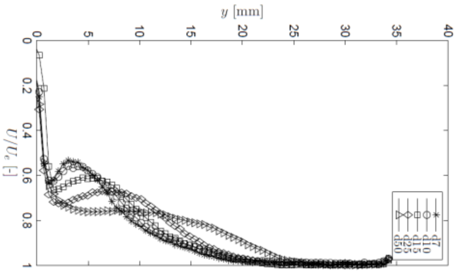

Fig. 1 Typical wake-like axial velocity profiles downstream of the VG, extracted from the span-wise location of the vortex core position

$$\tau_{vg} = \begin{cases} 0, & \forall\, x < x_{vg} \\ A.\,exp^{-\sigma(x-x_{vg})}, & \forall\, x > x_{vg} \end{cases}, \tag{1}$$

indirectly capturing the presence of the VG. A second approach seeks new scaling laws for actuated boundary layer profiles. For this, high resolution Particle Image Velocimetry measurements performed in [3] for low profile VGs are used. This data will be partially used to validate the implemented code modifications. Sample results for the controlled axial velocity profiles are shown in Fig. 1 and the 3D nature of the boundary layer development is shown in Fig. 2.

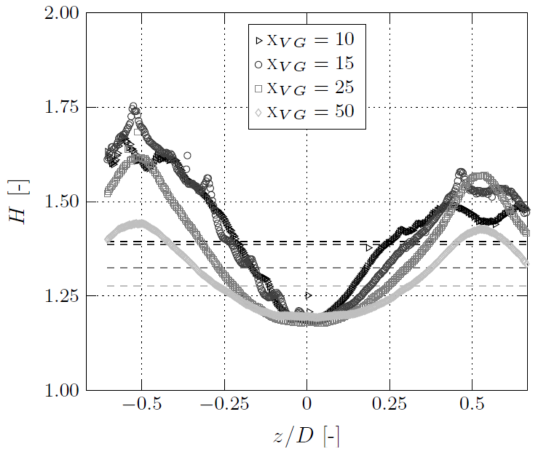

Fig. 2 Span-wise variation of the actuated boundary layer shape factor over a VG-pair span at four different streamwise locations.

IV. CONCLUSIONS AND NEXT STEPS

The final paper and presentation will discuss results comparing the newly implemented modelling scheme in the in-house RFOIL code, compared with current flat plate experimental data. Comparisons will also be made with the DU-range of wind turbine airfoils sporting vortex generators, which have been measured in previous experimental campaigns at the TU Delft low turbulence wind tunnel [4].

ACKNOWLEDGEMENTS

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