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MODELLING OF CROSSFLOW-INDUCED TRANSITION BASED ON LOCAL VARIABLES

Christoph Müller[1] and Florian Herbst[1]

[1]Institute of Turbomachinery and Fluid Dynamics
Leibniz Universität Hannover
Appelstraße 9, D-30167 Hannover, Germany
mueller@tfd.uni-hannover.de

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ABSTRACT

The turbulent breakdown of three-dimensional crossflow boundary layers is modelled in the CFD code TRACE. For this purpose, the γ-Re_θ- transition model by Langtry and Menter [1] is used and extended by an additional term in order to destabilize the boundary layer. An important feature of the γ-Re_θ- transition model is that only local variables are used to trigger transition.

Based on three local characteristic parameters a destruction term P_{CF} was formulated which respects effects of the crossflow intensity and leads to a destabilization of the boundary layer, where a non dimensional form of the local helicity $H = |u_i \cdot \omega_i|$ is used to quantify the intensity of the crossflow. As shown in Fig. 1, an increase of the Reynolds number on a 45° swept NLF (2)-0415 profile leads to a higher value of P_{CF}. In this figure P_{CF} has been integrated perpendicular to the surface of the NLF (2)-0415 profile, weighted with the parameter $F_{\theta t}$ that is only present in the boundary layer. In addition to this, the ONERA 'D' profile was used in order to calibrate the model on a testcase with a constant Reynolds number under varying sweep angles.

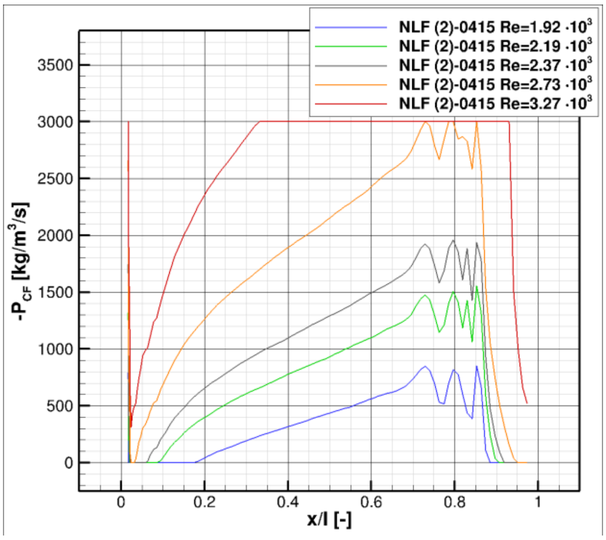


Figure 1: Integrated values of the destruction term along the chord length; different sweep angles are plotted

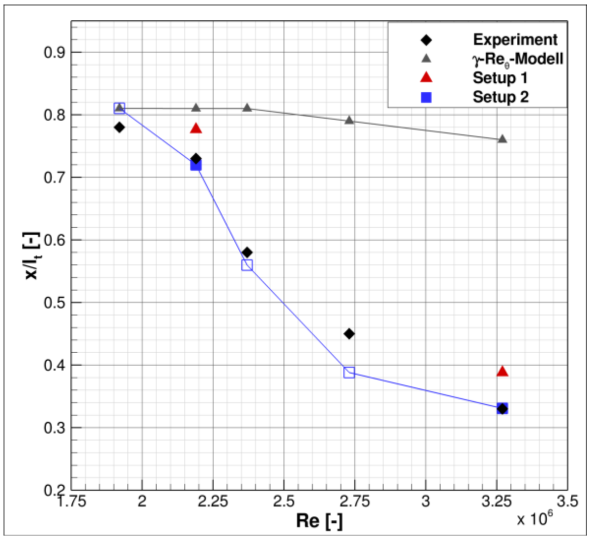
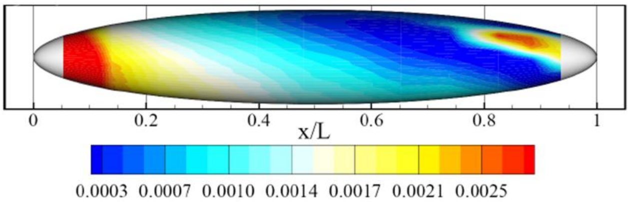


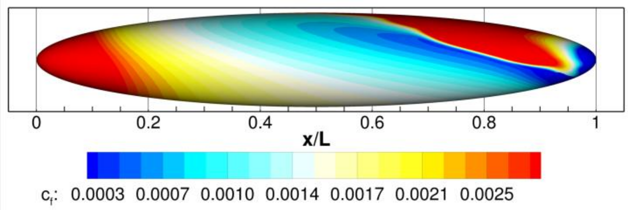
Figure 2: Transition positions on the NLF (2)-0415 profile; comparison of experimental and numerical results

As a result, the model shows good performance on the NLF (2)-0415 profile, which has been experimentally investigated by Dragenhart and Saric [2] (Fig. 2). In this figure two setups with different calibration constants are presented. The filled symbols represent Reynolds numbers which had been used within the calibration. In addition, the baseline γ-Re_θ-transition model is presented, which is not able to detect the present crossflow.

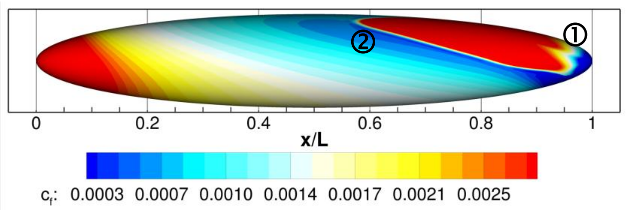
As the crossflow model is based on local quantities, this model supports the transition modelling on complex three-dimensional geometries, such as a spheroid presented by Kreplin et al. [3] (Fig. 3), which has been used for validation. There are still major differences between the experimental and numerical results, originating from the separation induced transition mode in the baseline model (Fig. 3 (a) and (b)). Besides this, the modified model shows an impact in regions ① and ② in Fig. 3 (c) where an intensive crossflow is present. Therefore, the authors consider this work as a promising approach for a robust and universal way of modelling three-dimensional boundary layers. This is due to the model formulation, which is based on physical quantities and its high variability in the calibration, using six calibration constants.



(a) experimental results; Kreplin et al. [3]; published in Seyfert and Krumbein [4]



(b) numerical results; baseline model



(c) numerical results; modified model

Figure 3: Comparison of experimental and numerical results on a 6:1 spheroid; $Re = 1.5 \cdot 10^6$; $\alpha = 5°$

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