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NUMERICAL SIMULATION OF TRANSITIONAL FLOWS WITH LAMINAR KINETIC ENERGY

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Abstract: *The article deals with the numerical solution of transitional flows. The single point k-k_L-ω model of Walters and Cokljat (2008) based on the use of a laminar kinetic energy transport equation is considered. The model doesn't require to evaluate integral boundary layer parameters (e.g. boundary layer thickness) an is therefore suitable for implementation into codes working with general unstructured meshes. The performance of the model has been tested for the case of flows over a flat plate with zero and non-zero pressure gradients. The results obtained with our implementation of the model are compared to the experimental data of ERCOFTAC.*

Keywords: ***Turbulence, transition, Navier–Stokes equations***

1. Introduction

The laminar-turbulent transition plays very important role in many flows of engineering interest. It has big impact on the heat transfer and losses. Unfortunately most of the state-of art turbulence models (e.g. Menters SST $k-\omega$ model, EARSM model of Hellsten) completely fail with the prediction of transition. However there are some attempts to modify basic models (e.g. low Reynold model of Wilcox (1998), TSL model of Zheng et al. (1998)) with promissing results, the experience shows that this approach is not capable of reliably capturing all factors that affect transition, see Menter et al. (2006).

The algebraic models based on empirical correlations (see e,g, Straka and Příhoda (2010)) offers simple approach with sufficient accuracy. On the other hand the implementation into a general unstructured code is quite difficult due to necessity of some non-local informations (momentum boundary layer thickness, intermitency at wall, etc.). Therefore the applicability of these models is moreless limited to research/academic codes using structured meshes.

This article deals with the RANS-based transitional model developed by Walters and Leylek (2004) and Walters and Cokljat (2008). The three-equation model is based on the low Reynolds $k-\omega$ model with an equation for the so called laminar kinetic energy k_L expressing the energy of streamwise fluctuations in pre-transitional region.

2. Mathematical model and numerical method

However the goal is to implement the transitional model of Walters and Cokljat (2008) into in-house finite-volume code, we chose to test the model with the help of OpenFOAM package. However the current version of OpenFOAM 2.1.0 already includes $k-k_L-\omega$ model for incompressible flows, the implementation fails to predict friction coefficient in turbulent part of the boundary layer (see fig. 1). Therefore we develop own implementation of the model with some corrections.

We assume compressible flows given by the set of Favre averaged Navier–Stokes equations extended by three-equation $k-k_L-\omega$ model based on Walters and Cokljat (2008). The solution is obtained with the finite volume method using segregated SIMPLEC scheme (see eg. Ferziger and Perić (1999)).

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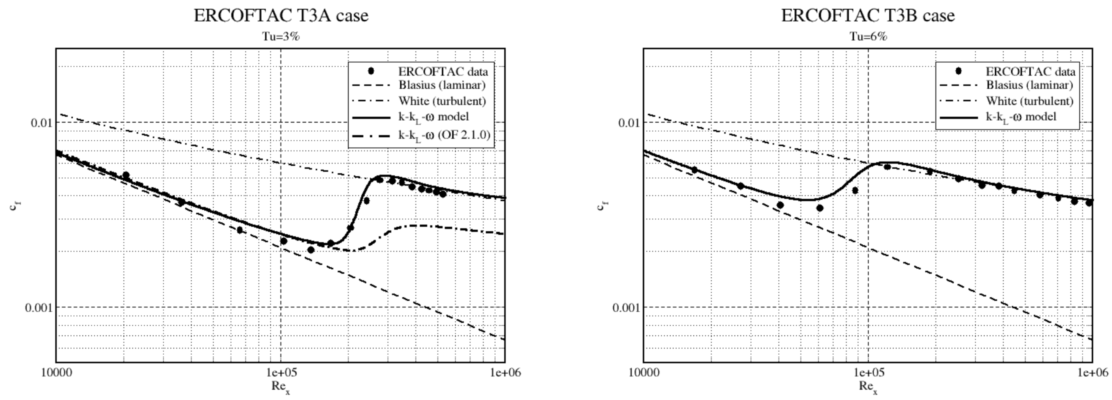

Fig. 1: Friction coefficient for zero pressure gradient flat plate flows.

3. Simulation of flows over a flat plate

The model has been validated using T3 series of experimental flat plate test cases of ERCOFTAC. The T3A, T3B, and T3A- test cases had zero streamwise pressure gradients with freestream turbulence of 3%, 6%, and 1% respectively. The T3C2 has favourable pressure gradient in the first part of the plate followed by the adverse pressure gradient in the second part. The figure 1 shows comparison of computed skin friction for T3A and T3B case with the experimental data of ERCOFTAC. One can see that the ready-made implementation of the model (labeled by OF 2.1.0 at the figure) fails even with T3A case. On the other hand our implementation gives good agreement with experimental data form ERCOFTAC database.

4. Conclusion

The results indicate that the model of Walters and Cokljat (2008) is able (after minor modifications) to predict the laminar-turbulent transition for simple flows over flat plate. Future work will be oriented to the implementation of the model to in-house code.

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