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Laminar-Turbulent Transition Modelling based on a New Intermittency Model Formulation

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ABSTRACT

The importance of accounting for the effect of laminar-turbulent transition in the simulations of aerodynamic and turbomachinery devices, like wings and blades, has in recent years become increasingly accepted. While a range of modelling approaches has been developed for external aerodynamic flows (see e.g. [1]) such methods require a relatively sophisticated code infrastructure and are therefore not easily adapted to general purpose CFD codes. In addition, methods based on stability theory are not suitable for the prediction of bypass transition, as present in many industrial devices, especially in turbo-machinery applications. It was therefore recognized that the existing RANS models need to be extended in order to enable them for inclusion of the effect of transition. In recent years, significant effort has been invested into the formulation of such models. The first authors group has proposed a concept termed 'Local-Correlation-Based Transition Modelling' (LCTM) and developed a 2-equation γ-Re_θ model within this framework [2-5]. The concept is based on the idea of developing a transport equation-based framework which is able to predict transition locations using empirical correlations, instead of attempting to model directly the physics of the transition process. The LCTM approach has the advantage that any transition process for which empirical data are available can be included into the system. The γ-Re_θ model has found wide-spread acceptance and is now implemented in a range of industrial and research CFD codes.

The authors recognized that there is potential for simplification and improvement of the first version of the γ-Re_θ model. The main areas considered were:

- Reduction of the γ-Re_θ model to a single equation for the intermittency γ.
- Simplified empirical correlations for easier fine-tuning.
- Galilean invariant formulation.
- Inclusion of Crossflow instability mechanism.

Based on these goals, a new LCTM model has been developed. It only solves one equation for the intermittency γ and is again based strictly on local variables. In addition, it avoids the usage of the absolute value of the velocity as used in the γ-Re_θ model – making the formulation Galilean invariant. Significant effort was invested in ensuring a simple formulation with a limited number of user accessible constants, which allow the fine-tuning of

the model for specific applications. Finally, an additional indicator was developed, which allows the detection of crossflow instabilities and allows its connection to the Arnal C1-criterion.

The presentation will give the basic motivation for the new model development and will also discuss the model formulation in relation to alternative concepts. Numerous test cases will be shown, demonstrating the models generality and flexibility with respect to user fine-tuning. Finally, examples for the prediction of crossflow instabilities will be given.

It is to be emphasized that not all elements of the new formulation are published and that only the general concept, but not the detailed formulation can be provided in the presentation.

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