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AN EXTENSION AND FURTHER VALIDATION OF THE PANS METHOD IN INDUSTRIALLY RELEVANT FLOWS

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The paper presents an extension of a turbulence modelling concept in AVL FIRE [1] previously reported in Basara [2]. This concept is based on the bridging closure model which varies seamlessly between the Reynolds-averaged Navier–Stokes (RANS) model and direct numerical simulation (DNS). Depending on the criterion used, this approach can provide RANS or DNS results or any results between RANS and DNS. Two of the most developed bridging methods are the partially integrated transport model (PITM) and partially averaged Navier–Stokes (PANS) model. The PITM closure derivation is based on energy spectrum decomposition and the PANS model is obtained from a parent RANS closure by applying the averaging-invariance principle. Probably, the most attractive bridging method is the Partially-Averaged Navier-Stokes (PANS) formulated by Girimaji [3-4]. The PANS model is used in the industry more than other seamless methods due to its simplicity, robustness and recent theoretical extensions as well as due to the detailed validations on the number of complex cases presented in many publications. We use the PANS variant (Basara et al. [5]) derived from the four equation near-wall eddy viscosity transport model, namely k-ε-ζ-f turbulence model (Hanjalić et al. [6]). As this model represents a practical and accurate RANS choice for a wide range of industrial applications, especially when used in conjunction with the universal wall functions, it's PANS variant therefore guarantees that the proper near-wall model is used when the resolution parameter is of a higher value. The key point in this approach is how to define and calculate the resolution parameter which can be placed in any part of the spectrum including the dissipation range as shown in earlier studies. In the practice, this parameter which determines the unresolved-to-total kinetic energy ratio is defined by using the grid spacing and calculated integral length scale of turbulence. When the grid size is smaller, then more of the turbulent kinetic energy can be resolved. There are different ways to define the resolution parameter and the work presented here will validate three different approaches as this is a crucial point to get the best PANS method's performance. In the first and already well-established approach for the PANS, the integral scale of turbulence is obtained by summing up resolved turbulence, calculated as difference between instantaneous filtered velocity and the averaged velocity field, and unresolved turbulence obtained from its own equation. This paper will analyse results obtained with two different formulas for the resolution parameter. Additionally, the paper will validate the recent proposal of Basara and Girimaji [7] which is based on a modelled equation for the resolved kinetic energy. This new approach allows simple and accurate calculations of the cases with moving geometries where calculations of averaged velocity fields and with that also a resolved turbulence field would be too costly. Figure (1) shows a very challenging engine application as calculated with the latest PANS developments and the full paper will show advantages and disadvantages of different methods used for the prediction of the parameter which determines the unresolved-to-total kinetic energy ratio. The paper will present a variety of test cases, from simple flow benchmarks to complex industrial flows.

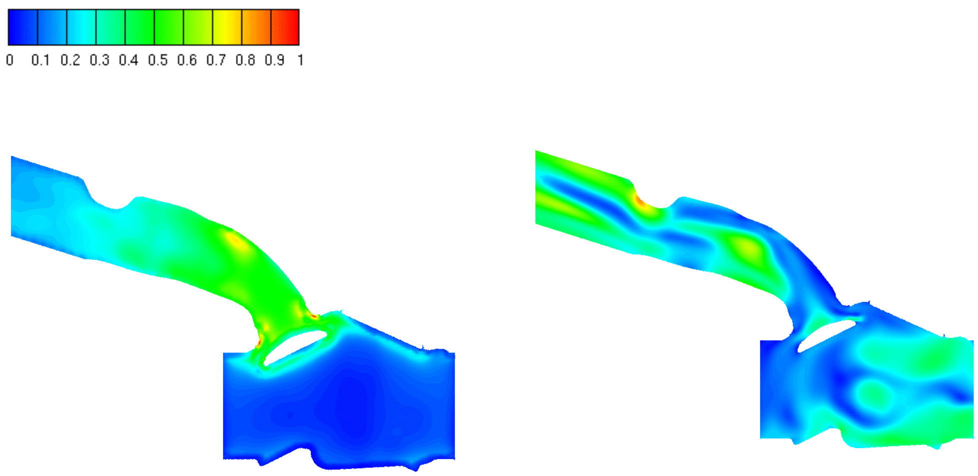

Figure 1: An instantaneous values of the parameter which determines the unresolved-to-total kinetic energy ratio (left) and instantaneous velocity field (right) in the engine as calculated following approach of Basara and Girimaji [7].

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