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TESTING EDDY VISCOSITY BASED AND NUMERICALLY BASED LES TURBULENCE MODELS IN THE HPC CODE ALYA

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When trying to apply LES turbulence models to real industrial problems one is faced with a wide range of alternatives. In this work we shall present those whose blending with our unstructured equal order FE HPC code Alya is more straightforward. On one hand we shall explore eddy viscosity models that is the most standard approach. Alya includes the Smagorinsky model with van Driest damping, the wall-adapting local eddy-viscosity model (WALE) developed by Nicoud, and the Sigma model, a more recent alternative by the same author. On the other hand we shall test variational multiscale models (VMS) that are a key ingredient of Alya's numerical strategy to both stabilize the convective term and allow for equal order interpolations for the velocity and the pressure. VMS methods are a widely spread approach within the FE community. For laminar flows they work exclusively as a stabilization mechanism. For turbulent flows the stabilization introduces a numerical diffusion that acts as an implicitly LES model similar to MILES and ILES methods used with other spatial discretizations. Alya includes a wide range of VMS methods starting from the standard ASGS and OSS methods and their improved versions that include both the linear and non-linear time tracking of the subscales [2].

When testing eddy viscosity models several numerical approaches can be adopted. The most straight forward one would be introduce no stabilization method at all since the added turbulent viscosity should avoid numerical instabilities due to the convective term. If this case inf-sup stable finite elements would be needed. Such elements have a higher number of degrees of freedom for the velocity than for the pressure. In [3] it is shown that, contrary to RANS turbulence modelling, for LES turbulence modelling an accurate representation of the pressure is needed. Therefore, if a fair comparison of results with equal order elements is expected, the same number of pressure degrees of freedom should be used. This would imply a much higher number of degres of freedom for the velocity than in an equal interpolation element leading to a very ineficient method. Therefore we only test equal order finite elements. Two approaches are explored, the first one is to use any of the previouslly mentioned VMS methods expecting them to act only as an stabilization method (which is what they where originally intended for) and not as a turbulence model. It has to be noted that as the viscosity is increased by the introduction of a turbulent viscosity the stabilization method automatically reduces the amount of numerical viscosity. The second approach is to modify the VMS method so that it only stabilises the pressure but not the convective term.

The idea of this work is to gain experience in the applicability of the previously mentioned options to industrial problems. In order to do this we shall start from a typical academical example, the turbulent flow in a channel, and proceed to more real world problems. The first step in this direction will be to test the same methods on the same problem but at a higher Reynolds number and using wall laws with a higher $y+$. The capabilities of the different methods will be further explored on the flow over periodic hills. Then the flow around a simplified truck model with experimental results available in[1] will be studied. Finally the most promising alternatives will be tested on the flow around race boat sails.

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