On wall modeling for finite element LES

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ABSTRACT

Wall modeling is key for making LES of high Reynolds number flows computationally feasible. It avoids resolving dynamically important eddies in the near-wall region that become smaller as the Reynolds number increases. In the standard finite element approach for wall modeling the mesh does not extend all the way to the wall (see Fig. 1). This is a key difference with finite differences and finite volumes. The wall law method prescribes a null Dirichlet boundary condition only for the normal velocity. For the tangential components, a traction that depends on the velocity magnitude and has a direction opposite to it is applied. A particularity of the approach used by the finite element community is that the velocity, used to obtain the traction, is evaluated at the boundary of the domain , point A (see Fig. 1). We adapt the implementation used in the finite difference community to finite elements. In this case, the mesh extends up to the wall. Supposing closed (nodal) integration rule to make it closer to what happens in finite differences, the traction that is applied at the wall, point B (see Fig. 1), does not depend on the velocity at the wall but at the first point from the wall, point C. In the case of open integration rule, which is what we actually use in our examples, the only difference is that when obtaining the traction at a gauss point on the boundary, one uses the velocity at a point at a distance h in the normal direction towards the interior of the domain, where h is the element size in the normal direction. We also explore a method called exchange location proposed in [1] that uses a bigger h. This helps to improve the solution because an important part of the wall modeling error comes from the under-resolved LES in the first grid points off the wall. Both the finite difference and exchange location approaches provide significant improvements in the prediction of the mean velocity for a channel at $Re_\tau = 2003$ with a 64^3 linear hexahedral mesh compared to the standard finite element approach. The results are also better than those obtained in [2] for the same problem with a similar number of degrees of freedom and a spatial discretization based on quadratic splines. A 2D hump is also tested.

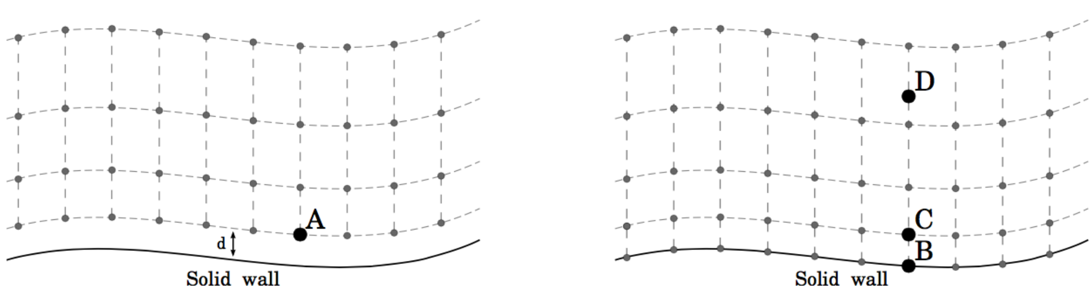

Figure 1: Wall modeling - Standard FE approach (left) , approaches proposed in this work (right)

REFERENCES

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