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SYMMETRY-PRESERVING DISCRETIZATION OF NAVIER-STOKES ON UNSTRUCTURED GRIDS: COLLOCATED VS STAGGERED

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The essence of turbulence are the smallest scales of motion. They result from a subtle balance between convective transport and diffusive dissipation. Mathematically, these terms are governed by two differential operators differing in symmetry: the convective operator is skew-symmetric, whereas the diffusive is symmetric and positive-definite. On the other hand, accuracy and stability need to be reconciled for numerical simulations of turbulent flows around complex configurations. With this in mind, a fully-conservative discretization method for general unstructured grids was proposed in Ref. [1]: it exactly preserves the symmetries of the underlying differential operators on a collocated mesh. In summary, and following the same notation than in Ref. [1], the method is based on a set of five basic operators: the cell-centered and staggered control volumes (diagonal matrices), Ω_c and Ω_s, the matrix containing the face normal vectors, N_s, the cell-to-face scalar field interpolation, $\Pi_{c\rightarrow s}$ and the cell-to-face divergence operator, M. Once these operators are constructed, the rest follows straightforwardly from them. Therefore, the proposed method constitutes a robust and easy-to-implement approach to solve incompressible turbulent flows in complex configurations that can be easily implemented in already existing codes such as OpenFOAM® [2]. However, any pressure-correction method on collocated grids suffer from the same drawbacks: the cell-centered velocity field is not exactly incompressible and some artificial dissipation is inevitable introduced. On the other hand, for staggered velocity fields, the projection onto a divergence-free space is a well-posed problem: given a velocity field, it can be uniquely decomposed into a solenoidal vector and the gradient of a scalar (pressure) field. This can be easily done without introducing any dissipation as it should be from a physical point-of-view. In this work, we will explore the possibility to build up staggered formulations based on the above mentioned reduced set of discrete operators.

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