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MINIMUM-DISSIPATION SCALAR TRANSPORT MODEL AND LOW-DISSIPATION METHODS FOR LES OF THERMALLY STRATIFIED TURBULENT FLOWS

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A low-dissipation numerical method is applied to a thermal fluid system and implemented in OpenFOAM. The governing equations of mass, momentum, and energy are discretized with symmetry-preserving methods [1], resulting in a significantly lower numerical dissipation compared to alternative schemes. The developed numerical methods are publicly accessible in OpenFOAM. The minimum-dissipation model (QR) [2] of large-eddy simulation is generalized to incorporate heat transfer and buoyancy effects. The model constant C=0.024 is taken as in flows with a constant temperature. This generalized QR model has many desirable properties. It automatically includes stratification effects, additional thermal effects corrections are unnecessary. This model also includes the effect of buoyancy, in addition to shear, on the suppression and production of turbulence. It switches off at a no-slip wall, ensuring accurate capture of near-wall flow behavior without needing a wall model. It also switches off in laminar and transitional flows so that it is capable of predicting laminar-turbulent transition. It is consistent with the exact subfilter stress tensor and scalar flux on isotropic grids. A differentially heated fluid-filled cavity (Rayleigh number based on the cavity height Ra=6.4e8, 2e9 and 1e10, Pr=0.71) is considered as a test case here [3]. The key findings from the application of the proposed numerical methods are as follows: 1) The symmetry-preserving discretization with the scalar QR is capable of accurately capturing transition points, heat transfer, and flow features across various Rayleigh numbers; 2) Accurate predictions of flow statistics are achieved; 3) The van Kan pressure projection is more accurate than Chorin methods.

REFERENCES

[1] E.M.J. Komen, J.A. Hopman, E.M.A. Frederix, F.X. Trias, R.W.C.P. Verstappen, A symmetry-preserving second-order time-accurate PISO-based method. *Comput. Fluids.*, Vol. **225**, pp. 104979, 2021.

[2] R.W.C.P. Verstappen, How much eddy dissipation is needed to counterbalance the nonlinear production of small, unresolved scales in a large-eddy simulation of turbulence? *Comput. Fluids.*, Vol. **176**, pp. 276–284, 2018.

[3] F.X. Trias, M. Soria, A. Oliva and C.D. Pérez-Segarra, Direct numerical simulations of two- and three-dimensional turbulent natural convection flows in a differentially heated cavity of aspect ratio 4. *J. Fluid Mech.*, Vol. **586**, pp. 259–293, 2007.