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High-fidelity simulation of high-speed turbulent reactive flows: Development of a low-dissipative density based OpenFOAM® solver with DLBFoam for accelerated chemistry

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High speed turbulent reactive flows can be encountered in many scenarios, such as the fire from accidental leak of H_2 from high-pressure storage and the direct injection of gaseous H_2 at elevated pressure within H_2-powered internal combustion engines. Presence of shock discontinuities in such high speed flows complicated the numerical modeling as they feature shock discontinuities along with turbulence. Shock capturing numerical schemes are effective in resolving shock discontinuities, however, the numerical diffusion introduced by these schemes can adversely affect the mixing and turbulence. Therefore, it is crucial to employ low-dissipative numerical approach to accurately capture turbulence, which significantly affects the mixture formation, flame stability, and emissions. To address this, a low-dissipative numerical approach with a modified shock sensor has been implemented within `OpenFOAM®` to simulate high-speed turbulent reactive flows using Large Eddy Simulation (LES). In previous studies [1, 2], utilization of `DLBFoam` for solving chemistry led to a speed-up benefit ranging from approximately 10 times for H_2 to 200 times for C_{12}, compared to standard `OpenFOAM`. The newly developed solver leverage the speed gain of `DLBFoam` to enable efficient reactive simulations of high-speed flows. The new solver was validated against several benchmark problems, such as the Sod shock tube, the Woodward-Colella interacting blast wave, and the wind tunnel with a forward step. The effectiveness of the new solver in simultaneously resolving both shocks and turbulence in non-reacting, highly under-expanded H_2,CH_4, and N_2 jets has already been demonstrated in the study [3]. Currently, the solver has been successfully tested on reactive simulations of a temporally evolving supersonic H_2 shear layer in air. Results for under-expanded jet flames and further validation using reactive benchmark cases will be presented at conference.

References

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