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Numerical simulations of high-pressure (supercritical) CH_4/LOx flows

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Understanding the fundamental mechanisms associated with the combustion of cryogenic propellants in a supercritical environment is a numerical challenge that is crucial for the design of liquid rocket engines (LRE). Propellants are delivered under severe conditions, i.e. at low temperatures under high-pressure conditions, and the resulting injections lead to interactions between dense and light fluids. Simulations are performed with the numerical code SiTCom-B, which solves the conservation equations of species mass fractions, momentum and total energy in their fully compressible form over a structured mesh in a finite volume formulation. Based on the work of Giovangigli et al. [1], the augmented Navier-Stokes-Korteweg (NSK) system is used to describe any potential liquid-vapor interfaces in a CH_4/LOx reacting mixture. The diffuse interface model allows a smooth transition from supercritical to subcritical conditions [2]. An extra vector $w = \nabla\rho$ is thus added to obtain the augmented formulation and ensure the stability of the diffuse interface model [3]. The Soave-Redlich-Kwong equation of state is used to model real gas thermodynamics, incorporating Chung and Takahashi corrections to accurately account for transport properties in high-pressure simulations.
Various reacting and non-reacting cases are studied to evaluate the NSK strategy against the original high-pressure Navier-Stokes formulation: 1/ A mixing layer of LOx-O_2, 2/ a mixing layer of CH_4-LOx and 3/ a splitter plate configuration of the methane oxy-combustion process performed with adapted reduced chemistry [4].

References

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