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A TABULATED DATA TECHNIQUE FOR CRYOGENIC TWO-PHASE FLOWS

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Abstract. Flashing flows of liquid oxygen (LOX) are prevalent in space applications, where LOX can be used as rocket engine propellant [1]–[3]. Towards this direction, the cryogenic flow in a converging-diverging nozzle has been investigated in the present study by utilising real fluid thermodynamics under the homogeneous equilibrium mixture (HEM) assumption for the LOX. A tabulated data method for the Helmholtz energy equation of state (EoS) has been developed in OpenFOAM (OF) [4] and has been incorporated into an explicit density based solver. Due to the wide variation of the speed of sound and consequently of the Mach number noticed in the liquid, vapour and mixture phases, a Mach consistent numerical flux has been employed suitable for subsonic up to supersonic flow conditions [5]. Since the Helmholtz EoS is computationally inefficient compared to simplified EoS, an ad-hoc thermodynamic table containing all the thermodynamic properties for the LOX has been created and stored prior entering the time loop [6], accompanied by a static linked-list algorithm for reducing the search time. Once the thermodynamic element of the table which satisfies the values of the density and internal energy as predicted from the numerical solution of the Navier-Stokes equations is identified, the unknown thermodynamic properties are approximated by a finite element interpolation [7]. The numerical method has been firstly validated against the Riemann problem at similar cryogenic flow conditions. Then, 2-D axisymmetric simulations of the phase-change process in a converging-diverging nozzle are performed and compared with prediction from other numerical tools as well as experimental data. It is concluded that the results are satisfactory while the applicability of the Helmholtz EoS to LOX simulations is demonstrated. This suggests that the proposed methodology can be utilized for the simulation of flashing flows.