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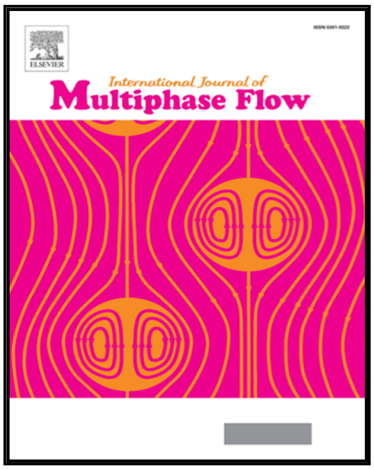

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Numerical investigation of bubble dynamics using tabulated data

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Abstract

An explicit density-based solver of the compressible Euler equations suitable for cavitation simulations is presented, using the full Helmholtz energy Equation of State (EoS) for n-Dodecane. Tabulated data are derived from this EoS in order to calculate the thermodynamic properties of the liquid, vapour and mixture composition during cavitation. For determining thermodynamic properties from the conservative variable set, bilinear interpolation is employed; this results to significantly reduced computational cost despite the complex thermodynamics model incorporated. The latter is able to predict the temperature variation of both the liquid and the vapour phases. The methodology uses a Mach number consistent numerical flux, suitable for subsonic up to supersonic flow conditions. Finite volume discretization is employed in conjunction with a second order Runge-Kutta time integration scheme. The numerical method is validated against the fundamental Riemann problem, comparing with the exact solution which has been derived in the present work for an arbitrary EoS. Further validation is performed against the well-known Rayleigh collapse of a pure vapour bubble. It is then used for the simulation of a 2-D axisymmetric n-Dodecane vapour bubble collapsing in the proximity of a flat wall placed at different locations from the centre of the bubble. The predictive capability of the incorporated Helmholtz EoS is assessed against the widely used barotropic EoS and the non-isothermal Homogeneous Equilibrium Mixture (HEM).

Keywords: Bubble dynamics, cavitation, Helmholtz equation of state, exact Riemann solver

Nomenclature

U	Conservative variable vector
F	r-flux vector
G	z-flux vector
S	Geometric source vector
ρ	Density (kg/m^3)
u_r	Velocity in the r-direction (m/s)
u_z	Velocity in the z-direction (m/s)
p	Pressure (Pa)
e	Internal energy (J/kg)
e_{liq}	Internal energy of the liquid (J/kg)
e_{vap}	Internal energy of the vapour (J/kg)
E	Total energy (J/kg)