A (novel) Weakly-Compressible Volume-of-Fluid (VoF) Method for the Self Pressurisation of Cryogenic Storage Tanks

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April 13, 2023

The design of cryogenic storage tanks rely on accurate modelling of the self-pressurisation process which occurs due to heat transfer with the environment. This complex process involves gas compressibility, natural convection and phase change. In this context, an efficient and novel weakly-compressible Volume-of-Fluid (VoF) method is developed and implemented in ELEMEN- TAL® [1, 2, 3, 4]. The model is based on the two-fluid formulation proposed by Baer & Nun- ziato [5] and is reduced to a four-equation model via a non-dimensional analysis of a liquid-gas hydrogen system at saturation conditions. This is in the interest of reducing complexity and com- putational costs. The resulting model consists of a VoF transport equation, a gas phase continuity equation, and a one-fluid homogeneous momentum and thermal energy conservation method. The system of governing equations is solved using ELEMENTAL® ’s existing semi-implicit pressure- based projection method which is extended to include a simultaneous pressure and temperature solve. The developed model is then validated using standard test cases. These include an adiabatic syringe case to test the accuracy to model compressibility effects and a two-phase heat diffusion problem to validate non-isothermal effects. For all tested cases, a good correlation is obtained be- tween the numerical and analytical solution. Finally, to demonstrate the accuracy of the method for capturing liquid-gas hydrogen pressurisation, a 2D equivalent of the popular Flight-Weight case [6, 7] with a 50% liquid fill, is modelled. The modelled pressurisation shows a good correlation with experimental measurement.

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