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COMPRESSIBLE TWO-PHASE FLOW IN SLOSHING TANKS

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ABSTRACT

The maritime transport of liquid natural gas (LNG) in partially filled tanks grows considerably. This enhances the demand for methods that accurately predict the fluid behaviour inside sloshing tanks. To examine the relevant flow phenomena and liquid motion inside LNG carriers, model experiments have been carried out on a 1:10 scale. Various tank filling ratios and different types of motion have been tested to study the sloshing behaviour at various sea states. The model experiments provide extensive validation material for the numerical simulation tool ComFLOW.

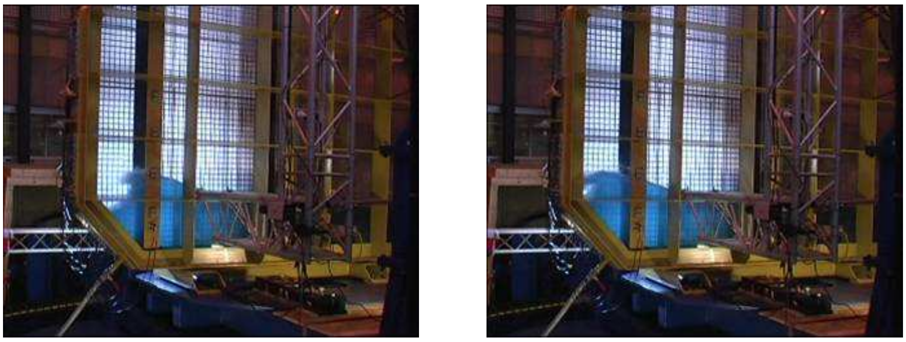

Figure 1: Air entrainment during model test (10% filling rate; irregular sway and roll motion)

Some details of the improved Volume Of Fluid (iVOF) method in ComFLOW will be presented. The method resolves the governing equations in both the liquid and gas phase, where the latter may be compressible. Compressibility of the second phase is important in case of violent flow conditions, especially when interesting two-phase phenomena occur, such as air entrapment and air entrainment (Figure 1). In the numerical method, particular attention has been paid to the average density around the interface. Simple averaging techniques may result in spurious velocities, especially in case of high density ratios. In ComFLOW, these are prevented by the use of a gravity consistent averaging approach. The two phases are convected by means of a first-order upwind scheme (B2) or a more accurate, less

dissipative, second-order upwind scheme (B3). The interface is explicitly reconstructed by means of a local height function and subsequently advected, ensuring a sharp interface without smearing.

The behaviour of the sloshing liquid strongly depends upon the regularity of the tank motion and the filling ratio of the tank. Video frames, wave probes and pressure transducers have been used to compare the fluid flow of simulations and experiments (Figures 2 and 3). Two-phase effects, such as air entrapment, are more common in case of increasing tank filling ratios and irregular tank motion. A realistic simulation of these effects is possible by accurately modeling compressible two-phase flow, especially when a relatively fine grid is used and the less-dissipative second-order upwind scheme is applied.

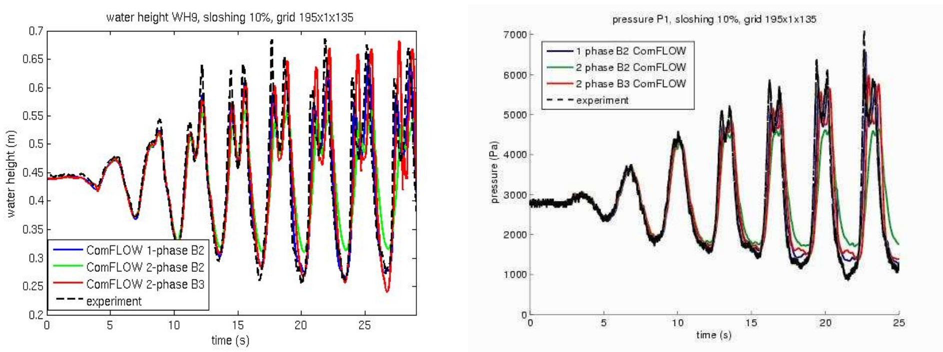

Figure 2: Water heights at the tank-center and pressure signals at the lower right corner for a case with 10% filling rate and regular sway motion. Experiments are compared with 1-phase (B2) and 2-phase (B2 and B3) simulations.

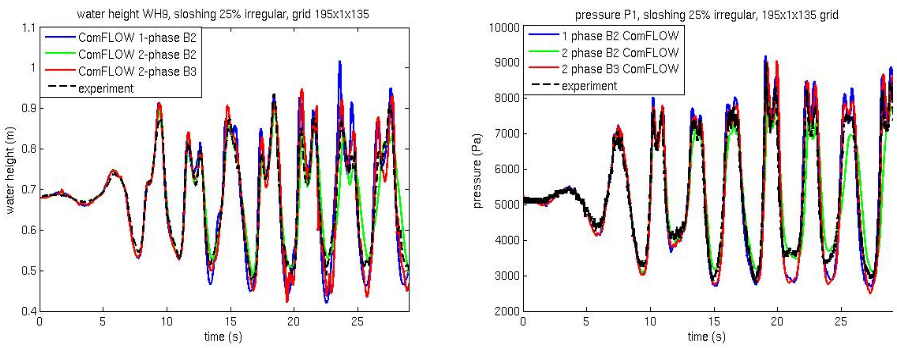

Figure 3: Water-height and pressure profiles as in Figure 2, but now for a case with 25% filling rate and irregular sway and roll motion.

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