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C3Or3B-06: Experimental and numerical investigations on depressurization process in a large liquefied hydrogen tank

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In order to establish a "hydrogen-based society"for carbon-neutral, Japanese and Australian governments promoting the project of "International liquefied hydrogen supply chain". In this project, huge amount of LH2 made from brown coal in Australia will be transported by marine ship. GH2 is liquified by renewable energy, and the LH2 is load on the cargo ship and transported to Japan.

As a pilot project, the world's first LH2 tanker, "Suiso Frontier"was developed and successfully transported LH2 from Australia to Japan in 2022. The LH2 tank on the ship is a pressure accumulation type, having 1,250 m3 in volume. During the shipment of LH2 for 3 weeks, the pressure and Temperature inside the tank are gradually increased due to the accumulation of heat input. The LH2 is pressurized by GH2, that is, a gas-liquid two-phase system of single specie. Then, when the ship arrives at Japan, the pressure of LH2 must be decreased before the unloading from the ship, called the operation of "depressurization".

In the depressurizing operation, the decreasing speed is quite important. Of course, the decreasing speed can be controlled by careful operation of valve opening. However, due to a wrong operation of valves, or in case of emergency release of pressure, there remains the possibility that the decreasing speed come to be too rapid, which should cause an explosive boiling or a geysering phenomenon in the tank. At the same time, the liquid surface should lifted up to the top wall of the tank.

Related to such a rapid depressurization, we had conducted experiments with small vessel containing LN2 or LH2. There are many experimental data and predictive methodology of CFD for a small vessel, however, we must predict what is happened, or what is NOT happened in a real scale tank having 1-million times larger in volume than the small vessel in laboratory scale.

To establish the predictive methodology, thermo-fluid characteristics in large scale tank are strongly desired. In this paper, by use of a LH2 tank of 30m2 as an infrastructure for rocket propulsion research, depressurization process was experimentally investigated. Owing to heat exchanger and valves connected to the LH2 tank, the initial distribution of temperature in vertical direction could be changed. When the liquid was occupied by sub-cooled LH2, the pressure would decrease adiabatically and rapidly w/o boiling. In the other case, when the liquid was occupied by saturated LH2, the pressure would decrease slowly with boiling. This was because the flow rate of exhaust gas and generating rate of boiling gas was almost balanced. In the cases with saturated LH2 with higher liquid level, it was observed that adiabatic depressurization followed by pressure recovering. The flow field inside the tank could not be visualized, however, explosive boiling in super-heated liquid was seemed to be induced.

The flow field was also investigated numerically by use of original CFD code developed in the University of Tokyo. The pressure recovery was well reproduced in CFD and the corresponding boiling was also calculated. Different from experiments, we can impose a hazardous and dangerous conditions in numerical simulations. We will use the CFD as the strong tool of cryogenic fluid management, not only for the understanding real behavior, but also evaluating hazard analysis.

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