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Numerical study on evaporation characteristics of LH2 tank during transportation under typical driving conditions

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Liquid hydrogen (LH_2) is believed as the top-rising storage method for long-distance and massive bulk transportation of hydrogen. However, LH_2 is easy to vaporize, and also flammable and explosive. It's necessary to release the boil-off gas for pressure reduction after the safe pressure limit of the container. An improper release time or frequency would pose a safety threat to the surroundings, leading to a dilemma between hydrogen's extensive application and its utility safety.
This paper applied the volume of fluid (VOF) method to establish a computational fluid dynamics (CFD) model for the phase change of liquid hydrogen. The evaporation characteristics of a 40-ft ISO LH_2 tank under the road transportation environment were studied, with reference to China's heavy-duty vehicle driving cycle standard (CHTC-TT). It aims at providing guidance and suggestions for the boil-off gas release device and active release strategy while transporting.
Linked by the glass-fiber-made supporting members, the shell and cylinder of the tank were made of 16MnDR and 316 steel, respectively. Multiple layers were adapted as the isolation method. Pipes, valves, and other attachments or structures were simplified. The tank was assumed to be exposed in the atmosphere of 293K at 1 atm. Liquid hydrogen of 20.3K and a 50% filling rate was set in the cylinder. The physical feature of hydrogen was obtained from the NIST database.
Four working conditions of normal or 1000 times higher heat leakage, and street or expressway transportation were simulated. Specifically, the case of street transportation experienced four driving cycles spanning 1800 seconds, while the other cases experienced two driving cycles adding up to 1600 seconds on the highway. The line charts of temperature and pressure, and the radar chart of pressure changes were given.
The results show that under the normal heat leakage condition, the pressure growth rate of the container on the expressway is 34.41% lower than the urban road scenario, and 0.19% lower than the static condition studied before. In addition, there are sudden pressure increments in those two conditions. A corollary for the aforementioned phenomenon is that the internal energy of the liquid is increased by violent driving with speed changes, fostering the untypical evaporation and a corresponding ullage pressure growth. Under the high heat leakage, the evaporation rates of LH_2 are almost consistent, and reach the gas-release criteria of 1.0 MPa at about 1250th second and 1350th second, respectively. This implies that the external heat leakage becomes the main heat source, and the effect of speed change behavior on pressure is negligible.
Therefore, it's suggested that drivers should give priority to the road with less major acceleration and deceleration, to reduce the irreversible sudden increment of pressure in the tank. When the vacuum status is lost or there is a fire, drivers have about 20 minutes of safe time to drive to a safety zone and finish the rescue operation.

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