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Comparative Study on Thermodynamic Models of Liquid Hydrogen Storage Tanks

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ABSTRACT

Liquid hydrogen (LH2), with its high volumetric energy density and high purity, has become a promising choice for hydrogen storage. As the demand for hydrogen as a clean energy source continues to grow, the importance of liquid hydrogen in energy storage is becoming increasingly significant. However, the safe operation and storage of liquid hydrogen face several challenges, particularly the self-pressurization process within storage tanks. During storage, heat ingress into the tank causes the evaporation of liquid hydrogen, leading to a continuous rise in vapor pressure, resulting in self-pressurization. Accurately predicting this process is crucial for ensuring the safety of the hydrogen storage system. Computational fluid dynamics (CFD) models can accurately simulate this process, but due to their long computational times, which often take weeks or even longer to produce results, they have significant limitations in practical applications. To overcome this issue, thermal models with fewer nodes and faster computation speeds have become the focus of research. Among these thermal models, the thermal multi-zone model has gained widespread attention because it can more accurately describe the heat and mass transfer processes at the vapor-liquid interface.

Based on the thermal multi-zone model (TMZM), this paper compares three coupling methods for the vapor and liquid phases: first, a temperature-based thermodynamic model, which simplifies calculations using the relationship between temperature and pressure; second, a thermodynamic model based on interface heat conservation, which focuses on the heat exchange process at the vapor-liquid interface; and third, a thermodynamic model based on evaporation rate, which models the process using evaporation and condensation rates. The results show that the maximum error of the temperature-based thermodynamic model compared to experimental data is 6.57%, the maximum error of the interface heat conservation-based thermodynamic model is 2.75%, and the maximum error of the evaporation rate-based thermodynamic model is 4.83%. Therefore, the interface heat conservation-based thermodynamic model provides the most accurate predictions for temperature and pressure. Based on this, the paper further uses the interface heat conservation-based thermodynamic model to analyze the variation patterns of key parameters, such as pressure and temperature, in the liquid hydrogen storage tank under different conditions.

KEYWORDS

Hydrogen storage liquid; thermodynamic model; self-pressurizing

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