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Numerical study on the filling temperature variation in high pressure storage tank

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Faced with the growing energy shortages environmental pollution, ecological deterioration, the development of clean and efficient new energy is the only way to solve the above problems. Hydrogen has become the most promising secondary energy of 21st century for its excellent advantages such as high combustion efficiency, broad source, no polluting product and reproducible ability. It has important strategic significance for solving the problems of environmental pollution and energy shortage puzzling all over the world. There is a certain degree of risk for compressed hydrogen storage in practical applications. Therefore, safe and reliable high pressure storage of hydrogen is needed to be studied.

In the currently developed hydrogen filling system, hydrogen is compressed through a compressor and stored in the tank as high pressure. In the filling process from A(tube trailer) to B(high pressure tank), thermal stress in the B is arisen due to the temperature rise of hydrogen together with the internal pressure increase in the tank. This temperature rise in the compressed hydrogen storage tanks is related with filling parameters, and thermodynamic parameters. Thus, in order to secure the structural reliability of the high pressure tank, it is important to predict and control the temperature change of hydrogen during the filling process.

The main contents and research results are as follow:

(1) The prediction model of temperature variation during the hydrogen gas cycling test of the compressed hydrogen storage system. In this study, a theoretical analysis model for temperature rise in hydrogen filling process for hydrogen storage tanks based on theoretical analysis was developed. The temperature of hydrogen gas in adiabatic filling process for the tank has been analyzed and the temperature rise was obtained, that was, the maximum value of the temperature rise in filling process was found out. Based on the theoretical model, the effect of the initial temperature and initial pressure in the storage tank on the temperature rise were obtained.

(2) In the paper, the main influence factors on the temperature rise during high pressure filling of hydrogen storage tank were investigated through the thermodynamic analysis. Considering the complexity of the non-adiabatic filling process, based on reasonable simplifications for filling process, a numerical simulation model for predicting filling process of hydrogen storage tank is presented, which has considered turbulence flow, real gas effect, and solid heat transfer issues. The simulation model has been verified with experimental data. Through the numerical analysis, the influences of various filling parameters on temperature rise within the tank were analyzed. The influence principles and preliminary strategies of hydrogen temperature were obtained.

(3) Safe fast filling during the hydrogen gas cycling process. Based on the investigations carried out, three effective control for temperature rise are proposed in the high pressure filling process.

1. Controlling the filling rate. Our research found that the mass flow rate has a high effect on the temperature rise. Therefore, controlling the filling rate will be decreased the temperature of hydrogen and reduced the energy consumption. In the initial filling process, the temperature rises rapidly; therefore, the filling rate can be controlled slowly at the initial process and then faster in the overall time.

2. Filling with multi-stage initial pressure. In the filling process, the tank is filled by the three tanks in the order of low pressure tank, middle pressure tank, and high pressure tank.

3. Reducing inlet temperature. Firstly, a heat exchanger is arranged in front of the hydrogen storage tank. The temperature decrease after the hydrogen flows through the heat exchanger can effectively suppress the temperature rise. Secondly, precooling the hydrogen is a method to reduce the inflow temperature of hydrogen gas.

The works of this paper can provide guidance for the temperature control of high pressure hydrogen storage system and optimization of filling conditions for hydrogen stations. This study also offer necessary theory and numerical methods for guiding safe operation and standards formulation of hydrogen storage system for hydrogen stations.

Keywords: Compressed hydrogen storage, High pressure filling, Thermal theory, Simulation validation, Hydrogen safety.