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An Investigation of the Cool-Down Behavior of a Cryogenic Tank during the Filling Process

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In this paper, a numerical study is performed on the filling process of a specified cryogenic tank from room temperature down to the low temperature. The cool-down behavior of the tank and the flow characteristics inside are analyzed considering the effects of the state (gas and liquid) of the filling substance and the filling rate. CFD simulations are carried out on saturated hydrogen gas filling processes and liquid hydrogen filling processes at four different mass flow rates, respectively. Numerical results show that the flow and temperature fields within the tank are controlled by the combined action between forced convection from the inlet of cold gas and natural convection near the tank wall in the gas filling process. The influence of forced convection is emerging with the filling rate increasing, especially in the initial and final stage of the filling process at higher filling rates (>2 kg/s), which results in a negative temperature gradient along the axis from the inlet (bottom) to the outlet (top) in the initial stage. The wall temperature of the tank presents different distribution patterns at different filling rates. In addition, the thermal stress distribution of the tank wall during the filling process is analyzed. The greatest stress appears in regions near the inlet and outlet due to existing constraints, and the values evidently depend on restricting conditions (rigid, elastic or free). In the liquid filling process, the cool down of the tank wall always follows the rise of the liquid level and the overall cooling rate increases with the increase of the filling rate in a rational range.

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