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EFFECT OF FORCED CONVECTION BY BOILING BUBBLE ON POOL BOILING HEAT TRANSFER COEFFICIENT OF LIQUID NITROGEN FOR BUNDLE-TUBE HEAT EXCHANGER FOR COOLING OXIDIZER IN LAUNCH GROUND SYSTEM

Abstract

The stages of supplying and operating the oxidizer, liquid oxygen, for KSLV-II (Korean Space Launch Vehicle) include the cooling of ground system, the cooling of the oxidizer tank, piping and valve system of launch vehicle, and the filling process and the replenishment process. The replenishment process, supplementary charging step, serves to suppress the evaporation amount of the oxidizer in the oxidizer tank and maintain the target oxidizer filling level in a situation where waiting for several hours from the end of the main charging until the time of launch. To this end, the liquid oxygen supplied in the supplementary charging step is cooled to a temperature lower than the atmospheric pressure saturation temperature, 86 to 90 K, through a heat exchanger with liquid nitrogen and injected. The heat exchanger making liquid oxygen subcooled used in the launch ground facility is a basic shell-tube type heat exchanger, and is called a stacked spiral coil type heat exchanger after its tube shape. The inside of the shell of the heat exchanger is filled with liquid nitrogen in a saturated state of atmospheric pressure of 77 K, and the liquid nitrogen serves as a cooling source for cooling liquid oxygen. Determining the heat transfer coefficient is, therefore, indispensable for heat exchanger design. Saturated liquid nitrogen, which is a cooling source outside the piping, has a boiling heat transfer phenomenon due to a temperature difference between the wall and fluid temperature of the oxidizer piping, which requires additional modeling and investigation. In this study, an experimental apparatus was fabricated to improve the modeling limitation due to the limitation of the pipe uneven flow situation of the existing launch ground facility as described above. Experiments were performed according to thermal parameters such as liquid oxygen mass flow rate and inlet temperature, and shape parameters such as arrangement of heat exchangers and pitch between coils through the improved experimental apparatus. The liquid nitrogen side boiling heat transfer coefficient was derived, and the shape coefficient was introduced by comparing the boiling heat transfer results according to the shape of the heat exchanger. The existence of forced convection heat transfer due to boiling bubble is verified experimentally with comparing the derived outer heat transfer coefficient. Higher mass flow rate which causes more fluid flow and bubbles, more dominant effect of forced convection heat transfer by rising bubble in net heat transfer mechanism in pool boiling.