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MODELING AND EXPERIMENTAL VALIDATION FOR THE PASSIVE THERMODYNAMIC VENT SYSTEM (TVS) OF CRYOGENIC PROPELLANT TANK

Abstract

Thermodynamic Vent System (TVS) was introduced by Rockwell as an indirect vent method to prevent a cryogenic liquid propellant tank from being pressurized excessively in micro-gravity condition. It is operated to control the pressure in the tank by two steps; mixing the liquid propellant with the ullage gas and venting the propellant indirectly from the tank. We investigate so-called passive TVS, which manages the pressure without mixing function to focus on the efficient design of the heat exchanger for a reliable and a lightweight propulsion system. For successful operation of the passive TVS, essential factors such as heat removal capability, venting mass and venting time per each TVS cycle should be anticipatable with high accuracy. In this study, numerical models of the passive TVS are suggested with thermodynamic and heat transfer equations. Their predictability is also verified by experiments. The fluid in the tank is assumed as a homogeneous saturated state and a steady state per each time step. Two-phase flow in the heat exchanger and conduction heat transfer in semi-infinite medium are supposed to calculate the amount of heat transfer through the heat exchanger. In experiments, liquid nitrogen (LN2) is employed to imitate the cryogenic liquid propellant. A copper chamber is fabricated as the propellant tank to alleviate thermal stratification effect. It is thermally insulated by Multi Layer Insulation (MLI) at vacuum condition. The inner diameter and the height of the tank are 198 mm and 216.7 mm, respectively. In addition, the coil heat exchanger without fins and with fins are selected as the designs of the experimental heat exchanger to check the accuracy of modeling. The model predicts experimental results according to the heat ingress, LN2 fill level and the shape of the heat exchanger. Although the gravity exists in the experiment, the model shows that the effect of the gravity can be neglected in the heat transfer behavior of the passive TVS since heat transfer by conduction is dominant over the heat transfer by natural convection in the tank. Consequently, we propose boundary conditions of factors for the successful operation of the passive TVS.