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ENHANCEMENT OF THERMAL CONTROL PERFORMANCE BY USING LIQUID METAL RADIATOR

Abstract

Thermal control is essential for spacecraft to maintain the temperature of on-board equipment within allowable thresholds, under extreme thermal vacuum environments in-orbit during a mission lifetime. For this, the spacecraft thermal design has mainly adopted a passive approach owing to its reliability and simplicity. Generally, most external surfaces of spacecraft are covered with a multi-layer insulator used for thermal insulation from incident solar and planetary fluxes, whereas radiators with high emissivity are applied to specific areas to dissipate internal heat waste into space. These radiators can be high emissivity coatings, an optical solar reflector, or a second surface mirror. However, applying such fixed emittance radiators involves the additional use of heaters to keep the equipment temperature above their specified lower limit, by compensating for the inherent heat loss due to excessive cooling through the radiator when the equipment is not operated under cold conditions. Although the heater can provide a simple and effective solution from the viewpoint of thermal control, loss of power budget for the spacecraft is unavoidable. Power consumption due to the heater might be reduced by using a thermal louver that can change its radiation characteristics according to temperature conditions. However, this would lead to increased system complexity owing to additional sensors and actuators to control the louver, and its mechanical moving parts might be vulnerable to vibration loads under a launch environment. To overcome the limitations, we focused on liquid metal for enhancing the thermal control performance of a conventional fixed emissivity radiator. This liquid metal has a relatively high heat capacity and thermal conductivity, as well as a low melting point. In this study, we propose a variable conductance radiator (VCR) using the characteristics of liquid metal. A key point of the proposed VCR is the movement of liquid metal according to temperature conditions. In hot conditions, the first reservoir is filled with liquid metal to effectively transfer heat from the equipment to the radiator for cooling. In cold conditions, the liquid metal is transferred to the second reservoir by using a peristaltic pump, such that the equipment mounted under the first reservoir is thermally insulated from the radiator. Thus, the proposed VCR can avoid unwanted heat loss and minimize the use of a heater. To validate the effectiveness of the proposed VCR, its thermal control performance was compared with that of a fixed conductance radiator through a numerical thermal analysis.