Paper ID: 40075
student

50th IAA SYMPOSIUM ON SAFETY, QUALITY AND KNOWLEDGE MANAGEMENT IN SPACE ACTIVITIES (D5)
Prediction, Measurement and Effects of space environment on space missions (3)

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TACKLING CONVECTIVE HEAT LOSSES WITHIN MARS SURFACE MISSION SYSTEMS

Abstract

There is a need to come up with lightweight, energy-efficient and robust thermal control strategies for spacecraft operating in the harsh Mars environment. Conventional solutions used in recent missions have utilized thermoplastics and aerogel material for passive thermal control. However, engineers have faced challenges with integration, testing and robustness, along with the risks of contaminating the on-board sensitive organic tracer instruments. NASA's Mars Curiosity rover along with ESA's ExoMars 2020 rover utilize the local Mars atmosphere (primarily low thermal conductivity CO2) to fill the spaces around critical internal systems. The Martian atmospheric density is a small fraction of that of Earth's, but is sufficient for thermal convection to set in within the rover, reducing the efficiency of such a thermal control strategy. Thermal design teams have reported a maximum critical gap height, below which convective heat transfer losses are minimal. This study is motivated by the lack of available empirical data for complex enclosure geometries in which the influence of corners and step profiles on convection onset and stabilization is unknown. We present results from a CFD study aimed to characterize the effect of a stable convection cell within a high gap on the heat transfer within an adjacent low gap (with heights less than the documented 'maximum critical' dimension) for Mars surface atmospheric conditions and gravity. The study covers a range of subcritical low gap heights and finds an increase in heat transfer due to the adjacent high gap convection cell. The losses are higher for lower gap heights and are attributed to the rise in fluid velocity that enhances heat transport. The thermal convection onset criteria are defined based on the impact of adjacent convection cells and heat transfer correlations are defined for a range of representative Rayleigh numbers. The findings will be validated by conducting heat transfer experiments within a specially assembled rig within a thermal vacuum chamber. The work aims to provide heat transfer correlations for more realistic geometric features that are found within Mars rovers than an ideal two-dimensional gap. This will aid rover thermal design teams to optimize the gas gap dimensions. Qualitative temperature and velocity distribution data from the CFD shall add to the limited body of knowledge on enclosure-driven thermal convection.