Experimental Investigation of Nano-Enhanced-PCM-Based Heat Sinks for Passive Thermal Management of Small Satellites

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Abstract : Phase-change materials (PCMs) are considered one of the most promising substances to be engaged passively in thermal management and storage systems for spacecraft, where it is critical to diminish the overall mass of the onboard thermal storage system while minimizing temperature fluctuations upon drastic changes in the environmental temperature within the orbit stage. This makes the development of effective thermal management systems more challenging since there is no atmosphere in outer space to take advantage of natural and forced convective heat transfer. PCM can store or release a tremendous amount of thermal energy within a small volume in the form of latent heat of fusion in the phase-change processes of melting and solidification from solid to liquid or, conversely, during which temperature remains almost constant. However, the existing PCMs pose very low thermal conductivity, leading to an undesirable increase in total thermal resistance and, consequently, a slow thermal response time. This often turns into a system bottleneck from the thermal performance perspective. To address the above-mentioned drawback, the present study aims to design and develop various heat sinks featured by nano-structured graphitic foams (i.e., carbon foam), expanded graphite (EG), and open-cell copper foam (OCCF) infiltrated with a conventional paraffin wax PCM with a melting temperature of around 35 °C. This study focuses on the use of passive thermal management techniques to develop efficient heat sinks to maintain the electronics circuits’ and battery module’s temperature within the thermal safety limit for small spacecraft and satellites such as the Pumpkin and OPTIMUS battery modules designed for CubeSats with a cross-sectional area of approximately 4″×4″. Thermal response times for various heat sinks are assessed in a vacuum chamber to simulate space conditions.

Keywords : heat sink, porous foams, phase-change material (PCM), spacecraft thermal management
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