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Microgravity Experiments from Sub-Orbital to Orbital Platforms (3)

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THE EFFECT OF THERMOCAPILLARY CONVECTION ON PCM MELTING IN MICROGRAVITY: RESULTS AND EXPECTATIONS

Abstract

Phase change materials (PCMs) are of interest in thermal management for their ability to store and release large amounts of energy near the phase transition temperature. Space exploration is an especially fitting area for PCM applications because significant (undesired) temperature variations can result from the cycles of radiation exposure experienced by orbiting spacecraft or the waste heat generated by on-board systems. Implementing an efficient and effective thermal control system is a critical requirement, particularly for manned missions.

Among the range of possible materials with appropriate operating temperatures for space missions, organic PCMs like alkanes are attractive for their stability. Their effectiveness can be limited, however, by low thermal conductivity and the resulting lag in response time. One strategy for reducing response time is to modify the effective thermal conductivity of the PCM device through the addition of more conductive material but, with the exception of nanoparticle mixtures, this approach tends to increase the

associated mass and/or size budgets. Even without changing conductivity, the existence of convective flows in the liquid phase can significantly enhance performance of the PCM device. On ground one can take advantage of gravity (and orientation) to promote natural convection, but not in microgravity environments. The thermocapillary effect has been proposed as a simple alternative to improve heat transfer properties in space applications since, if the design includes a free surface, the temperature gradient inherent to the operation of the PCM will induce variations in surface tension that can generate convective flow.

The Thermocapillary Effects in Phase Change Materials in Microgravity (TEPiM) experiment recently demonstrated the positive effect of thermocapillary flow on the melting of n-octadecane. Experiments were performed in parabolic flights using rectangular geometry, and observed an enhancement of the heat transfer rate by as much as a factor of (approximately) 2. These results, although limited by the short microgravity time to a small fraction of the full PCM cycle, strongly support the claim that thermocapillary flows can be used to improve PCM performance in space and should be investigated further. Additional microgravity experiments covering the entire PCM melting/freezing cycles are required to definitively evaluate this improvement and the robustness of the proposed PCM design. We expect that future space exploration missions can benefit from such investigations and corresponding improvements in the efficiency of passive PCM devices.