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ENHANCING PHASE CHANGE MATERIAL (PCM) EFFICIENCY THROUGH TIMELY MELTING-SOLIDIFICATION CYCLE INTERRUPTION.

Abstract

Phase change materials (PCMs) possess the unique ability to absorb and release heat during phase transitions, making them invaluable for passive thermal control mechanisms. Since the 1970s, solid Phase Change Material (PCM) systems have played an important role in various space missions. In terrestrial applications, the presence of convective flows in the liquid phase helps to solve the problem of PCM low thermal conductivity. However, this approach is not applicable in microgravity. As an alternative strategy, the use of the thermocapillary effect, where a non-uniform temperature induces surface tension gradients driving convective motion, has been proposed as a source of convective heat transport in microgravity PCM devices. The upcoming MarPCM/ISS project aims to explore alternative methods for optimizing heat management [1]. The numerous numerical simulations of the melting phase highlighted enhancing heat transfer efficiency due to Marangoni convection.

In practice, thermal operations typically involve complete solid-liquid-solid conversion cycles. To optimize PCM performance, we explored three different scenarios based on the temperature configuration between sidewalls before and after melting. We identified the most promising case, which involves the timely switching of temperatures between cold and hot walls at a certain moment, preceding full melting or attaining steady state. This specific moment corresponds to the beginning of a decrease in heat extraction efficiency. To implement this concept in practice, we propose rotating the PCM material inside the package while maintaining wall temperatures fixed. The suggested rotation approach has the potential to simplify technological design and facilitate manipulation of the system. Future microgravity experiments could validate the efficacy of this innovative solution.

[1] Porter at al. The "Effect of Marangoni Convection on Heat Transfer in Phase Change Materials" experiment, Acta Astronautica, Volume 210, 2023, Pages 212-223