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C3Or3B-06: Compact nitrogen pulsating heat pipes – Experimental thermal analysis with numerical insights

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With the increasing cryocooler-based cooling techniques, there is a growing demand for thermal links that efficiently transfer heat load to the cryocooler stages. This demand can be addressed by pulsating heat pipes (PHPs) designed to operate effectively at cryogenic temperatures.
Despite progress in this field, the current literature does not allow for precise prediction of PHP performance under cryogenic conditions. To address this gap, we propose a numerical model developed in OpenFOAM leveraging its flexibility for source code modification to meet specific research needs. The implementation of the model includes customized equations for phase fraction, momentum and energy, thereby incorporating phase change dynamics based on the Volume of Fluid approach.
In order to validate this numerical model, a compact PHP has been constructed with a simplified geometry to minimize computational resource requirements while maintaining functionality. A laboratory setup has been built to experimentally test the designed PHP at different cryogenic temperature ranges. The cooling is provided by a two-stage cryocooler having a cooling capacity of ˜30 W at 77 K. The PHP is fabricated from stainless steel tubes with an inner diameter of 1.3 mm. It has projected overall dimensions of approximately 0.19 m x 0.11 m. Nitrogen is used as the working fluid with operating temperatures ranging from 77.3 to 94 K. The experimental tests reveal one of the highest effective thermal conductivity values reported for cryogenic PHPs of this size. We also present preliminary results validated against experimental data demonstrating the precision of the implemented model in predicting the thermal performance of cryogenic PHPs.

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