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C1Po1B-05: Numerical and experimental investigation of the compressor coupling characteristic of a 20K thermal-coupled two-stage high-frequency pulse tube cryocooler

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With the rapid development of space technology, the demand for 20K thermal-coupled two-stage pulse tube cryocoolers (PTC) for space infrared detection equipment is increasing. The entire machine is composed of two parts: compressor and cryocooler, so the coupling characteristics of compressor and cryocooler have a serious impact on the performance of the entire machine. In this paper, the efficiency of the 2nd-stage of the thermal-coupled two-stage PTC is theoretically analyzed. Based on Sage, the model of the 2nd-stage of the PTC was established. After simulation calculation, the piston displacement, pressure wave, mass flow and phase angle of PTC coupling with different compressors were studied, and the performance of the entire machine was compared. The experimental results are highly consistent with the simulation results, which verifies the accuracy of the Sage model. Through experiments, the power factor, optimal frequency, no-load cooling temperature, and cooling capacity at 20K of PTC coupled with different compressors were compared and studied. By comparing the force balance diagram of the compressor and the phasor diagram of the PTC, the coupling characteristics of the entire machine are compared. With a total electrical power consumption of 490W, the maximum cooling capacity of a 1135mW@20K was obtained. When the total electrical power consumption was reduced to 185W, a cooling capacity of 647mW@20K was obtained, resulting in a maximum relative Carnot efficiency (rCOP) of 4.9%.

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