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C1Po1B-06: Performance simulation and model verification for a 20K thermal-coupled two-stage high-frequency pulse tube cryocooler

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Currently, most high-precision infrared detectors used in space operate in the liquid hydrogen temperature range and require a two-stage pulse tube cryocooler (PTC) to provide a cryogenic environment. However, the existing two-stage thermal-coupled PTC suffer from low cooling capacity and efficiency. Therefore, in this study, the 2nd-stage of the PTC is considered as a whole system and a Sage model is established. The model is coupled with different inertance tube combinations to comprehensively simulate the performance. The simulation results are compared with the experimental results from the published article "Experimental optimization of phase and compressor of a 20K thermal-coupled two-stage high-frequency pulse tube cryocooler". The accuracy of the model simulation for the no-load optimal frequency and the cooling capacity at 20K is verified. 70% of the simulated values for the no-load optimal frequency deviate from the experimental values by 0-1Hz. 84% of the simulated values for the cooling capacity at 20K deviate from the experimental values within a range of ±20%. It is observed that all experimental values for the optimal frequency at 20K is consistently 2-4Hz higher than the simulated values. The reasons for this phenomenon are revealed from the perspective of the phase angle between the mass flow and pressure wave inside the 2nd-stage regenerator, using the enthalpy flow phase-shifting theory. The research results provide a foundation for the application of Sage software in the study of overall performance of two-stage thermal-coupled PTC.

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