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Theoretical and experimental investigations on impedance of pulse tube cold fingers to match with linear compressors

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The impedance match between the cold finger and the linear compressor of the Stirling-type pulse tube cryocooler (SPTC) is significant to optimize the compressor efficiency and to improve the cold finger cooling performance. Several researches ever studied the impedance match and concluded that there existed the optimal acoustic impedance of the cold finger to acquire the highest compressor efficiency. However, few researches have been done to design the cold finger with the optimal impedance. In this paper, an electrical circuit analogy model has been developed according to continuity equation and momentum equation. The model is used to design the specific dimensions of the cold finger. And furthermore, through the calculation of the pressure and the volume flow rate with the model, the impedance of each component of the cold finger such as regenerator, pulse tube, heat exchanger, phase shifter and reservoir can be achieved, respectively. The total impedance is the sum of every component. For a series of linear compressors developed in the authors'laboratory, their respective mechanical parameters such as linear motor force factor, piston damp, coil resistance etc. have been tested and then the optimal acoustic impedances to match each compressor have been acquired. According to the model, specific cold fingers with optimal acoustic impedances have been worked out. Experimental investigations on acoustic impedance of these cold fingers have been made through measurements of pressure and mass flow rate at several positions of the cold finger, to compare with the theoretical values in the model. The actual performance of a series of SPTCs based on the theoretical and experimental investigations have been measured, the motor efficiencies of the compressors reach 74.2%–83.6% and the relative Carnot efficiency of the cold fingers achieve 3.0%@40 K, 9.6%@60 K, 16.2%@80 K, etc.

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