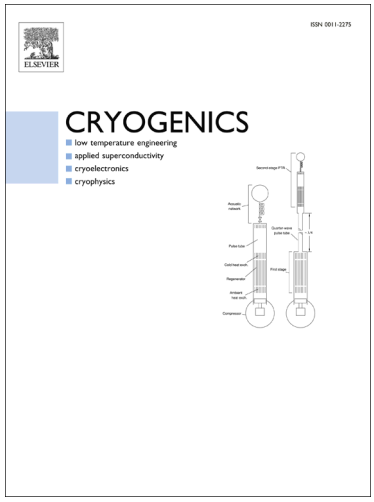

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Analysis and Comparison of Different Phase Shifters for Stirling Pulse Tube Cryocooler

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Abstract

Investigations of phase shifters and power recovery mechanisms are of sustainable interest for developing Stirling pulse tube cryocoolers (SPTC) with higher power density, more compact design and higher efficiency. This paper investigates the phase shifting capacity and the applications of four different phase shifters, including conventional inertance tube, gas-liquid and spring-oscillator phase shifters, as well as a power recovery displacer. Distributed models based on the electro-acoustic analogy are developed to estimate the phase shifting capacity and the acoustic power dissipation of the three phase shifters without power recovery. The results show that both gas-liquid and spring-oscillator phase shifters have the distinctive capacity of phase shifting with a significant reduction in the inertial component length. Furthermore, full distributed models of SPTCs connected with different phase shifters are developed. The cooling performance of SPTCs using all four phase shifters are presented and typical phase relations are analyzed. The comparison reveals that the power recovery displacer with a more complicated configuration provides the highest efficiency. The gas-liquid and spring-oscillator phase shifters show equivalent efficiency compared with the inertance tube phase shifter. Approximately 10-20% of the acoustic power is dissipated by the phase shifters without power recovery, while 15-20% of the acoustic power can be recovered by the power recovery displacer, leading to a maximum coefficient of performance (COP) above 0.14 at 80 K. A merit analysis is also done by presenting the pros and cons of different phase shifters.

Keywords: Stirling pulse tube cryocooler, phase shifter, gas-liquid phase shifter, spring-oscillator phase shifter, power recovery

1. Introduction

In recent decades, the SPTC has attracted substantial attention due to the advantages of avoiding moving parts at cryogenic temperature, low vibration and reliable operation.

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