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Optimising the Performance of a Standing Wave Loudspeaker Driven Thermoacoustic Heat Pump

A Thesis

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Abstract

Thermoacoustic refrigeration system is a form of the emerging green technologies based upon the use of the pressure acoustic waves to supply the cooling effect.

The present study investigates experimentally and theoretically the behavior of the heat transfer and coefficient of performance of a standing wave loudspeaker driven thermoacoustic refrigeration system. Experiments are performed to investigate the effect of the dimensionless stack position (X_{sn}), dimensionless stack length (L_{sn}), frequency (f), acoustic power ($\dot{W}$), and porosity (B) on the temperature difference and the coefficient of performance. The dimensionless stack lengths are varied from 0.076 to 0.191 while the dimensionless stack positions ranged between 0.286 and 1.72 using Celcor Ceramic material for the stack and two porosities of 0.8 and 0.85, and using air as a working fluid at the atmospheric pressure. An error analysis is done to the measured properties and the maximum relative error was of 2.08 % for the coefficient of performance. In a theoretical study, the effect of changing the operating conditions and geometric parameters on the temperature difference across the stack and the coefficient of performance using the simulation software DeltaEC 6.3b11 is also investigated. Helium as a working fluid was used as a working fluid in the theoretical model. The theoretical collected data for the coefficient of performance and the temperature difference across the stack is compared for the two working fluids air and helium.

The physically understanding of the operating conditions and geometric parameters change effect on the temperature difference across the stack and the coefficient of performance of the thermoacoustic heat pump is presented. Based on the obtained results, the resonance frequency change was observed with changing the stack different geometric parameters.

A dimensionless stack position from 0.25 to 0.5 was observed experimentally to invert the hot and the cold sides across the stack. Better values for the geometric parameters and operating conditions are obtained such as the stack porosity that compromise both the temperature difference and the coefficient of performance was 0.8. Better parameters values for the other stack geometric parameters and the operating conditions to compromise both the temperature difference and the coefficient of performance are also collected.

The experimental results validation is presented by comparing the results of one previous researches and our collected results for close values of the stack porosity and its dimensionless length at different dimensionless stack positions. This validation showed that our collected data are close to the compared results.

The experimental collected data for the temperature difference across the stack and the resonance frequency are compared with DeltaEC results for the same operating conditions and geometric parameters. The comparison results for the temperature difference across the stack showed a good agreement. The experimental resonance frequency change was observed to be at the same trendline with DeltaEC results. The relative error is observed to have large value and this is because DeltaEC uses an ideal equation for calculating the resonance frequency which doesn't include viscous and thermal dissipation effects on the frequency.