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Energy Procedia 109 (2017) 456 – 462

Energy Procedia

International Conference on Recent Advancement in Air Conditioning and Refrigeration, RAAR 2016, 10-12 November 2016, Bhubaneswar, India

Numerical analysis of a modified type pulse tube refrigerator

Sachindra Kumar Rout[a]*, Arun Kumar Behura[b], Sisir Dalai[c] and Ranjit Kumar Sahoo[c]

[a]*Assistant Professor, C.V.Raman College of Engineering, Department of Mechanical Engineering, Bhubaneswar 752054,India*
[b]*Assosiate Professor, Poornima College of Engineering, Department of Mechanical Engineering Jaipur, Rajsthan*
[c] *National Institute of Technology, Rourkela, Odisha, India*

Abstract

The loss generated due to direct current gas flow in pulse tube refrigerator (PTR) is one of the major problems which significantly affect the cooling performance. It generates temperature fluctuation at the cold end of the PTR. A new type PTR has been proposed in the present work to diminish the DC flow problem by attaching an additional connection at the hot end from a secondary compressor and investigated numerically using CFD simulation software FLUENT. It is reported a significant enhancement of cooling performance by means of the proposed model. The numerical outcomes of the proposed model are equated with the outcomes of the orifice type pulse tube refrigerator (OPTR) model. The model used for analysis is an axisymmetric model. At 34 Hz operating frequency and 1.2 pressure ratio the numerical simulation is conducted. The proposed model achieves a temperature of 98 K at cold end where as a simple OPTR having same dimension riches a temperature of 130 K. To get an optimum result experimentally for the pulse tube refrigerator, is a very difficult and also high expensive hence the numerical approach is an alternate solution.

Peer-review under responsibility of the organizing committee of RAAR 2016.
Keywords: MPTR; pulse tube; DC gas flow;orifice.

1. Introduction

Due to the close circuit between hot end heat exchanger and aftercooler through a by pass, there is a positive direct current flow (DC flow) inside the double inlet Pulse tube refrigerator. There are two types DC flow, positive

* Corresponding author. Tel.: +91-8895815648; fax: +0-000-000-0000 .
E-mail address: sachindra106@gmail.com

1876-6102
Peer-review under responsibility of the organizing committee of RAAR 2016.
doi:10.1016/j.egypro.2017.03.067

DC flow and the negative DC flow. The major problem associated with the DC flow is that temperature instability at the cold end due to the circulating steady flow around the aftercooler, regenerator, cold heat exchanger, hot heat exchanger and the pulse tube develops an extra heat load to the cold heat exchanger. This result deteriorates in the performance of a pulse tube refrigerator. Due to convective heat loss [1] direct current flow deteriorates the performance of the PTR. The convective loss causes temperature fluctuation at the cold end which is additional negative influence owed to DC flow. By diminishing the DC gas flow or by breaking the flow circuit due to the by pass the performance of the PTR can be enhanced. There are few works has been reported to eliminate DC flow loss by investigators which are shortened here. Inertance type pulse tube refrigerator (ITPTR) [2-4] and active buffer pulse tube refrigerator (ABPTR) [5-8] can diminish the direct current flow and can provide a greater performance but they have their own limitations. As there are numbers of valve used in ABPTR, it makes complicacy in configuration and short life span compare to other type pulse tube refrigerator. The ITPTR model has the limitation that it cannot achieve much lower temperature compare to the DIPTR mode. Different approaches have been proposed by many researchers to suppress the DC flow such as Double-orifice pulse tube refrigerator [9] and the multi-bypass PTR [10] but unable to completely finish it. Membrane suppressor method proposed by Hu [11] et al gives a better solution to DC flow which can completely solve the DC flow loss. The closed-loop flow path generated due to the bypass is break by a use of membrane. An innovative barrier method of a limp rubber balloon was proposed by Swift et al. [12] to solve DC flow problem. This can diminishes the DC flow inside the loop path in a thermos-acoustic Starling crycooler. Shiraishi and Murakami [13] experimentally manufactured and tested a diaphragm inserted in the bypass-tube which completely diminishes the DC flow. From the literature survey it is reported that there is no numerical work found in this DC flow suppression type pulse tube refrigerator. Using ANSYS FLUENT software package an innovative method is proposed and numerically solved to study the transport phenomenon of a MPTR. In this proposed modeling an axisymmetric model is established by using a supplementary compressor input at the hot end heat exchanger as a substitute of the double inlet valve which purpose is equivalent to difragram function. This can disruption the bypass of a DIPTR as difragram performs. Fig. 1 shows the schematic diagram of (a) OTPTR (b) DIPTR (c) MPTR.

Nomenclature

C_p	specific heat gas constant, (J/kg-K)
C	inertial resistance (m^{-1})
E	overall energy (JKg^{-1})
h	specific enthalpy (J/kg)
k	thermal conductivity (W/m-K)
p	pressure (N/m^2)
t	time (s)
T	temperature (K)
V	volume (m^3)
v	velocity (m/s)
Greek Symbol	
ϖ	permeability tensors term (m^2)
τ	stress tensors term (N/m^2)
ρ	density (kg/m^3)
ν	kinematic viscosity
τ	stress tensors (N/m^2)
ϕ	porosity
ω	angular frequency (rad/s)
μ	dynamic viscosity (kg/m s)
Subscripts	
f	fluid
S	solid
z	frequency