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NUMERICAL MODELING OF REFRIGERATOR VORTEX TUBE COOLING PERFORMANCE

By
Mahmoud Mohamed Abdelghfar

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE
In
MECHANICAL POWER ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis: NUMERICAL MODELING OF REFRIGERATOR VORTEX TUBE COOLING PERFORMANCE

Key Words: Vortex, Separation, Refrigeration, Swirling, Turbulence

Summary:

The refrigerator vortex tube is an industrial simple device that used for generating cold and hot air streams from one pressurized air source. Diverse clarifications for the phenomenon of the temperature separation were introduced last years, but till now there isn't a clear proposal that explains this phenomenon completely. This effort is devoted to simulate the flow within the refrigerator vortex tube and explain its operating mechanism. Furthermore, this study shows the influence of cold mass fraction, air inlets number and shape and the divergence angle of the hot tube on the cooling performance to provide optimum geometrical and operational properties.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name:

Date:

Signature:

Dedication

To all my family members, my brother Khaled, my wife, and my daughter Reem.

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NOMENCLATURE

LIST OF SYMBOLS

A_c	Area of the vortex tube cold outlet, m^2
A_i	Area of the vortex tube inlet, m^2
D	Vortex tube diameter, m
d_c	Cold orifice diameter, m
d_c/D	Ratio of the cold orifice diameter to the tube diameter
$d_{plug,i}$	Control valve inner diameter, m
$d_{plug,o}$	Control valve outer diameter, m
E	Energy, J
K	Thermal conductivity, W/mK
k	Isentropic coefficient
L	Vortex tube working length, m
L/D	Ratio of the tube length to its diameter
$\dot{m}$	Mass flow rate, kg/s
$\dot{m}_c$	Cold side mass flow rate, kg/sec
$\dot{m}_h$	Hot side mass flow rate, kg/sec
$\dot{m}_{in}$	Mass flow rate at the inlet, kg/sec
P	Total pressure, N/m^2
P_{atm}	Atmospheric pressure, N/m^2
P_o, P_{in}	Inlet pressure, N/m^2
P_r	Radial pressure, N/m^2
R	Gas constant, J/kg.K
r, z, θ	Cylindrical coordinates
T	Total temperature, K
T_c	Cold temperature, K
T_h	Hot temperature, K
T_o, T_{in}	Inlet temperature, K
V	Volume, m^3
V_r	Radial velocity, m/s
V_z	Axial velocity, m/s
V_θ	Tangential velocity, m/s
ρ	Density, kg/m^3
ΔT_c	Cold temperature drop, K