ENHANCEMENT OF HEAT TRANSFER ON PHASE CHANGE MATERIAL WITH CORRUGATED FINS

By

Ahmed Reda Hamed El Lathy

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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Enhancement of heat transfer on phase change material with corrugated fins

Key Words:
Thermal storage; latent heat thermal energy storage ; fins ; phase change materials; solidification process

Summary:

Thermal Energy storage is a key component in any strategy aims at achieving better utilization of the available thermal energy resources. There are different technologies of thermal energy storage. Latent heat thermal energy storage (LHTES) is considered one of the most promising technologies. The main disadvantage of LHTES is the low thermal conductivity of the phase change material (PCM), where thermal energy is stored. Finned tubes are commonly used to improve the heat transfer in LHTES. This thesis studies the use of longitudinal corrugated fins in enhancing the solidification rate of PCM located in the annular area between two concentric tubes. The geometry of the corrugated fins is described in terms of the number of corrugations per fin and the height of the corrugations. The impact of both the number of corrugations per fin and the corrugation height on the solidification rate are investigated. The numerical model does not take into account the buoyancy effect, which allows the use of two-dimensional geometrical model. The results show that the use of corrugated fins reduces the solidification time by up to 35% for the studied configurations. However, the effectiveness of the corrugated fins is generally lower than the effectiveness of straight fins. The low effectiveness is attributed to the low heat transfer rate at the concave surface of the corrugated fins. Based on the results, it is recommended that the number of corrugation per fin should be kept at minimum.

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:

Acknowledgments

First and foremost, I thank **God**, the most gracious, the ever merciful for helping me finishing this work.

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Nomenclature

List of Symbols

a	amplitude, ºC
A	cross-section area, m^2
A_{pcm}	area of one PCM, (m^2)
A_f	area of one fin, (m^2)
A_T	area of the tube at exact PCM section, (m^2)
C_p	specific heat of phase change material, (j/kg.K)
d_{fn}	fin diameter, (mm)
F_o	Fourier number, $\alpha t/l_c^2$
H	latent heat of phase change material, (j/kg)
k	thermal conductivity, (W/m ºC)
l_f	fin length, (mm)
l_t	fin thickness, (mm)
l_b	spacing between fins, (mm)
L	specific latent heat, (J/kg)
L_c	characteristic length, (m)
L_T	length of the tube at exact PCM section, (mm)
L_f	length of one fin, (mm)
m	mass, (kg)
n	number of fins
N_F	fins density, ($fin.m^{-1}$)
r	radius, (mm)
r_i	inner tube radius, (mm)
r_e	external tube radius, (mm)
r_f	fins radius, (mm)
t	characteristic time, (s)
$T_{in,s}$	temperature of inner surface of the inner tube, (C^o)

$T_{PCM,I}$	initial temperature of Phase change material, (C^o)

Greek Letters

γ	amplitude angle
λ	wave length
α	thermal diffusivity, ($k/ C_p\rho$) (m^2/s)
ρ	density, (kg/m^3)
ΔT	temperature difference between phases

Superscripts and Subscripts

Amb	ambient
cr	critical
f	fin
i	component
L	liquid
m	melting
ref	reference
S	solid
w	wall

Abbreviations

FVM	finite volume method
HTF	heat transfer fluid
LHTES	latent heat thermal energy storage
PCM	phase change material
STES	sensible thermal energy storage
SR	solidification ratio, (A_S/A_l)
S. Rate	solidification rate
TCES	thermo chemical energy storage
TES	thermal energy storage
USD	united states dollar

Abstract

Thermal Energy storage is a key component in any strategy aims at achieving better utilization of the available thermal energy resources. There are different technologies of thermal energy storage. Latent heat thermal energy storage (LHTES) is considered one of the most promising technologies. The main disadvantage of LHTES is the low thermal conductivity of the phase change material (PCM), where thermal energy is stored. Finned tubes are commonly used to improve the heat transfer in LHTES. This thesis studies the use of longitudinal corrugated fins in enhancing the solidification rate of PCM located in the annular area between two concentric tubes. The geometry of the corrugated fins is described in terms of the number of corrugations per fin and the height of the corrugations. The impact of both the number of corrugations per fin and the corrugation height on the solidification rate are investigated. The numerical model does not take into account the buoyancy effect, which allows the use of two-dimensional geometrical model. The results show that the use of corrugated fins reduces the solidification time by up to 35% for the studied configurations. However, the effectiveness of the corrugated fins is generally lower than the effectiveness of straight fins. The low effectiveness is attributed to the low heat transfer rate at the concave surface of the corrugated fins. Based on the results, it is recommended that the number of corrugation per fin should be kept at minimum.