

NUMERICAL STUDY OF THE EFFECT OF DROP SHAPED DIMENSIONS ON HEAT EXCHANGER PERFORMANCE

by

AwadallahAhmed Mohamed Osman

B.Sc Mechanical Engineering 2009

Nile Valley University

Thesis submitted to the Sudan University of science and Technology
partial fulfillment of the requirementsfor the degree of M.Sc. in power
engineering

Supervisor

Dr. ObaiYounisTaha

Faculty of Graduate Studies

Mechanical Engineering School

October 2014

Abstract

This research presents the results of numerical study of heat transfer and pressure drop behavior in a compact heat exchanger (CHE) designed with drop-shaped pin fins. The heat exchanger used for this research consists of a rectangular duct fitted with different drop-shaped pin fins dimensions with the same heat transfer wetted surface area. A three dimensional finite volume based numerical model using ANSYS FLUENT 14.5 has been conducted to select the optimum pin fin dimension considering maximum heat transfer and minimum pressure drop across the heat exchanger. The total four cases that tested having pin tails length to drop diameter L/D of 1.75, 1.5, 1.25 and 1.

The numerical results indicated that the case which had the ratio L/D of 1.75 achieved the best performance of pressure drop for the same heat transfer coefficient.

التجربة

يوضح هذا البحث نتائج محاكاة لانتقال الحرارة وفقدان الضغط في مبادل حراري مدمج صمم بزعانف مسمارية على شكل قطرة. المبادل الحراري المستخدم لهذا البحث يتكون من قناة مستطيلة الشكل مثبتة فيه زعانف مسمارية مختلفة من ناحية الابعاد ولكن لها نفس مساحة انتقال الحرارة. تم اجراء المحاكاة في نموذج ثلاثي الابعاد باستخدام برنامج ANSYS Fluent 14.5 لاختيار الابعاد المثالية التي تعطي اعلى انتقال حرارة واقل فقدان ضغط للمبادل الحراري. أجريت الدراسة على اربع نماذج لها نسبة

$$L/D=1.7, 1.5, 1.25, 1$$

نتائج المحاكاة اثبتت ان النموذج الذي له نسبة $L/D=1.75$ حقق افضل اداء بالنسبة لفقدان الضغط لنفس معامل انتقال الحرارة مقارنة مع النماذج الاخرى.

Acknowledgments

First I would like to express my deep appreciation and gratitude to Dr.ObaiYounisTaha for his constant support and exceptionally helpful guidance throughout this study. Working under his supervision greatly contributed to improving the quality of the thesis.

Also I would like to thank my parents. “You have offered unconditional tolerance and support throughout not only my graduate work, but throughout my entire life”.

List of Contents

Abstract	ii
Acknowledgments	iii
Nomenclature	vi
List of Figures	viii
List of Tables.	x
1. Introduction	1
1.1 Heat Transfer Enhancement Techniques.	1
1.2 Compact Heat Exchanger	3
1.3 Problem Statement	3
1.4 Objectives of the Study.	4
1.5 Scope of the work.	4
2. Literature Review.	6
3. Numerical Methods	9
3.1 ANSYS Fluent Solver	9
3.2 The Finite Volume Method	10
3.3 The Differencing Schemes	12
3.4 Turbulence	13

3.5 Compared Parameters	16
4. Results.	18
4.1 Computational Domain Descriptions	18
4.2 Test Cases	19
4.3 Computational details.	20
4.4 Boundary condition.	21
4.5 Grid Independence Study	23
4.6 Validation.	25
4.7 Results and Discussions.	27
5. Conclusions and Recommendations	39
5.1Conclusions	39
5.2 Recommendations	40
Appendix	41
References	43

Nomenclature

A_{wf}	Flow wetted surface area (mm^2).
A_{wh}	Heat transfer wetted surface area (mm^2).
V_{op}	Total fluid volume inside the heat exchanger (mm^3).
D_h	Hydraulic Diameter (mm).
A_{ave}	The average flow area (mm^2).
D	Pin diameter (mm).
H	Pin height (mm).
L	Total test section length, Pin tail length (mm).
$\dot{Q}$	Heat transfer rate (W).
Nu	Nusselt number.
Re	Reynold number.
$\bar{h}$	Average heat transfer coefficient ($\frac{W}{m^2K}$).
f	Friction coefficient.
T_{in}	Air inlet temperature (K)
T_{out}	Air outlet temperature (K).
T_{wall}	Wall temperature (K).
ΔT_{lm}	The log mean difference temperature (K).
ΔP_{ave}	The average pressure difference (Pa).

K Thermal conductivity ($\frac{W}{m \cdot K}$).

k Turbulent kinetic energy.

l Turbulent length scale.

I_i Conductive and diffusing flux.

Greek

μ Dynamic viscosity ($\frac{Kg}{m \cdot s}$).

μ_t Eddy viscosity or turbulent viscosity ($\frac{Kg}{m \cdot s}$).

θ Pin fin angle.

ρ Density ($\frac{Kg}{m^3}$).

ε Turbulence dissipation rate ($\frac{m^2}{s^3}$).

Subscripts

e East face of control volume.

w West face of control volume.

E East node of control volume.

W West node of control volume.

P Node of control volume.

EE East of the east node of control volume.

WW West of the west node of control volume.

List of Figures

Figure (3.1): Quadratic profiles used in the QUICK scheme	12
Figure (4.1): Pin fin section in the computational domain	18
Figure (4.2): Different tested pin fins	19
Figure (4.3): Symmetry planes and CHE model	21
Figure (4.4): Finite element model	21
Figure (4.5): Models view with boundary conditions.	23
Figure (4.6): The variation of Heat Transfer Flux with various mesh	24
Figure (4.7): The variation of Outlet Temperature with various mesh	25
Figure(4.8): Friction coefficient variation against Reynolds number. . . .	26
Figure (4.9):Heat transfer coefficient variation against Reynolds number. .	27
Figure(4.10): Nusselt number variation against Reynolds number.	27
Figure (4.11):Heat transfer coefficient versus Reynolds number.	28
Figure (4.12):Nusselt number versus Reynolds number	29
Figure (4.13):Friction coefficient versus Reynolds number.	30
Figure (4.14): Velocity vectors of the last row in case1 ($L/D=1.75$)	31
Figure (4.15): Velocity vectors of the last row in case2 ($L/D=1.5$)	32
Figure (4.16): Velocity vectors of the last row in case3 ($L/D=1.25$).	32
Figure (4.17): Velocity vectors of the last row in case4 ($L/D=1$)	33
Figure (4.18): Velocity vectors for case 3 at Reynolds number 12500.	33

Figure (4.19): Velocity vectors for case 3 at Reynolds number 15000. . . .	34
Figure (4.20): Velocity vector for case1	34
Figure (4.21): Velocity vector for case2	35
Figure (4.22): Velocity vector for case3	35
Figure (4.23): Velocity vector for case4	36
Figure (4.24): Temperature contour for case1	36
Figure (4.25): Temperature contour for case2	37
Figure (4.26): Temperature contour for case3	37
Figure (4.27): Temperature contour for case4	38

List of Tables

Table (4.1): Geometrical dimension of the tested cases	20
Table (4.2): Grid independence for model with hexahedral elements	24