

EFFECT OF TUBE INCLINATION ANGLE
ON THE THERMAL AND FLUID DYNAMIC
PERFORMANCE OF FLAT TUBE HEAT
EXCHANGER

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I hereby declare that the work in this thesis is based on my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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LIST OF SYMBOLS

α	Tube inclination angle ($^{\circ}$), thermal diffusivity (m^2/s)
β	Heat transfer surface density (m^2/m^3)
δ	Fin thickness (mm)
θ	Angle of attack, fin inclination angle
μ	Dynamic viscosity, (kg/m.s)
ρ	Density (kg/m^3)
σ	Deviation
∞	Fluid
A	Heat transfer surface area (m^2)
Al	Aluminum
c	Characteristics
Cu	copper
$cond$	Conduction
$conv$	Convection
$elec$	Electrical
F	Friction factor
F_p	Fin pitch (mm)
F_h	Fin height (mm)
h	Convection heat transfer coefficient
in	Inlet
J	Heat transfer factor
k	Thermal conductivity of the tube (W/m.K)
K	Turbulence kinetic energy(m^2/s^2W)
L	Length of the tube (m)
\dot{m}	Mass flow rate (kg/s)
n	Number of terms in the model
N	Number of tube rows
Nu	Nusselt number
out	Outlet
P_l	Longitudinal tube pitch
Pr	Prandtl number
Q	Heat transfer rate (W)
rad	Radiation
Re	Reynolds number
s	Surface
t	Total
T	Temperature ($^{\circ}C$)
U	Overall heat transfer coefficient
ν	Kinematic viscosity (m^2/s)
V	Air velocity (m/s)
w	wall
x	Predictor
X	Thickness (mm)
y	response

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CCD	Central Composite Design
CDWVGs	Curved delta winglet vortex generators
CHEs	Compact heat exchangers
CFD	Computational Fluid Dynamics
CNC	Computer Numerical Control
CPU	Central Processing Unit
CRVGs	Curved rectangular vortex generators
DO	Direct optimization
DOE	Design of Experiment
DWLVGs	Delta Winglet longitudinal Vortex generators
DWRVGs	Delta Winglet Vortex generators
DWVGs	Delta Winglet rectangular Vortex generators
EU	European Union
Exp	Experimental
Fkm	Fakulti Kejuruteraan Mekanikal
FTHEs	Flat tube heat exchangers
HVAC	Heating ventilation and air conditioning
HE	Heat exchanger
HEs	Heat exchangers
IR	Infrared thermography
LMTD	Log Mean Temperature Difference
LVs	Longitudinal Vortex
NCWPs	Novel combined winglet pairs
PEC	Performance Evaluation Criteria
PID	proportional–integral–derivative
PIV	Particle image velocimetry
PRVG	Punched rectangular vortex generators
PTVG	Punched triangular vortex generators
RSM	Response Surface Methodology
RWVG	Rectangular Winglet Vortex generators
Simu	Simulation
UMP	Universiti Malaysia Pahang
VGs	Vortex generators