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Study of plate heat exchanger performance working with three types of Refrigerants exposed to hot air flow

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Abstract

The thermal effectiveness of typical type plate heat exchanger exposed to uniform hot air flow working with three Refrigerants (R134a, R290 and R513a) that are heat exchanged with cold water assuming constant flow rate for the flow domains have been calculated using the number of transfer units method through utilizing the numerical simulation via the AUTODESK CFD 2019 (student version) package. The simulation is performed using the standard K-ε turbulence model, the variation effect of the Refrigerants inlet temperature range (35-50) °C on the effectiveness is investigated considering the hot air flow inlet temperature range between (45-50) °C. The results showed that the PHE effectiveness is maximumly decreased by (14%) for the R513a and by (17%) and (19%) for R134a and R290, respectively.

Keywords: plate heat exchanger, hot air flow, effectiveness evaluation.

Nomenclature

a, b, C	Nusselt number correlation coefficients
Cp	Specific heat (KJ/kg. °C)
h	Film heat transfer coeff. (W/m^{2}K).
K	Kinetic energy (Kg/m^{2}sec^2)
m	Mass flow rate (Kg/sec)
T	Temperature (°C)
t	Time (sec)

Greek Symbols

$\mu\tau$	Turbulent viscosity, kg/m.sec
ρ	Density, kg/m^3
ε	Dissipation of kinetic energy
$\sigma_k, \sigma_\varepsilon$	Turbulent model constants

Subscripts

H	Hot fluid
min	Minimum value
in	Inlet flow ports

Non-dimensional Numbers

Nu	Nusselt number
Pr	Prandtl number, [Cpμ/k]
Re	Reynolds number, [ρUD/μ]

1. Introduction

One of the most efficient heat exchangers that are the best alternative ones to the shell and tube type in the mobile and the compact air-conditioning units is the plate heat exchanger (PHE) [4] due to its small size, and efficient heat exchange rate consists of several pressed metal chevron or pillow plates with or without adjusting hard rubber gaskets between them. J.F. Seara et al. [1] implemented an experimental evaluation of the heat transfer rate and the overall heat transfer coefficient of the water-water ethylene mixture in the titanium brazed offset strip fins PHE. They developed a general correlation for the heat transfer coefficient in PHE channels in terms of Reynolds number for isothermal outbound conditions, and the overall heat transfer coefficient increased with increased fluids mass flow rate. The Hydro Fluro Olefins (HFO's) refrigerants attains high heat transfer rate, non-flammability and lower pressure drop are the R1234yf-ze Refrigerants where several researches have been performed to evaluate their performance and formulate convection heat transfer correlations. J. Zhang et al. [2] performed experimental tests on the brazed PHE working as an evaporator in an organic Rankin cycle using the HFO's in addition to the HFC R134a, they measured the boiling heat transfer coefficient and the pressure decrease for variable inlet saturation conditions, mass flux and attained outlet vapor qualities. They developed an evaporation correlation for the heat transfer coefficient.

The PHE thermal effectiveness is calculated numerically using the NTU method in parallel flow process by H. Dardour et al. [3] using water liquid as the hot and the cold fluid. The numerical solution is performed using the Runge-Kutta method involving Newton Raphson convergent criteria. The results showed that the effectiveness is decreased with the increased thermal flow rate ratio of the heat-exchanged fluids, while it remains nearly constant for NTU greater than (4).

The main objective of the present research is to evaluate the typical PHE thermal effectiveness (using the NTU method) subjected to forced convection by means of uniform hot air flow from both sides of the plates with variable inlet temperature range from (45-50°C), considering three types of Refrigerants in a superheated state; R134a, R290 and the (R1234yf/R134a) mixture R513a, respectively. The heat exchange of the Refrigerant passage flow through the HE will be with cold water by adopting the counter-flow process, the CFD numerical simulation solution is performed using the AUTODESK CFD 2019 student version considering the K-ε as the turbulence model considering the refrigerants inlet temperature range between (35-50) °C.