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RESEARCH ARTICLE

CORRELATION OF OVERALL HEAT TRANSFER COEFFICIENT IN THE THREE ZONES OF WIRE AND TUBE CONDENSER

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ABSTRACT

Numerical and experimental analysis has been studied to estimate the overall heat transfer coefficient in the three zones along wire and tube condenser. The model is based on the empirical formulation of the refrigerant and air sides heat transfer coefficients in finite sections along condenser tube which is solved using EES software. To validate the obtained result from the numerical model, a test rig for a vapour compression refrigeration system with R-134a builds for this purpose. Investigating the temperature distribution and heat transfer coefficient along the length of condenser under different operating conditions have shown that, the de-superheated, two-phase and sub-cooled zones are approximately occupied 15 %, 80% and 5% of the total condenser length respectively. The ratio of Overall heat transfer coefficient to the saturated heat transfer coefficient was significantly affected by the variations of the ambient temperature. Comparison between experimental and numerical results has displayed maximum deviation of 5.5% which is reasonably acceptable. Finally, an acceptable relation has been made to summarize all the important parameter that's effects directly on the heat transfer contributions of the de-superheating, saturated, and subcooling in one equation to simplex the boring calculations of overall heat transfer coefficient. Proposed correlation presents a mean square error about 3.1 %.

KEYWORDS

Overall heat transfer coefficient, Wire-and-tube condenser, Modelling, Correlation.

1. INTRODUCTION

Wire and tube condenser is widely used in commercial and domestic refrigeration systems refers to its simplicity and cost wise. Wire and tube condenser ingredient of a steel tube bent into a single passage serpentine shape. Pairs of steel wires are welded on both sides of serpentine tube are welded bundle to the extended surface (fins). Wire and tube condensers dissipate the heat by natural convection to the air. Always the refrigerant leaves the compressor toward the condenser in a completely vapor phase then de-superheated and change to saturated liquid by remove heat to an ambient (air). Sometimes the refrigerant exit the condenser as sub-cooled liquid, depend on temperature level of the cooling medium and the shape of the condenser. Investigating the heat transfer coefficient at de-superheat, two-phase and sub-cooled zones and therefore the overall of heat transfer coefficient determining associated with the locations of these regions along condenser length represents important aspects in designing and analysis of Wire-and-tube condenser to ensure satisfactory performance of the refrigeration system [1].

Many researchers have modelled the three-zones of this type of condenser and investigated the heat transfer coefficient in these regions numerically and experimentally. Bansal and Chin developed a numerical model to analyse wire and tube condensers that are always utilize in house refrigerators. A numerical model was developed using the finite element method [2].

G. A Quadir et al. analysed the wire-on-tube heat exchangers under normal operating conditions, free convection environment using finite element method [3]. The effects of ambient temperatures and mass flow rates of the refrigerant on phase change location are determined. A. Ameen et al. experimental investigation and developed a numerical analysis of a wire-and-tube condenser performance [4]. All zones model was proposed and an analysis according to its position and the related mass flow rate of refrigerant and ambient temperature. Joaquim M. Goncalvesa et al. presented a semi-empirical modelling approach for simulating the steady-state behaviour of vapour-compression refrigeration systems [5]. They used the zones numerical model for the condenser coupled with models for refrigeration cycle to estimate the steady-state COP.

Hofmanas and Paukstaitis studied the external heat transfer of a wire and tube condenser numerically [6]. Numerical investigations were carried out in the two circumstances, under the natural and mixed convection state. The main results of the investigations are the visualizations of the distribution of velocity and temperature fields. Matheus et al. presented two simulation models to estimate the thermal-fluid behaviour of condensers used in house refrigerators [7]. For both models simplifying assumptions were made, flow and heat transfer was considered one-dimensional.

The aim of this research is to provide the worker in the field of condenser design a fast and simple prediction of the overall heat transfer coefficient of wire and tube condenser as a ratio of saturated zone heat transfer without wading in calculating the other two zones (superheat and subcooled) and condenser geometric details

2. MODELLING AND THEORETICAL ANALYSIS

The performance of the wire-and-tube condenser was modelled using a developed methodology based on finite element approach. In this approach, the wire and tube condenser was divided into three zones, de-superheated, two-phase and sub-cooled based on state of refrigerant conditions. The numerical model to predict heat transfer coefficients for refrigerant side and airside based on heat transfer analysis and suitable empirical correlations at finite equal segments along condenser tube as shown in Figure 1 and Figure 2 and then solved the governing equations

Ra	Airside convection resistance	$^{\circ}C/W$
R_r	Refrigerant side convection resistance	$^{\circ}C/W$
S_t	*Geometric parameters of tube*	
T	*Temperature*	
T_{∞}	Ambient temperature	$^{\circ}C$
U	Average overall heat transfer coefficient	$W/m^2{}^{\circ}C$
u	Velocity	m/s
x	Quality	
X_{tt}	Lockhart and Martinelli parameter	
v	*Vapor*	
vol	*Volumetric*	
w	*wire*	
Greek symbols		
α	*Void fraction*	
β	*Thermal expansion coefficient*	*1/c*
δ_l	*Thickness of liquid*	*m*
$\boldsymbol{\eta}$	*efficiency*	
μ	*Dynamic viscosity*	*Kg/ms*
ρ	*Density*	*Kg/m³*

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