Short Communication

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Study of the Effects Tube Designs to the Heat Transfer Performance of Evaporator Chiller System Based on Industrial Standard

Omar Khaled Qasem Ahmed Al-Ahaqdari[1], Noor Idayu Binti Mohd Tahir[*,1]

[1]Faculty of Engineering, UCSI University, Kuala Lumpur, Malaysia
*Corresponding author: NoorIdayu@ucsiuniversity.edu.my

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Abstract

Three-design geometry of tube thicknesses which are 0.64 mm, 0.71 mm, and 0.89 mm with tube arrangement at 30° are analysed based on the industry tube catalogue. The analysis has been conducted to investigate the effect of tube performance in the evaporator chiller system. The geometrical design was performed using SOLIDWORKS 2021, and the simulations were performed using ANSYS 2020 R2 CFD fluent. The CFD results of heat transfer rate were investigated for all the tube thickness and found that 0.89mm has the highest followed by 0.64 mm and 0.89 mm respectively. CFD heat transfer rates were compared and validated with analytical calculations and found that in all tube thicknesses less than 10 %.

Introduction

A heat exchanger is a part of the system configured for efficient heat transfer. Condensers and evaporators are used in heat exchangers. In-car radiators and coolers, the heat exchanger has been used. The same goes for the chemical process industries too. Heat exchangers in industrial and technological applications are common. The heat exchanger architecture is complicated, a study of the rate of heat flow, efficiency, and pressure is complied[1]. Heating and cooling, humidification, and dehumidification are the main tasks of an air conditioning system for reaching the necessary indoor air temperatures[2]. In residential and industrial settings, air conditioning can be used as an indoor device for the development and preservation in an indoor environment of certain temperatures, relative humidity, and air quality. Usually, an air conditioner makes the evaporator colder and even hotter than the condensation temperature. In the air conditioning system, a low-temperature coolant is provided. The labelled components are i)Compressor ii) Condenser iii) Expansion valve iv) Evaporator [3]. The heat exchanger shell and tube consist of circular tubes fitted with tubes in a cylindrical shell, parallel to the shell. One fluid runs through loops, and another fluid runs through the exchanger's axis. Tubes are one of the main components of evaporator Shell and tube exchangers, several internal designs rely on the necessary heat transfer and lower pressures efficiency and methods used to minimize the heat tension, avoid leakage, promote cleaning and contain the process. Pressures, temperatures, corrosion protection, high asymmetric flow accommodation, and so forth. TEMA standardized many types of tube heat exchangers (Tubular Exchanger Manufacturers Association) [4].

Research Methodology

The analysis was gathered from ANSYS CFD fluent, compare, and validated by analytical calculations. The methodology consists of primarily analysis pre-processing, solver, and post-processing.

Primary analysis

The data collection of the design parameters of the shell and tube were taken from TEMA standard as shown in Table 1 while flow and thermal data (boundary conditions) input were taken from the industry as shown in Table 2.

Table 1: Show the evaporator geometry sizing and the materiall

Evaporator parameters	Dimensions Specifications
Shell Diameter	217.27 mm
Shell Thickness	7.04 mm
Shell and heads length	1068.17mm
Shell head inletand outlet (nozzle)	64.87 mm
Shell llength inlet and outlet	38.10 mm
Shell head inletand outlet (nozzle) thickness	7.04 mm
Shell Material	Carbon steel SA 516 GR 70
Tube Diameter	19.05mm
Tube length	850.90 mm
No. of tubes	37
Tube pitch	23.8 mm
Tube sheet thickness	7.04 mm
Tube thicknesses	0.64 mm 0.71 mm 0.89 mm
Tube sheet diameter	217.27 mm
Tube sheet thickness	7.04 mm
Tube Pattern	30°
Baffles	0
Heads diameter	217.27 mm
Heads thicknesses	7.04mm
Tube head inletand oulet (nozzle)	64.78 mm
Tube head inletand outlet (nozzle) thickness	7.04 mm
Tube Material	Copper

Table 2: The boundary condition of the fluid

Working fluid conditions	Properties of liquid	
	Hot Stream (Water)	Cold Stream (R134-a)
Temperature	12.2 °C	-15 °C
Inlet Mass Flowrate	3.3 kg/s	2.5 kg/s
Density	998.2 kg/m3	1394.88 kg/s
Specific heat capacity	4182 J/kg.K	1288 J/kg.K
Viscosity	0.001003 Pa.s	0.0003587
Thermal conductivity	0.6 W/m.K	0.1013

Pre-Processing

Geometry Modelling

Evaporator geometry construction is made in 3-D dimensional. Solid-Work 2021 was being used because of the reason that the software is user-friendly compared to the ANSYS built-in software such as design modeler or space-claim moreover solid- works can be used to construct part by part component so that later it will be easier to do assembly whereby the ANSYS built-in CAD software does not have such option for the complex CAD design as shown in Fig. 1.

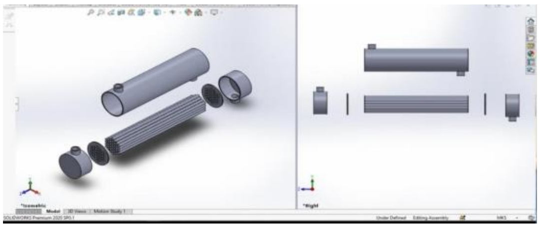

Fig. 1. Geometry design of the evaporator

Meshing

Meshing is a method of generating the nodes and elements in a computational domain. Each tiny cell in a computational domain is made up of the nodes and elements and then the numerical equation will be solved in each mesh. The mesh in a computational domain will affect the accuracy, convergence, and speed of the solution the fluent will import the workbench domain into the ANSYS meshing. skewness, aspect ratio, and orthogonal quality. Fig. 2 shows the mesh of the shell and tube heat exchanger (evaporator).

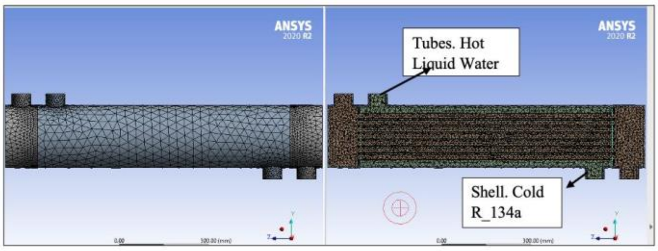

Fig. 2. The mesh of shell and tube heat exchanger (evaporator)

Element selections

Next step, name selection was made for the inlet and outlet boundary condition as well as for the domain of the two different fluids in each of the three different designs. Table 3 is the next Section is the boundary condition, where the inlet and outlet boundary are specified as shown in Table 3.

Table 3: Boundary conditions

Domain	Type	Parameter
Inlet Water	Mass flowrate	Mass Flowrate: 3.3 kg/s Temperature: 12.2 °C
Outlet Water	Pressure outlet	Gauge pressure: 0 Pa
Inlet R-134a	Mass flowrate	Mass flowrate: 2.5 kg/s Temperature: -15 °C
Outlet R-134a	Pressure outlet	Gauge pressure: 0 Pa

Fluent setup is the last step in Fluent's mesh interface. The unassigned interfaces in the computational domain will not be able to solve in the solution. Initialization is a method of collecting all the available parameters in terms of the boundary interpolation method. This option allows the user to determine the turbulence from the generated result. Last step in the solution, which was to run the calculation.

Results and Discussion

The outcome results obtained from CFD simulation were compared and evaluated to observe the influence of tub. At a high temperature, water enters the inlet. The heat transfer between the refrigerant and the water is enhanced by the turbulent flow. The shell also has turbulence, which aids the refrigerant entering the shell head is flowing over the tubes containing the water and efficiently cooling the water by releasing its heat energy. The cooled water exits through the outlet after leaving the tube. The tube inlet temperature is the same for all tube thicknesses, which is 12.2 °C. The inlet temperature at the tube side is 12.2 °C, and the outlet temperature is 10.58 °C as shown below in Fig. 3.

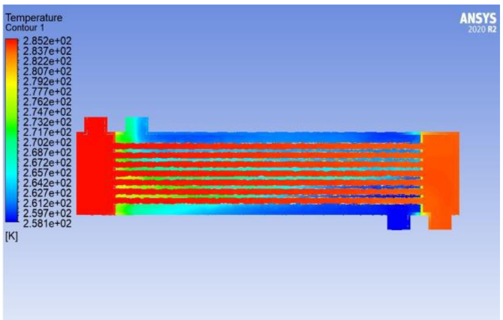

Fig. 3. Temperature tube thickness of 0.64mm

Validation of CFD heat transfer with analytical calculations

The calculations were discussed for LMTD and it is the logarithmic temperature difference between the hot and cold fluids passing through each end of heat exchanger tubes.

$$LMTD = \frac{(Thi-Tco)-(Tho-Tci)}{\ln\frac{(Thi-Tco)}{(Tho-Tci)}} \tag{1}$$

Where;

Thi is inlet hot temperature, Tho is outlet hot temperature, Tco is outlet cold temperature , and Tci is Inlet cold temperature.

Difference between Analytical and CFD Values (Error) calculations

The difference between the analytical and CFD values is due to the approximation and scaling down of the values of all the boundary conditions and parameters as shown in Table 4.

Table 4. Difference between the Analytical and CFD values

Thickness of Tubes	Values of LMTD c^0	Analytic Heat Transfer ($\dot{Q}$) W	Values of CFD ($\dot{Q}$) W	Difference between Analytical and CFD Values (Error) %
0.64 mm	52.6216	49407.4827	52525.5874	6.31%
0.71 mm	52.2982	50281.4567	52235.8235	3.88%
0.89 mm	52.6340	52071.7581	54524.5169	4.71%

Conclusion

Overall this study was achieved successfully, to select three different tube thicknesses based on industrial design, to design and simulate the shell and tube heat exchanger (Evaporator), and to analyze the effects of the tube's heat transfer. It was observed that the validations of the analytical calculations with CFD heat transfer results for all three tube thicknesses were less than 10%.

References

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