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CFD and Experimental Evaluation of R744 Transcritical Gas Cooler Used in Solar Assisted Heat Pump System

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ABSTRACT

In this paper, a helical coil tube in tube heat exchanger was designed and used in carbon dioxide solar assisted heat pump system (SAHP) to provide hot water for domestic applications and to operate an air gap membrane desalination (AGMD) unit. Both theoretical and experimental studies to investigate the performance of the gas cooler with Glycol Ethylene 50% and water as coolants were performed. The experimental part to study the behavior of the carbon dioxide in the supercritical region was conducted on the R744 heat pump test rig located at Department of Energy and Process Engineering – NTNU. On the other hand, FEA using ANSYS Fluent 18.1 was used to conduct the theoretical analysis. The study includes effect of inlet temperature of both coolants, effect of discharge pressure, effect of mass flow rate of water, and logarithmic mean temperature difference (LMTD). Good agreements between Experimental and simulation results were achieved. Results showed that the outlet temperature of the refrigerant from the gas cooler decreased from 81 °C to 40 °C, with 0.085 bar average pressure drop due to the heat rejection process. The outlet temperature of the refrigerant from the gas cooler in case of water is 8 °C lower than with ethylene glycol 50%. The outlet temperature of water reached 57 °C which is enough for domestic applications and to operate the AGMD unit to produce fresh water. It is observed that the pressure drop in the refrigerant by using water as coolant is higher by 0.2 bar than when ethylene glycol 50% used. Results also revealed that the value of LMTD of the gas cooler using ethylene glycol 50% is 24.3 % higher than the LMTD value when using water.

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Nomenclature

p	Pressure
ρ	Density
μ	Kinematic Viscosity
Cp	Specific Heat Capacity
K	Thermal Conductivity
T	Temperature
hc	Convective Heat Transfer Coefficient
u, v, w	Velocity components
\vec{g}	Gravity force
\vec{F}	The external applied force
LMTD	Logarithmic Mean Temperature Difference

1.0 Introduction

Heat Exchanger is a device built for efficient heat exchange between two separated fluids. Different types of heat exchangers are currently in use in distinct sectors of industry. Helical coils heat exchangers are a very spread solution, since they provide more heat transfer area between the two mediums in a small space, higher heat transfer rate and coefficient, and comparatively low manufacturing costs. They are widely used in air conditioning and refrigeration sector, petroleum refineries, power plants, chemical plants, chemical and food industries, and waste heat recovery systems [1]. Simultaneous conduction and convection heat

transfer mechanisms occur inside it in order to transfer or absorb heat from the first (primary) fluid to the second fluid. The convection heat transfer process plays the crucial role in the effectiveness, and the overall heat transfer coefficient and rate of the heat exchanger. Different factors affecting the efficiency of these heat exchanger such as the pressure of the two fluids, inlet temperatures of the fluids, types of fluids used, mass flow rates, diameters of the tubes, and types of tubes materials.

In conventional heat pump (HP) and solar assisted heat pump (SAHP) systems, the heat rejection heat exchangers are called condensers. Choosing the proper refrigerant to operate the HP systems is significant as its entire performance will be affected. According to Maina and Huan [2], the most important factors that must be taken into account in selecting the refrigerant for heat pump systems are safety, reliability, cost, heat transfer properties, performance, and environmental acceptability. HP systems usually operate with chlorofluorocarbon (CFC), hydrochlorofluorocarbon (HCFC) and hydrofluorocarbon (HFC) refrigerants which comparatively have high costs and cause global warming and other environmental issues. Wang et al. [3] reported that one of most significant demerit of using HCFCs and HFCs synthetic refrigerant is that their volumetric capacity

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decreases rapidly when inlet temperature of the condenser increases. In addition they contributes to Global Warming and Ozone Depletion. This situation forced the researchers and manufactures to develop more energy efficient and environmentally friendly systems which can be achieved through using natural refrigerants with zero impact on the environment and competitive thermo-physical and transport properties. Carbon Dioxide appears as suitable alternative fluid to conventional HCFCs refrigerants. Carbene dioxide is inexpensive, readily available, and odorless at low concentrations, compatible with materials, and not corrosive refrigerant non-toxic, and non-flammable. It is environmentally friendly with negligible Global Warming Potential (GWP =1.0) and zero Ozone Depletion Potential (ODP), unlike other synthetic HCFC and HFC refrigerants. By operating the system with carbon dioxide, the system then works on the trans-critical region where heat rejection occurs above the critical pressure and temperature of the refrigerant. Heat absorption process in low pressure side occurs on the subcritical side of the cycle. Due to that the condenser called gas cooler in CO₂ trans-critical systems.

R744 gas cooler is totally different from other conventional constant temperature condensation heat exchangers (condensers) used with other refrigerants. The flow arrangements and behavior of CO₂ in gas cooler affect the efficiency of the system and the optimal operating pressure which make it one of the most important parts in trans-critical cycle. Thermodynamically, R744 in heat pump systems could reject heat in the gas cooler at pressure level above the critical pressure which is 73.8 bars. When carbon dioxide is in the super-critical region, small variation in its temperature and pressure may lead to huge changes in the thermo-physical properties, especially if the temperature is near to the critical temperature (31°C). Meanwhile, changes in its thermo- physical properties may also result in high deviations in both fluid flow behavior and heat transfer [4, 5] Regardless the inlet pressure of CO₂, in the typical gas cooler, the change in its temperature is considered significant along the length of the heat exchanger. During the variation of the temperature, it may pass through the pseudo-critical point, where gigantic variations might occur in the heat capacity.

Tremendous of conducted studies and approaches to investigate the effect of different parameters and factors on the performance of the helical coil tube in tube heat exchanger were found in the literature. Ankanna and Reddy[6] conducted a parametric comparison on the performance of water helical tube in tube heat exchanger and straight heat exchanger. They found out that the helical heat exchanger is more effective and can provide more heat transfer area and heat transfer coefficient within same volume. A similar conclusion was observed by [1]. The effect of Dean Number, which is equal to multiplying the Reynolds number by the ratio of the outer diameter of the tube and mean diameter of the coil, of water helically coiled tube heat exchanger on the overall heat transfer coefficient was studied by Kumar et al. [7]. Theoretical results showed that increasing the Dean Number of the inner tube increased the overall heat transfer coefficient, and the total heat transfer rate of the heat exchanger. Elsayed[8] theoretically and experimentally investigated the flow boiling of R134a refrigerant in helical coil tube heat exchanger used in a small refrigeration system. Nano-fluid technology was used to enhance the heat transfer process of the heat exchanger. It was concluded that as the diameter of the tube decreased, the

boiling heat transfer coefficient increased up to 58%, while increasing the coil diameter decreased it by 130% before dry out. Kuvadiya et al. [9] numerically studied the effect of diameter of outer tube to the inner tube ratio (D/d ratio) of helical tube-in-tube H.EX at constant wall temperature. Water was used in the simulation as heat transfer medium. It was found out that increasing the D/d ratio affect the friction factor, Logarithmic Mean Temperature Difference LMTD, and increase the Nusselt number with maximum value for D/d=10. Patil et al. [10] presented a CFD analysis to study the effect of mass flow rate of water with number of turns on the outlet temperature of water from a helical coil heat exchanger. It is found that the outlet temperature increases with the number of tubes since the heat transfer area increased. Mishra[11] also used CFD tools in predicting the effect of D/d ratio on the Nusselt and Reynolds Numbers at different mass flow rate of water in helical coil tube in tube heat exchanger. The results showed that Nusselt Number increased by increasing the D/d ratio and mass flow rate.

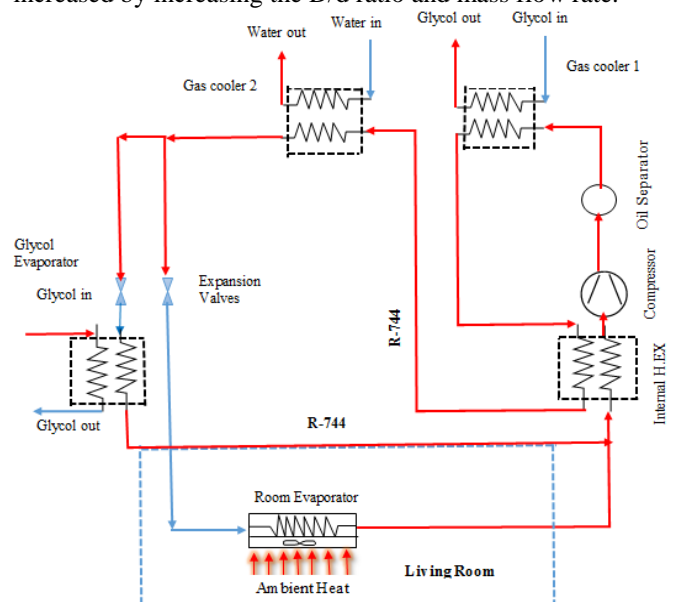


Figure 1. Schematic diagram of the R744 heat pump system used in the experiments.

Santosa[5] performed CFD analysis and series of experiments to evaluate and optimize the performance of finned-tube carbon dioxide (R744) gas cooler operating at supercritical pressure. Investigation about overall heat transfer coefficient, air side heat transfer coefficient, and refrigerant side Heat Transfer Coefficient (HTC) were conducted as well. It is concluded that fin slit between first and second row of tube showed significant effects on the heat rejection rate of the gas cooler. The overall heat transfer coefficient reached its maximum value when the specific heat capacity of R744 was highest. Yu et al. [4, 12] developed a tube in tube counter flow gas cooler with CO₂ and water as fluids, applicable for heat pump water heating system. Numerical analysis and experiments were conducted to investigate the overall heat transfer coefficient, heat transfer rate, and effect of inlet pressure of the CO₂ on the performance. Results showed that the effect of the inlet pressure on the variation of the CO₂ temperature is not as apparent as the variation of the heat transfer rate, even when there is a significant change in the overall heat transfer coefficient. In the present paper, a helical coil tube in tube heat exchanger was designed to be used in a solar assisted heat pump system. It was used in the system for water heating

purpose. The hot water will be used for domestic applications as well as to operate the Air Gap Membrane Desalination (AGMD) unit, as shown in Fig.1. Investigation about the performance of the gas cooler with Glycol Ethylene 50% and water as coolants was performed with ANSYS Fluent 18.1. The comparison includes effect of inlet temperature of both coolants and Logarithmic Mean Temperature Difference (LMTD). Due to some limitations during experiments, ethylene glycol 50% was used instead of water. The refrigerant thermo-physical properties at the supercritical region are functions of pressure and temperature and obtained online from *peacesoftware.de* [13], while for ethylene glycol solution and water they are functions of temperature only, and were obtained from *mhtl.uwaterloo.ca* online software [14]. Experiments to evaluate the performance of the gas cooler and to study the behavior of the carbon dioxide in the supercritical region was conducted on the R744 heat pump test rig located at Department of Energy and Process Engineering – NTNU.

2.0 Geometry and Meshing

The Helical Coils tube in tube gas cooler of the SAHP system was numerically modelled using Computational Fluid Dynamic (CFD), in the commercial package of ANSYS Fluent (Fluid Flow) 18.1. Three dimensional (3D) geometry was designed with ANSYS Workbench. Drawing the geometry must be very precise job since it has significant influences on generating the mesh which can dramatically change the numerical solution of the specific problem.

The gas cooler was made of copper with 6mm and 8mm inner and outer diameters respectively for the inner tube, and 10mm and 12mm inner and outer diameters respectively for the outer tube. Carbon dioxide is flowing through the inner tube, while Glycol Ethylene 50% (or water) flows through the outer tube. The gas cooler has 91 mm radius of the helical tube, with 135 mm width, and 20 mm distance between each two consecutive turns, as shown in Fig. 2. Mesh must be featured properly because it affects the number of cells (nodes and elements) which can significantly increase the computational time. Number of Nodes and elements of the performed mesh were 239457, 124243 respectively. Orthogonal Quality of mesh must ranges from 0 to 1 in order to get good mesh grid. In this case, the orthogonal quality value is 5.51204e-01

3.0 Setting up the Model

Double Precision was selected from the setup options because the dimensions of the gas coolers are comparatively small and in millimeters. Serial option and Pressure-based solver were chosen as they recommended by ANSYS. Gravity effect was taken into calculation in the X direction (-9.81). Steady State and transient simulation are offered by ANSYS. For the present R744 gas coolers, steady state analysis was carried out. In Model option, energy was enabled and K-epsilon (2eqn) was selected as the flow of the refrigerant is turbulent. Standard, and standard wall functions

were choose from *k-ε* (epsilon) model, and near-wall treatment. These options are recommended by researchers and ANSYS for turbulent flow inside tubes.

Thermo-physical properties of the refrigerant (R744) are function of pressure and temperature, and they are function of temperature only for ethylene glycol and water. To simplify the simulation, it is assumed that the changes in the thermo-physical properties of the secondary fluids (Ethylene Glycol and Water) along the gas cooler are negligible, as shown in Fig. 3. To make the transport properties of the refrigerant (R744) function of pressure and temperature during the simulation, Real Gas Redlich Kwong approach was chosen for density, while Kinetic Theory approach was selected for Specific Heat Capacity, Thermal Conductivity and Viscosity. Thermo physical properties for the refrigerant (R744) and the coolants (Ethylene Glycol 50% and water) at inlet of the gas cooler, which used in Simulation, are presented in Table 1.

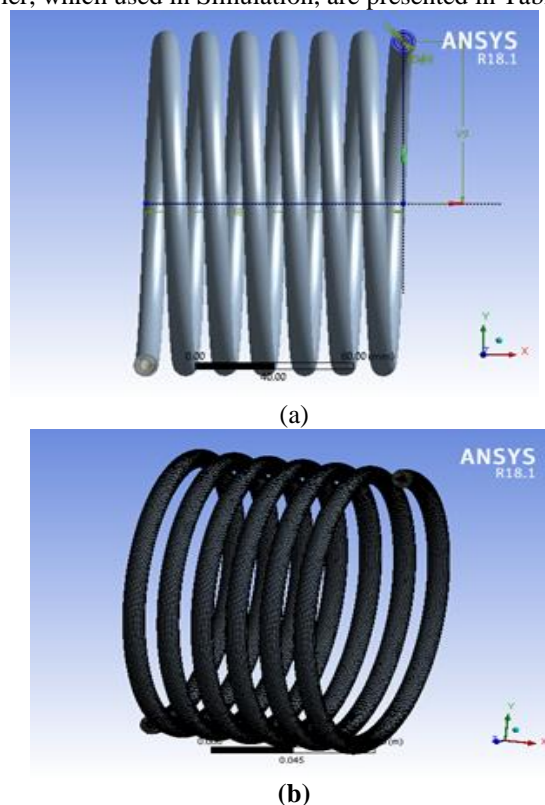


Figure 2. a) Helical coil tube in tube R744 gas cooler. b) Mesh preview.

Setting up the boundary conditions is important step in CFD simulations since they control the whole simulation results. After selecting materials for inner fluid, outer fluid, inner tube and outer tube, boundary conditions have been determined for both inlet and outlet of the refrigerant and coolant. Mass flow rate and inlet temperature were selected as boundary conditions for inlet of refrigerant and coolant, while outlet pressure was selected for outlet of both fluids as shown in Table 2.

Table 1. Thermo-physical Properties of water, R744, and ethylene glycol 50% in the gas cooler

Property	Water at 10 °C	Water at 15 °C	Water at 21.7 °C	Water at 26 °C	R744	Ethylene Glycol 50%
Temperature [°C]	10 °C	15 °C	21.7 °C	26 °C	81	21.7
Pressure [kPa]	101.325	101.325	101.325	101.325	9500	101.325
Density [kg m ⁻³]	9.9957E+2	9.9878E+2	9.9740E+2	9.9632E+2	204.045	1.0551E+3
Cp [kJ kg K ⁻¹]	4.0897	4.0819	4.0750	4.0721	1.74795	3.2909
K [W m.K ⁻¹]	0.58839	0.59678	0.60736	0.61375	0.0312	0.42716
Dynamic Viscosity [kg m.s ⁻¹]	1.2664E-3	1.1080E-3	9.3797E-4	8.4889E-4	21.3555	3.6881E-3

Table 2. Boundary conditions for gas cooler

Thermo-physical property	Hot-in	Hot-out	Cold-in	Cold-out
Mass flow rate [kg s ⁻¹]	0.055	-	0.058	-
Temperature [°C]	81 °C	-	21.7 °C	-
Hydraulic Diameter	6	6	8	8
Pressure [kPa]	-	9500	-	101.325

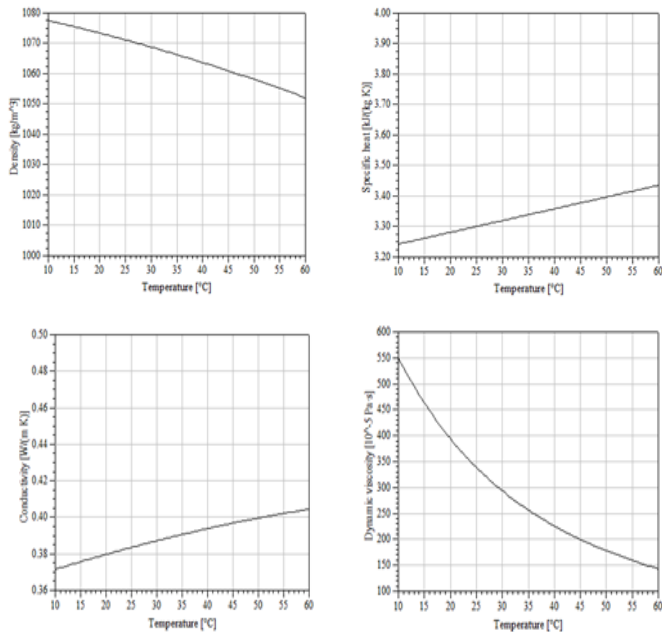


Figure 3. Change of thermo-physical properties of the ethylene glycol 50% as a function of temperature.

4.0 Governing Equations

The equations that govern heat transfer and fluid flow processes in ANSYS Fluent are based on continuity, momentum and Energy equations of Navier-Stokes. Because the three equations are non-linear, ANSYS implies and solve the discretized form of mass, momentum and energy equations through iteration for a domain, where the pressure (p), density (ρ), temperature (T), and velocity components (u , v , w) at each grid cell is solved and predicted in high accuracy [5, 15]. \vec{g} indicates the gravity force, and \vec{F} is the external applied force.

Continuity equation is:

$$\frac{d\rho}{dt} + \nabla \cdot (\rho \vec{V}) = S_m \quad (1)$$

Momentum Equation is:

$$\frac{d}{dt}(\rho \vec{V}) + \nabla \cdot (\rho \vec{V} \vec{V}) = \nabla P + \nabla \cdot (\tau) + \rho \vec{g} + \vec{F} \quad (2)$$

Energy Equation is:

$$\frac{d}{dt}(\rho E) + \nabla \cdot (\vec{V}(\rho E + P)) = -\nabla \cdot (\sum_j h_j j_j) + S_h \quad (3)$$

5.0 Results and Discussion

5.1 Experimental Results

R744 trans-critical gas cooler is used in the system in order to provide hot water for both domestic applications and desalination unit. The experimental investigation to predict its performance was conducted at Department of Energy and Process Engineering – NTNU. Experiments showed that refrigerant's inlet and outlet temperature of the gas cooler were 81 °C and 40 °C respectively, while Inlet temperature of ethylene glycol was 21.7 °C, and the outlet temperature reached 56 °C, as shown in Fig. 4. During experiments, the inlet pressure to the gas cooler was maintained at 95 bar.

Electric heater was used to heat up the coolant since maintaining the inlet temperature of glycol to the gas cooler is important step as it affects the COP of the system. Mass flow rate (kg m⁻¹) of the Glycol had significant influence on the value of high pressure and the outlet temperature of the refrigerant. Change in the mass flow rate of glycol with time was very small and it was less than 0.4 kg minute⁻¹. The mass flow rate of glycol was controlled to be as same as the mass flow rate of the refrigerant, as shown in Fig. 5. Pressure drop due to heat rejection process in the gas cooler was not high, and it is shown in the same Figure.

Experimental investigation to study the effect of discharge pressure on the inlet temperature of the refrigerant to the gas cooler was carried out at constant suction pressure, as shown in Fig. 6. It was observed that Inlet temperature of the refrigerant has direct relationship with discharge pressure at constant suction pressure. It is also observed that temperature of the refrigerant out of compressor was 10 °C approximately higher than that at inlet of the gas cooler. It is due to the thermal losses occurred from the oil separator since it was exposed to ambient.

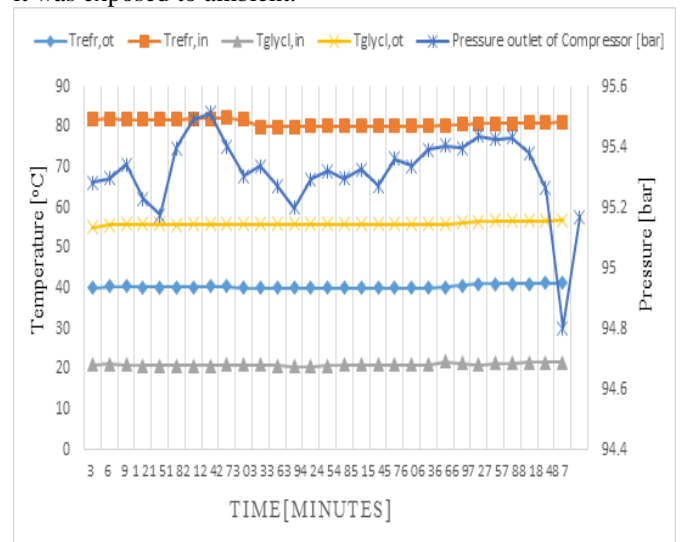


Figure 4. Experimental results for inlet and outlet temperatures of the refrigerant (R744) and ethylene glycol 50% in the gas cooler, and pressure outlet of compressor.

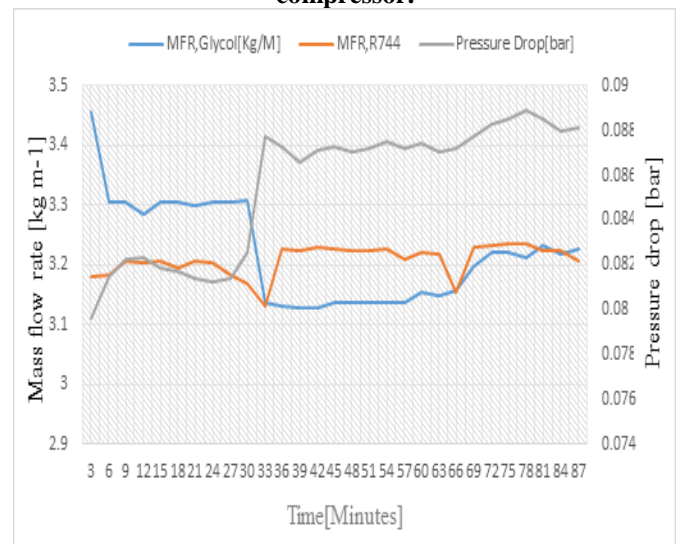


Figure 5. Pressure drop of R744 in the gas cooler, and Mass Flow Rates MFR [kg/m³] of ethylene glycol 50% and R744 in the gas cooler.

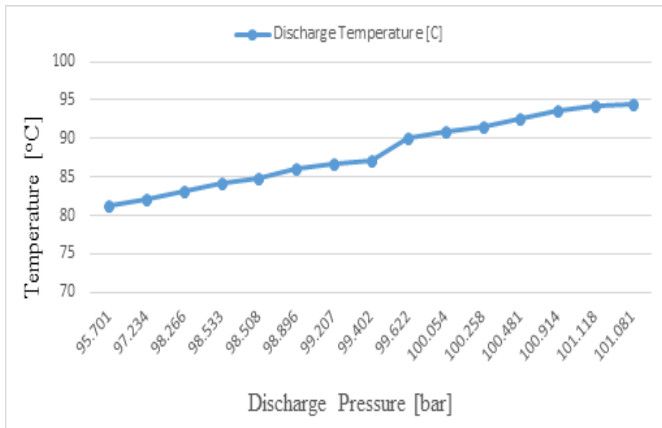


Figure 6. Effect of changing the discharge pressure on the inlet temperature of the refrigerant at constant suction pressure.

5.2 CFD Simulation Results

The CFD simulation firstly performed to validate the experimental results where ethylene glycol 50% used to cool down the refrigerant in the gas cooler. Thereafter, the coolant have been changed to water at same inlet temperature of ethylene glycol to predict the temperature of water possible to be obtained in the water tank. CFD simulation have also been conducted to investigate the effect of different inlet temperature of water in the gas cooler. This can provide a clear and complete picture about the performance of the gas cooler with different coolants, and provide guidelines for more improvements relevant to effectiveness of the gas cooler and water heating unit. The R744 trans-critical gas cooler was designed in a way to get the same UA Value of the Plate Heat exchanger used in the experiments. CFD Numerical Analysis was conducted using ANSYS- Package 18.1. Good Agreement results obtained with experimental results. Experimental conditions were used as inlet parameters to the software such as mass flow rate, inlet temperatures, and pressures. Simulation for the gas cooler was run with 500 iterations which was sufficient to reach the solution convergence.

Contours and X-Y figures for fluids and tubes are attainable by ANSYS. Contours for static temperature of the refrigerant, inner tube, ethylene glycol, and outer tube are presented in Fig. 7a 7b, 7c, and 7d. Simulations showed close results to the experimental part. The inlet temperature of refrigerant and ethylene glycol to the gas cooler were 81 and 21.7 respectively. Mass flow rate for refrigerant and ethylene glycol were 0.053 kg s⁻¹ and 0.058 kg s⁻¹, respectively. The outlet temperature of refrigerant reached value of 40 °C, while temperature of ethylene glycol jumped to about 55 °C which is suitable for domestic applications and AGMD unit. Decreasing the mass flow rate of ethylene glycol can results to higher outlet temperature when it desired.

Contours of static pressures of the refrigerant (R744) is presented in Fig. 7.e. The gas cooler is placed on the high pressure side of the trans-critical cycle. The high rejection pressure of the system is 95 bars. In order to calculate the pressure drop in the gas cooler, the outlet pressure of the refrigerant was set 95 bar. After calculation and complete the iterations, ANSYS gives the value of inlet pressure. By deducting 95 bar from the inlet pressure value, pressure drop value can be obtained. It observed that the pressure drop in the ethylene glycol- CO₂ heat exchanger is 0.6 bar, which is higher than the experimental average value (0.086 bar).

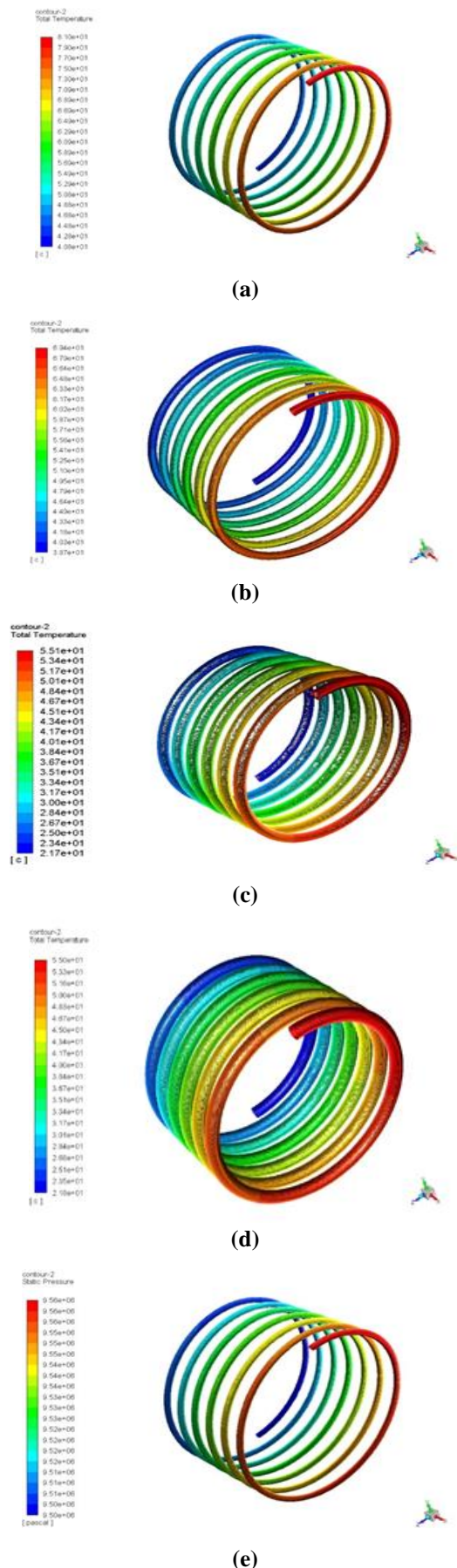


Figure 7. a) Total temperature contour of the refrigerant in the gas cooler. b) Contour of total temperature for inner tube. c) Contour of static temperature of ethylene glycol. d) Contour of static temperature of outer tube of the gas cooler. e) Static pressure contour of R744.

Contours of X, Y, and Z Velocity, and turbulent viscosity for both R744 and ethylene glycol were attainable by ANSYS. ANSYS calculates the velocity vectors (X, Y, and Z) of the refrigerant depending on the given inlet mass flow rate. For mass flow rate of 0.055 kg s^{-1} , 6mm inner diameter of the inner tube, and $204.045 \text{ kg m}^{-3}$ density of refrigerant, the obtained velocity is around 9 m/s . Reynolds number for the refrigerant in the gas cooler is greater than 2000 which means the flow is turbulent. Fig. 8 shows the velocity and the density (kg m^{-3}) of the refrigerant. Density decreased along the gas cooler since it is function of temperature and pressure. In order to predict the temperature of water inside the water tank, ethylene glycol was replaced by water in the gas cooler.

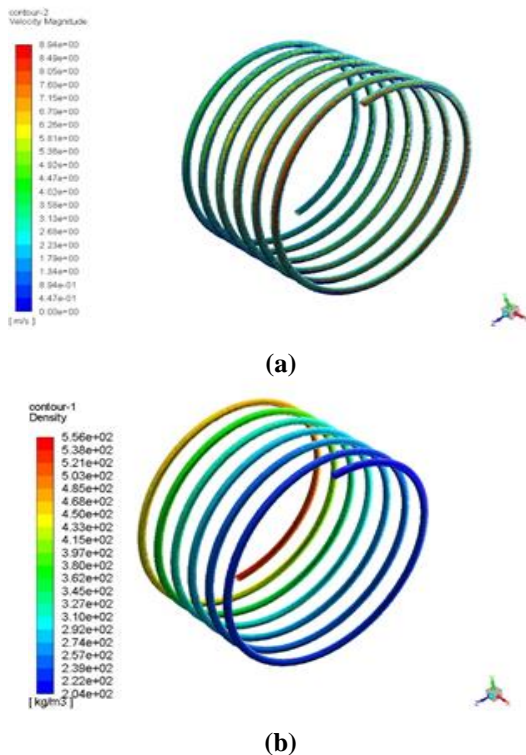


Figure 8. a) Contour of refrigerant (R744) velocity (m/s), and b) Contour of density of R744.

It could be called now water- CO_2 gas cooler. The new gas cooler was simulated under same boundary conditions of ethylene glycol. Same inlet temperature and pressure of the refrigerant (R744) were also used in simulation. Calculation was run for same number of iterations (500), and convergence was achieved. The simulation results showed that the outlet temperature of the refrigerant from the gas cooler decreased by about 8°C , while the outlet temperature of water reached 57°C . It is observed also the pressure drop by using water is higher than Ethylene Glycol 50% by 0.2 bar.

Effect of water inlet temperature on outlet temperature of both water and refrigerant in the gas cooler is an important parameter that must be studied. Previous studies showed that a reduction of 1°C of the outlet temperature of refrigerant from gas cooler leads to 3 to 4% higher COP in Heat Pump Water Heating systems [17]. It is because the lower refrigerant's outlet temperature, the lower enthalpy inlet to evaporator, the higher heat absorbed by evaporator and enthalpy difference, and the higher COP. Depending on experimental observations, inlet temperature of city water significantly affects the refrigerant outlet temperature at the gas cooler. The higher inlet temperature, the higher outlet temperature of refrigerant. This directly leads to huge

reduction in coefficient of performance of the system. Fig. 9 shows the impact of different inlet temperatures of water on outlet temperatures of refrigerant and water from gas cooler. 16.5 % and 6.49% additional reduction in the outlet temperature of refrigerant (R744) and water respectively obtained, when inlet temperature of water decreased from 21.7 to 10°C . The CFD analysis showed that, pressure drop for different inlet water temperature is almost same with negligible difference.

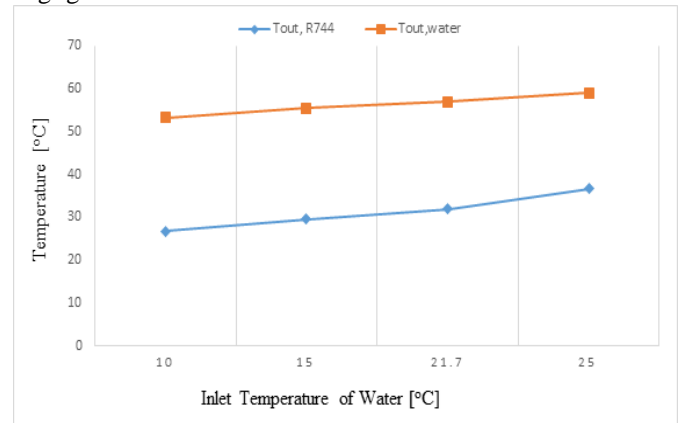


Figure 9. Effects of water inlet temperature on outlet temperature of both refrigerant and water in the gas cooler.

Impact of mass flow rate of both ethylene glycol and water on the outlet temperature of primary and secondary fluids in the gas cooler were theoretically investigated. The mass flow rate was varied from 0.025 to 0.085 kg/s in case of ethylene glycol and from 0.015 to 0.95 kg/s in case of water, as shown in Fig. 10 and Fig. 11. Effect of it on pressure drop of the refrigerant were also observed and recorded in order to determine the optimal mass flow rates. Optimal mass flow rate could be determined when lowest pressure drop obtained [16]. CFD analysis showed that the highest pressure drop value obtained in case of ethylene glycol was at mass flow rate of 0.085 kg/s with about 7 and 9 Celsius degree reduction in temperatures of both refrigerant and ethylene glycol, as shown in Fig.10.

Analysis of changing the mass flow rate of water showed that the highest pressure drop value was at 0.025 kg/s with 13 and 17.3°C increase in outlet temperature of refrigerant and water respectively, as shown in Fig. 11. Mass flow rate has direct impact on pressure drop till reaching the optimal mass flow rate value when pressure drop decreases. Figures revealed that the optimal mass flow rates are 0.065 kg/s and 0.035 kg/s for ethylene glycol and water respectively.

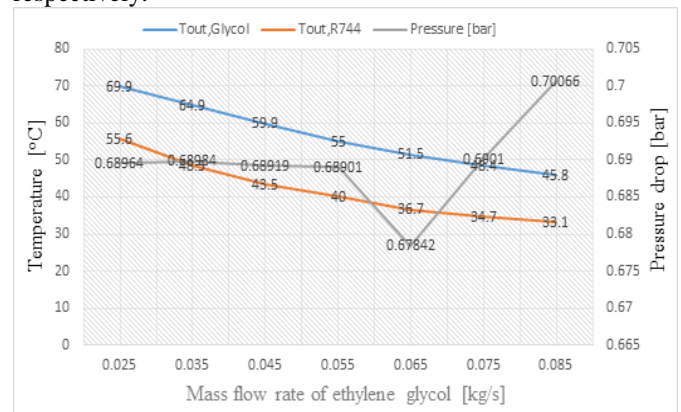


Figure 10. Effect of mass flow rate of ethylene glycol on outlet temperatures and pressure drop.

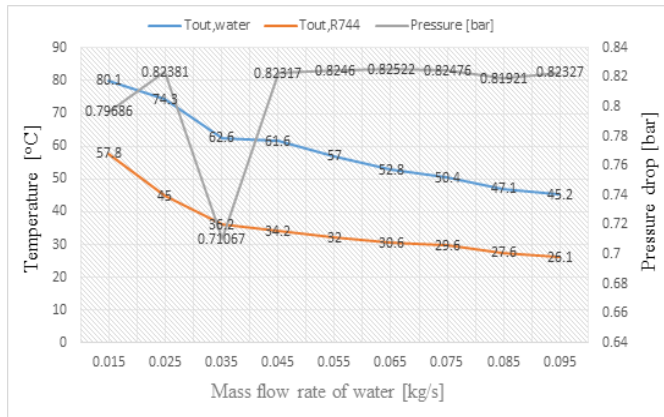


Figure 11. Effect of mass flow rate of water on outlet temperatures and pressure drop.

The Logarithmic Mean Temperature Difference LMTD is used in heat transfer analysis to determine the driving force for heat transfer in heat exchangers. It is an important parameter the rate of heat transfer between the two fluids in the heat exchanger. The higher value of LMTD, the higher heat transfer rate between the two mediums. For the present R744 trans-critical gas cooler, it is used to compare the rate of heat transfer from it with ethylene glycol 50% and water. Simulation results showed that the value of LMTD of the gas cooler using ethylene glycol 50% is 24.3 % higher than the LMTD value when water used, as shown in Fig.12.

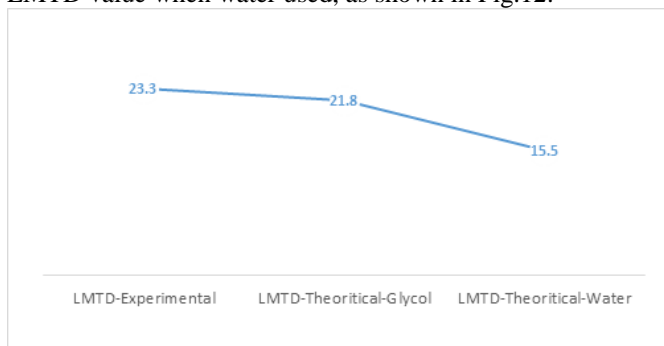


Figure 12. Theoretical and experimental LMTD of the R744 trans-critical gas cooler.

6.0 Conclusion

Helical coil heat exchangers are still superior than other types since they provide more heat transfer area between the two mediums in a small space, higher heat transfer rate and coefficient, and comparatively low manufacturing costs. R744 gas cooler is totally different from other conventional constant temperature condensation heat exchangers (condensers), due to the unique behavior of R744 compared with other refrigerants in the heat rejection region. The flow arrangements and behavior of CO₂ in gas cooler affecting the efficiency of the system and the optimal operating pressure which make it one of the most important parts in trans-critical cycle. In the present paper, a helical coil tube in tube heat exchanger was designed to be used in a solar assisted heat pump system to provide hot water suitable for domestic applications and to operate the Air Gap Membrane Desalination unit. Investigation about the performance of the gas cooler with ethylene glycol 50% and water as coolants was performed by ANSYS Fluent 18.1. Comparison between the performance of it in counter flows for both Ethylene Glycol 50% and Water was conducted. The comparison includes effect of inlet temperature of both coolants, effect of discharge pressure and Log Mean Temperature Difference (LMTD). Experimental work to validate the simulation

results was conducted in Department of Energy and Process Engineering – Norwegian University of Science and Technology (NTNU). Good agreements between the experimental and simulation results was achieved. Experiments showed that the outlet temperature of the refrigerants in the gas cooler decreased from 81 °C to 40 °C, with 0.085 bars average pressure drop due to the heat rejection process. Simulation results showed that the outlet temperature of the refrigerant from the gas cooler in case of water is 8 °C lower than when ethylene glycol 50% used. The outlet temperature of water reached 57 °C which is enough for domestic applications and to operate the AGMD unit to produce fresh water. It is observed the pressure drop by using water is higher than Ethylene Glycol 50% by 0.2 bar. 16.5% and 6.49% additional reduction in the outlet temperature of refrigerant (R744) and water respectively obtained when inlet temperature of water decreased from 21.7 to 10 °C. Simulation results also revealed that the value of LMTD of the gas cooler using ethylene glycol 50% is 24.3 % higher than the LMTD value when water used.

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