15th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2011, Prague, Czech Republic, 12-18 September 2011

EFFECT OF DESIGN AND OPERATION PARAMETERS ON HEAT TRANSFER COEFFICIENT IN CONDENSERS

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ABSTRACT
Accurate and optimum usage of energy sources is gaining importance all over the world due to the increase of energy need and limited energy sources. Optimum usage of energy sources is not only necessity for energy conversion systems, but also design and production of energy conversion devices. Therefore optimization of condensers is very important for HVAC systems which require as possible as minimum space and maximum heat transfer capacity, increase the demand for effective and compact devices in industry. Increasing condenser efficiency, both reduce the dimensions, the material usage and the investment cost of the devices. This can be maintained by increasing the heat transfer coefficient in condensers. In this study, the experimental results of the heat transfer coefficient of vertical micro-fin tube condenser have been investigated. Parameters such as mass flow rate and vapor quality change affecting the heat transfer coefficient are analyzed along the tube length. The results are compared with the different correlations presented in the literature.
Keywords: Condenser, Condensation, Heat Transfer Coefficient

1. INTRODUCTION
Accurate and optimum usage of energy sources is gaining importance all over the world due to the increase of energy need and limited energy sources. Optimum usage of energy sources is not only necessity for energy conversion systems, but also design and production of energy conversion devices. Optimization of condensers is very important for HVAC and automotive industries due to need for performance increase of systems, saving of used energy and less energy consumption. Especially, for condensers and the other devices in HVAC systems which require as possible as minimum space and maximum heat transfer capacity, increase the demand for effective and compact devices in industry. Increasing condenser efficiency, both reduce the dimensions, the material usage and the investment cost of the devices. This can be maintained by increasing the heat transfer coefficient in condensers.
The use of smooth or micro-fin tubes as heat transfer enhancement devices are the most prevalent passive enhancement device in use today. It has been shown that helical micro-fin tubes have a heat transfer coefficient increase of about 150-200 % compared to that of a smooth tube. However using this type of tubes in condensers is also resulting in higher pressure drop (around 100 %) compared to a smooth tube [1]. Besides geometric parameters, the other design and operation parameters affecting the flow regime are operating pressure and temperature, refrigerant type, mass flow rate, vapor quality change. Therefore a single set of correlations for heat transfer and pressure drop during condensation cannot be applicable due to the complexity of the hydrodynamic, heat transfer mechanism and the

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effect of flow regime (annular, wavy, etc..) on heat transfer and pressure drop. Deviations in correlations are change according to the varying operating conditions due to the complexity of two-phase flow. For that reason researchers are still doing experiments in order to compare the affect of different operating conditions and validity of the results with models.
In this study, the experimental results of the heat transfer coefficient of vertical micro-fin tube condenser have been investigated. Parameters such as mass flow rate and vapor quality change affecting the heat transfer coefficient are analyzed along the tube length. The results are compared with the different correlations presented in the literature.

2. EXPERIMENTAL FACILITY

The experimental test facility consists of two main subsystems: the vapor- compression loop and water loops. Cold-and hot-water loops were connected to the condenser and evaporator respectively. The vapor compression loop consisted of a pump, a water-heated evaporator and water cooled test condenser (Fig 1). Two test condensers were used namely a smooth tube and a helical micro- fin tube. Geometric parameters of the test tube are given in Table 1.

Table 1 Test tube geometric parameters of the test condenser

	Smooth	Helical
Material (Copper)	Hard-drawn	Hard-drawn
Helix angle	-	18
Apex angle	-	40
Number of fins	-	60
Outside diameter (mm)	9.75	9.5
Inside diameter(mm)	8.75	8.92
Tube wall thickness(mm)	0.5	0.3

The picture of the system is given in Fig.1

Figure 1. Experimental test facility

Steady state conditions were maintained with the energy balance error was less than 1% and temperatures and pressures were constant for a period of at least 15 min during the experiments.
The test section is of the tube-in–tube type with refrigerant flowing in the inner tube and water flowing in a counter flow direction in the annulus.

During the experiments, experimental variables were kept in the range of following values: Pressure, 5.8-5.9 bar, refrigerant mass flux 10-125 kg/m^2s, and the vapor quality change 0.14- 0.9. Refrigerant R-134a has been entered to the test section as superheated around 3 °C above saturated temperature at the inlet pressure. Mass flow rate, temperature and pressure values of both refrigerant and water at various point as well as along the test section, absolute pressure and pressure difference and amount of refrigerant condensed along the condenser test tubes were measured and recorded at each experiment.

3. RESULTS AND DISCUSSIONS

The properties of the refrigerant at the inlet and outlet of the condenser were determined by temperature and pressure measurements. From these measurements, the thermo-physical properties of the condensing refrigerant were calculated by using the refrigerant property database [2]. Besides that, the water heat flux was also calculated both from the measured water temperatures and mass flow rate values as well as the refrigerant heat flux (due to the refrigerant enthalpy change). Using these values, change in refrigerant quality and amount of heat transferred from the refrigerant, average and local Nusselt number at each mass flux can be calculated. Effect of heat flux on heat transfer coefficient during the condensation in micro-fin tube against the smooth tube is shown in Figure 2.

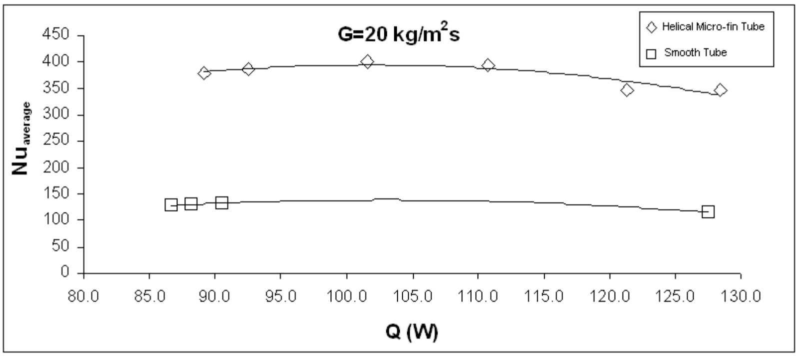

Figure 2. Experimental average heat transfer coefficient for micro-fin tube against the smooth tube

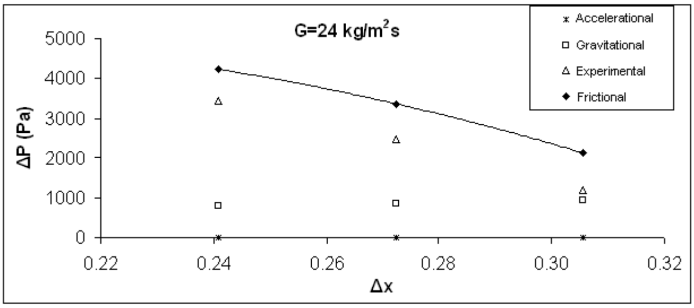

Figure 3. Pressure drop for R-134a in the helical micro-fin tube at 24 kg/m^2s

The heat transfer enhancement which can be as high as 300 %, can be attributed to the presence of a thin film layer on the tube sides and the mixing of the converging liquid at the top and the bottom of the tube. Figures 3 and 4 give the experimental and calculated pressure drop along the helical micro-fin test tube for 24 and 52 kg/m^2s refrigerant mass flux. The overall trend is a decrease in pressure gradient as the vapor quality decreases (change in vapor quality increases). At high qualities the pressure drop is high due to the friction generated by the high vapor velocities.

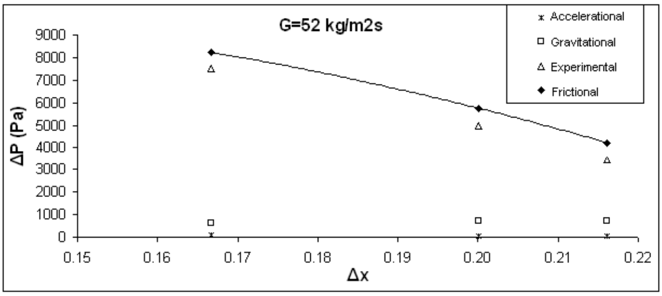

Figure 4. Pressure drop for R-134a in the helical micro-fin tube at 52 kg/m^{2}s

4. CONCLUSION

For the condensation experiments two different tubes were tested, namely smooth tube and a helical micro-fin tube with refrigerant R-134a at 5.8 -5.9 bar and 10-125 kg/m^{2}s mass flux. These experiments Heat transfer results show that the helical micro-fin tube had higher Nusselt number at various heat flux values than the smooth tube. This increase in heat transfer was due to the fins increasing the turbulence as well as maintains the annular flow regime at much higher quality changes when compared to the smooth tube.

5. ACKNOWLEDGEMENT

The experimental research work described in this paper was fully supported by a grant from the Scientific and Technological Research Council of Turkey (TUBITAK), Turkey (Project No: 108M262).

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