THEORETICAL AND EXPERIMENTAL STUDY OF HEAT PUMPS USING PURE AND MIXTURE REFRIGERANTS

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ABSTRACT

In this thesis, a theoretical and experimental study of the performance of two heat pump systems, one is water to water heat pump and the other is a direct expansion solar assisted heat pump, is presented. From the theoretical study the refrigerants R407C, R1270, R290, R170/R290, and R134A were selected and their performances were theoretically and experimentally compared with those of R22 when used in a propriety vapor compression refrigeration unit initially designed to operate with R22.

To carry out the experimental performances of the selected refrigerants, in the first part, the water to water heat pump has been designed and tested for the selected refrigerants. The experimental results showed that R1270 has a higher heating capacity up to12% than that of R22 and the heating capacity of R290 is 5% to 10% lower than that of R22. R134a has remarkably lower heating capacity than R22, around 25% lower. Refrigerants mixture R407C and R290/170 showed better capacity compared to R22.

All the tested refrigerants showed a higher COP than that of R22 except for that of R407C which is overlapping with that of R22 and is about 3% better than R22 on average, for the tested conditions. R1270, R290 has an increase in COP from 10 to 20% than R22. Refrigerant charge required for hydrocarbons (R1270 and R290 and R290/170) systems is only 40% of that in R-22. Thus, we can substantially minimize the effects to global warming and environmental hazard.

In the second part of the experimental work, a solar-assisted heat-pump water heater has been designed and tested for the selected refrigerants. The performance of the system has been investigated under the meteorological conditions of Malaysia. Similar trend of performance results for the tested refrigerants were obtained with an increase in the heating capacity and the COP. This increase in the performance is due to the high energy available from the solar radiation. The optimum solar collector area was found to be $A_c = 5.8\ m^2$ for this specific system, where it is possible to have a continuous supply of hot water at 60°C from a water supply of 30°C with a coefficient of performance up to 5.

In the modeling and simulation part, a steady state model for predicting the performance of vapor compression heat pumps over a wide range of operating conditions is presented. The model overcomes the idealizations of previous models, where the loss and efficiency-based is used to model the compressor and an elemental effectiveness-NTU methodology to model both brazed plate condenser and evaporator. The model requires only inputs that are readily available to the user (e.g. condenser and evaporator inlet water temperatures and mass flow rates). The outputs of the model include system performance variables such as the heating capacity, the coefficient of performance, the compressor electrical work input as well as states of the refrigerant throughout the heat pump cycle. The methodology employed within the model also allows the performance of heat pumps using mixtures to be modeled. The model is validated with experimental data where the agreement is found to be within ± 10% for pure refrigerants and 15% for mixtures.

The results showed that the developed method for the theoretical performance calculation can be used to evaluate and compare the performance of the refrigerants in a heat pump system with moderate accuracy and to have first judgments before any system is designed and fabricated.

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