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Performance Evaluation CO_2 Vapor Compression Heat Pump Considering Refrigerant Filling Pressure

Dr. M G Basavaraju[1]
[1] Senior Scale Lecturer,
Department of Mechanical Engineering (MTT),
Government CPC Polytechnic, Mysore,
Karnataka, India

Savitha D R[2]
[2] Lecturer,
Department of Mechanical Engineering (MTT),
Government CPC Polytechnic, Mysore,
Karnataka, India

***Abstract*:- Carbon dioxide (CO_2) is non-toxic, on-flammable, has zero ozone depletion potential and negligible global warming potential as refrigerant. By using CO_2 refrigerant, heat pumps are the most promising technologies to reduce global warming emissions and ozone depletion. A carbon dioxide heat pump requires further technological progress and environmental friendly refrigerants with higher Coefficient of Performance. CO_2 is one of the few non-toxic and non-flammable working fluids that do not contribute to ozone depletion or global warming, if leaked to the atmosphere. Carbon dioxide (CO_2) is non-toxic, non-flammable, has zero ozone depletion potential and negligible global warming potentials refrigerant. The aim of this paper is the evaluation of the energy performances using counter flow heat exchanger at different refrigerant filling pressure to the compressor. The performance of the heat pump evaluated considering the parameters like different refrigerant filling pressure, evaporator fan speed and water outlet temperature at different mass flow rate**

Key words: Heat pump, LMTD, COP, Ozone Depletion Potential, Evaporator

Nomenclature:
m_w Mass flow rate of water
T_{wo} Outlet temperature of water

INTRODUCTION:

Due to harmful effects of the chlorine based refrigerants on the environment, CO_2 has been used as a potential refrigerant due to the low critical temperature [1]. The use of this water heater in place of the ordinary water heater, which is mainly driven by gas, can lead to a significant reduction in the primary energy consumption. In order to improve the system performance of the CO_2 heat pump, it is necessary to develop an optimum design and a control method for the CO_2 heat pump water heater [2].

It works on the principle of vapor compression refrigeration system. Presently used refrigerants globally are Tetrafluoroethane (R-134a) and Dichloro Difluoro Methane (R-22). These are made from the components of chlorofluorocarbons and hydro chlorofluorocarbons. Increase in the amount of chlorofluorocarbons in the environment results in problems ODP and GWP. So, these refrigerants should be replaced by those which have no ODP and less GWP [3]. Therefore, naturally available refrigerant like CO_2 is used as a refrigerant [4]. It has many advantages like eco friendly, low cost, non flammable, non corrosive, non toxic, stable and suitable for wide range of operating conditions [5]. The heat pump consists of compressor, condenser, evaporator and capillary tube [6] which is best suitable for domestic water heater [7].

In the present study the modification of heat exchanger and experimental performance evaluation of vapor compression prototype heat pump model was carried out. By modifying the heat exchanger, improvement in COP is observed [8]. The variation of speed of compressor and evaporator affect the performance of the heat pump [9].The experiment was conducted to evaluate the water outlet temperature for different mass flow rate, different refrigerant filling pressure and evaporator fan speed.

EXPERIMENTAL SET UP:

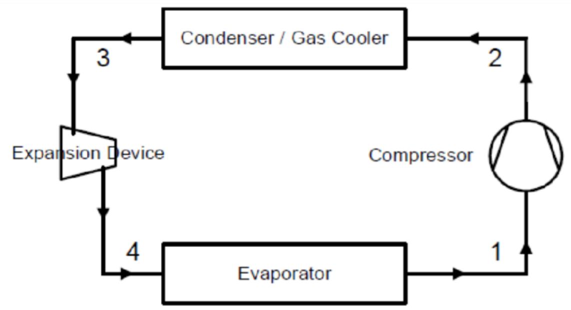

Fig 1: Heat pump cycle

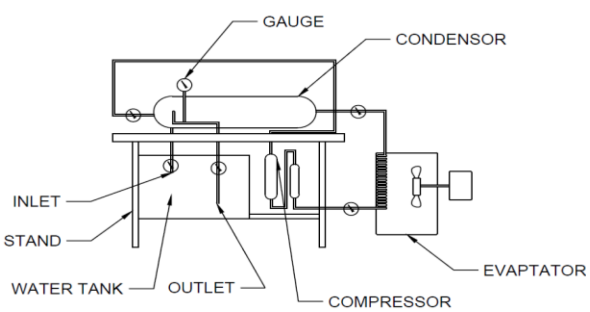

Fig 2: Line diagram of heat pump model

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The figure 1 and 2 shows the heat pump cycle and line diagram of heat pump model. Figures 3 and 4 show the experimental set up of prototype heat pump model. The supporting fabrication is done by using mild steel angles. The prototype heat pump model consists of the components like 2 numbers of condensers, compressor, evaporator, capillary tube and water tank. The compressor is 1 ton capacity reciprocating type 250V, 50Hz which compresses to maximum pressure of 280 PSI and temperature up to 110^{0}C.

Fig 3: Experimental set up

Fig 4: Experimental set up

In this model condenser and evaporator are the two heat exchangers used which works on counter flow method. Refrigerant (hot fluid) flows in the tube side and water (cold fluid) flows in the shell side. The specification of evaporator and condenser are as follows.

Heat exchangers	Condenser 1	Condenser 2	Evaporator
Configuration of heat exchangers	Coaxial, single pass and counter flow	Coaxial, single pass and counter flow	Coaxial, single pass, 1/83 HPGW, 1200 rpm
Inner /outer tube diameters	8mm/6 inch	10mm/5inch	12mm/10inch, 3 rows (cooling coil)
Total length of tubes	20 inch	21 inch	13 inch

The capillary tubes of diameter 2mm is used for expansion process. The refrigerant is expanded in 18mm diameter tube.

Experimental procedure:

The experiment was conducted to measure the rate of increase in water outlet temperature in the condenser at different pressures and mass flow rates. Refrigerant is filled to a pressure of 50, 60 and 70 PSI into the heat pump model at different intervals. Initial reading at 50PSI filling pressures both pressures and temperatures in the gauges are noted and inlet water temperature of condenser also noted. The heat pump is started and allowed to run for some time to reach steady state. The water is supplied from water tank to condenser through inlet valve using pump. After reaching the steady state, experiment is started by recording the pressure and temperature at different components of the system using temperature gauges and pressure gauges. The outlet mass flow rate and temperature of water from condenser is recorded. This procedure is repeated for 60 PSI and 70 PSI filling pressures of refrigerant and mass flow rate of water with constant time interval. The refrigeration cycle is as shown in the figure 3. The outlet water temperature recorded for different filling pressure under the variable conditions like different mass flow rate of water and evaporator fan speed at water inlet temperature is 27^{0}C.

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RESULT AND DISCUSSION:

Condenser 1 **Condenser 2**

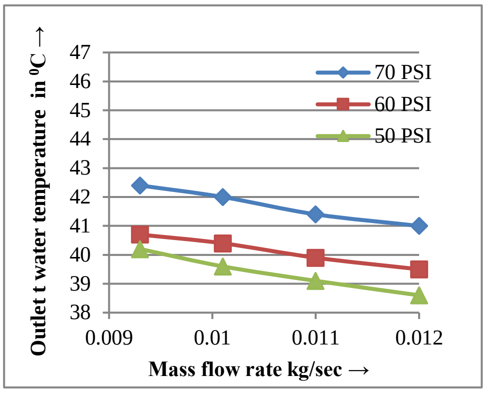

Fig. 5: T_{wo} V/s m_{wo} at 800rpm

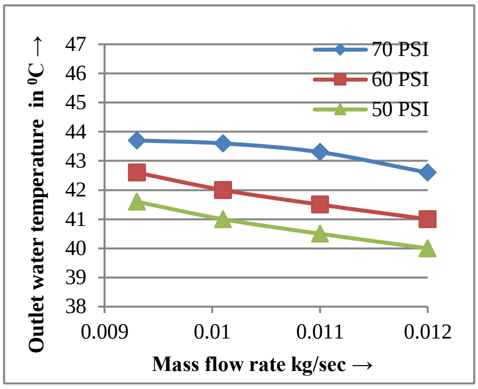

Fig 6: T_{wo} V/s m_{wo} at 800rpm

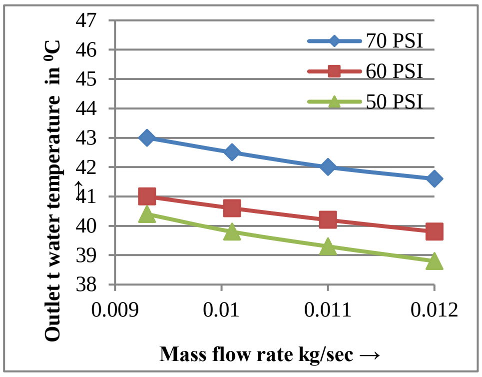

Figure 7: T_{wo} V/s m_{wo} at 1000 rpm

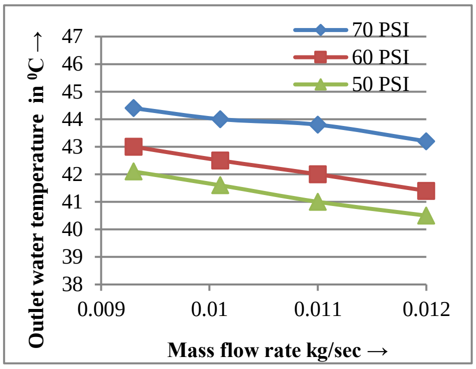

Figure 8: T_{wo} V/s m_{wo} at 1000 rpm

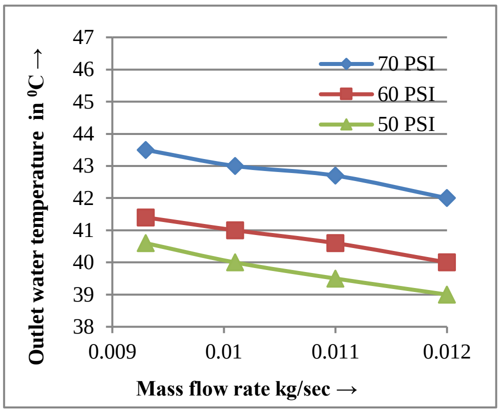

Figure 9: T_{wo} V/s m_{wo} at 1200 rpm

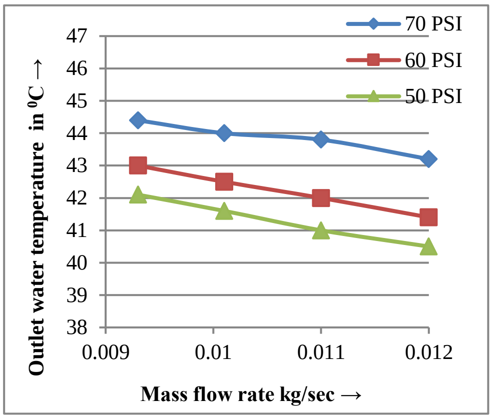

Figure 10: T_{wo} V/s m_{wo} at 1200 rpm

The experimental results of outlet water temperature of condenser (T_{wo}) versus mass flow rate of water for different pressures (50, 60 and 70 PSI)are shown for condenser 1 and 2 (different evaporator fan speed).The figures 5, 7, 9 show T_{wo} versus mass flow rate for condenser 1. The figures 6, 8, 10 show T_{wo} of condenser versus mass flow rate for condenser 2. The water is pumped from the water tank. As pressure increases, T_{wo} of condenser increases for different pressures. As mass flow rate decreases, T_{wo} of condenser increases for different pressures. The increase in T_{wo} of condenser is observed more for the pressure70 PSI and less for 50 PSI. The T_{wo} of condenser got from the experiment is in the range of 38.8^{0}C to 45^{0}C. The maximum outlet water temperature (45) is observed in condenser 2 for 1200 rpm evaporator fan speed and 70 PSI pressure. The minimum T_{wo}(38.8) is observed in condenser 1 for 800 rpm evaporator fan speed and 50 PSI pressure. The T_{wo} of condenser 2 (10 mm diameter tube used)at 1200 rpm and pressure 70 PSI is more compared to condenser 1(8 mm diameter tube used)

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because of area of contact for heat transfer is more in condenser 2.Also as the evaporator fan speed increases heat and T_{wo} increases because of quick rate heat transfer between air and refrigerant in evaporator.

CONCLUSION:

The experimental performance evaluation of CO_2 refrigerant prototype heat pump model to heat the water was performed. The parameters like different refrigerant filling pressure, evaporator fan speed and water outlet temperature at different mass flow rate are evaluated. It is observed that as increase in refrigerant filling pressure water outlet temperature increases. Increase in mass flow rate of water, decreases the outlet temperature of water in the condenser. The maximum outlet water temperature (45) is observed in condenser 2 for 1200 rpm evaporator fan speed and 70PSI pressure. The minimum T_{wo}(38.8) is observed in condenser 1 for 800 rpm evaporator fan speed and 50 psi pressure. Condenser 2 shows better performance at 70PSI refrigerant filling pressure.

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