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Evaluation of COP in CO_2 Vapor Compression Heat Pump Considering Preheating of Water

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***Abstract*:- The use of Carbon dioxide (CO_2) heat-pump is becoming more extensive in response to energy conservation requirements. The CO_2 heat pumps are the most promising technologies to reduce global warming emissions and ozone depletion. Growing environmental concerns over conventional heat pump refrigerants, chlorofluorocarbons (CFCs), and hydrofluorocarbons (HFCs) have forced researchers to look for alternative refrigerants. CO_2 is one of the few non-toxic and non-flammable working fluids that do not contribute to ozone depletion or global warming. The aim of this paper is to evaluate the COP performances by using counter flow heat exchanger at different evaporator fan speed versus mass flow rate of preheated water.**

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

NOMENCLATURE:
m_{wo} Mass flow rate of water
COP Coefficient of Performance
GWP Global Warming Potential
ODP Ozone Depletion Potential
psi Pound Force per Square Inch

INTRODUCTION:

As the cost of energy continues to rise, it becomes imperative to save energy and improve overall energy efficiency. In this light, the heat pump becomes a key component in an energy recovery system with great potential for energy saving [1]. Carbon dioxide (CO_2) has environmentally friendly characteristics, zero ODP and extremely low GWP and is being encouraged as one of the natural refrigerants to substitute CFCs and HCFCs in vapor compression systems [2]. 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 [3]. In order to improve the system performance of the CO_2 heat pump, it is necessary to develop an ideal design and a control method for the CO_2 heat pump water heater [4].

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 [5]. Therefore, naturally available refrigerant like CO_2 is used as a refrigerant [6]. It has many advantages like eco friendly, low cost, non flammable, non corrosive, non toxic, stable and suitable for wide range of operating conditions [7]. The heat pump consists of compressor, condenser, evaporator and capillary tube [8] which is best suitable for domestic water heater [9].
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 [10]. The variation of speed of compressor and evaporator affect the performance of the heat pump [11]. The experiment was conducted to evaluate the COP for different mass flow rate, different refrigerant filling pressure and evaporator fan speed.

EXPERIMENTAL SET UP:

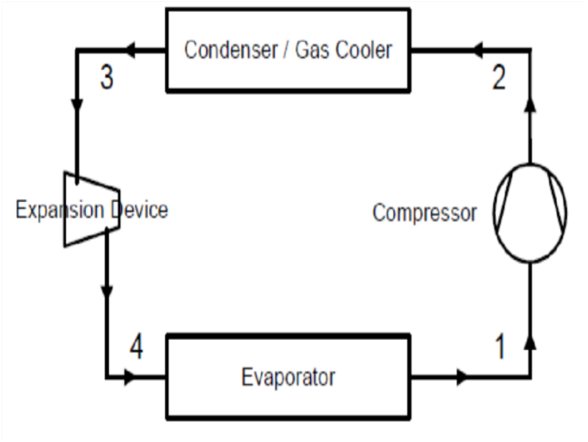

Fig 1: Heat pump cycle

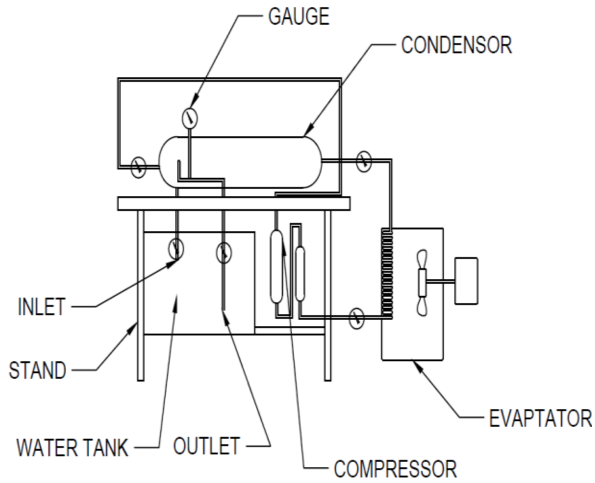

Fig 2: Line diagram of heat pump model

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 COP at different mass flow rate of water in the condenser at different pressures. Refrigerant is filled to a pressure of 60 and 70 PSI into the heat pump model at different intervals. Initial reading at 60PSI 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 and it is preheated to 36ºC. 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 temperature of water from condenser is recorded and mass flow rate is varied to different fan speed. This procedure is repeated for 70 PSI filling pressures of refrigerant. 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 spee

RESULT AND DISCUSSION:

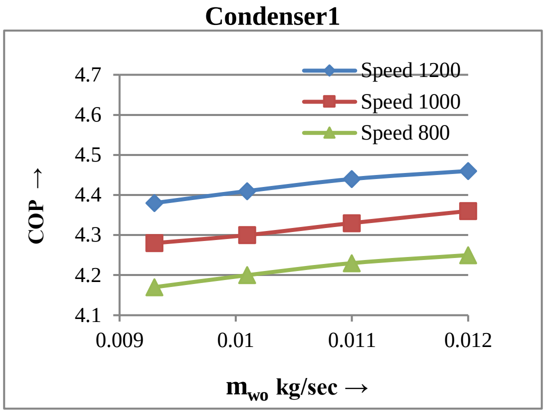

Figure 5 : COP versus m_{wo} at 60 psi

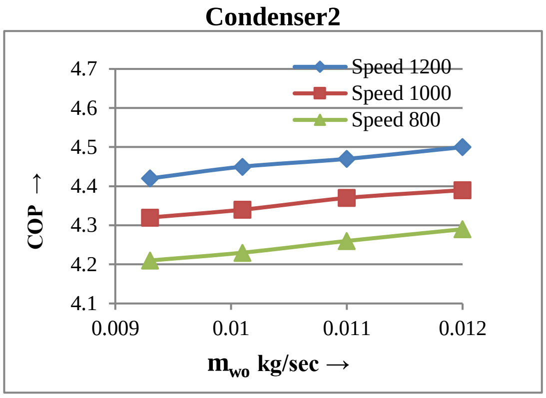

Figure 6 : COP versus m_{wo} at 60 psi

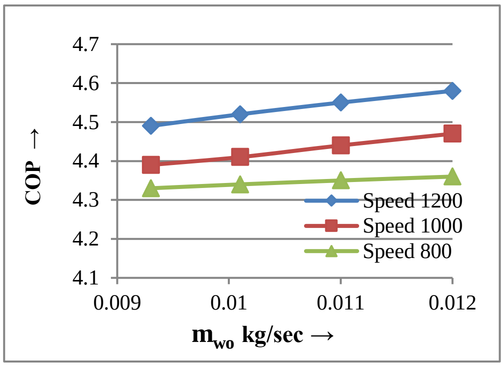

Figure 7 : COP versus m_{wo} at 70 psi

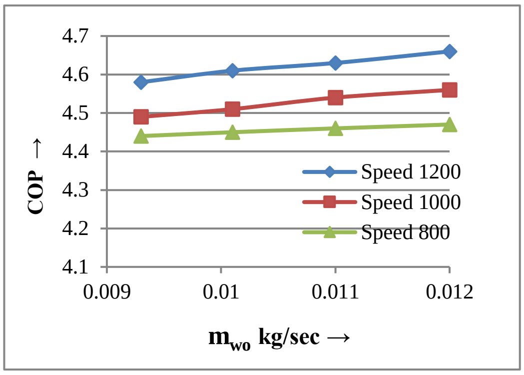

Figure 8 : COP versus m_{wo} at 70 psi

The experimental results of COP versus mass flow rate of water for different pressures (60 and 70 PSI) are shown for condenser 1 and 2 (different evaporator fan speed).The figures 5 and 7 show COP versus mass flow rate for condenser 1. The figures 6 and 8 show COP of condenser versus mass flow rate for condenser 2. The water is pumped from the water tank and it is preheated to 36ºC. The increment of COP is observed with respect to increase in pressure, mass flow rate corresponding to increments of the fan evaporator speed. It is observed that as increase of mass flow rate water increases the COP at different evaporator fan speed. In condenser1, minimum COP (4.17) recorded at 60 psi pressure and 800 rpm fan speed of the evaporator. The maximum and minimum COP is recorded as 4.58 and 4.17 in condenser1 and 4.66 and 4.21 in condenser2 respectively. More COP is observed in the fan speed of evaporator 1200 rpm compared to 1000 rpm and 800 rpm. The COP is recorded around 4.17 to 4.46 in the condensers. In condenser2, maximum COP (4.46) is achieved for 1200 rpm fan speed of the evaporator at a pressure of 70 psi. By comparing the COP performance between the condenser1 and 2, condenser2 shows the better performance.

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 with preheating are evaluated. The increase in inlet temperature of water supplied to condenser increases the performance of COP. The COP is additionally enhanced by the water preheating. The increase in pressure increases the COP of the heat pump because of increase in thermodynamic properties (temperature and volume) of the refrigerant to transfer more heat to cooling fluid in the condenser.

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