Thermal Analysis of Vapour Compression Refrigeration System with R22, 4404A, R407C and R410A Refrigerants

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Abstract- Refrigeration and air conditioning (RAC) play a very important role in modern human life for cooling and heating requirements. This area covers a wide range of applications starting from food preservation to improving the thermal and hence living standards of people. The utilization of these equipment's in homes, buildings, vehicles and industries provides for thermal comfort in living/working environment and hence plays a very important in increased industrial production of any country. On the basis of comparison of COP with different refrigerant, VCRS with R22 has max. COP as compared to others. Max. Compressor work with R407C is achieved i.e. 28.57 KJ/Kg. Max. Heat rejected from evaporator and condenser is achieved with 22 i.e. 147.9 KJ/Kg. Therefore, R22 can be used for achieving maximum COP with VCRS.

Keywords- Thermal Analysis, Vapour Compression Refrigeration System, with R22, 4404A, R407C and R410A..

INTRODUCTION

Refrigeration and air conditioning (RAC) play a very important role in modern human life for cooling and heating requirements. This area covers a wide range of applications starting from food preservation to improving the thermal and hence living standards of people. The utilization of these equipment's in homes, buildings, vehicles and industries provides for thermal comfort in living/working environment and hence plays a very important in increased industrial production of any country.

Due to the increasing demand of energy primarily for RAC & HP applications (around 26-30%) this leads to degradation of environment, global warming and depletion of ozone layer etc., to overcome these aspects there is urgent need of efficient energy utilization besides waste heat recovery for useful applications especially after the Kyoto and Montreal protocols. The scientific community is eagerly concentrating on the alternate and environment friendly refrigerants, especially after the Kyoto and the Montreal protocols.

However, in a quest to find out the alternate and environment friendly refrigerants, the energy efficiency of this equipment's while using conventionalrefrigerants is also very important. The CFCs and HCFCs remain as refrigerant fluids of choice for various applications for many years and now non-ozone depleting HFCs became favoured. The Montreal protocol banned production and consumption of ozone depleting compounds in 1987 and also accelerated the rate of phasing out of CFC andHCFC in order to reduce ozone depletion, and this was only possible by using HFCs in many applications. The Kyoto protocol laid down goals for the reduction of global warming substances in the year 1997 and subsequently the heat pump industry has consequently been forced to look for substitutes of CFCs and HCFCs.

In many applications hydrocarbons have been used but this has been limited by safety considerations. Energy saving and climate change is the outcome of system design, which includes the selection of refrigeration cycle, the working fluid (refrigerant), and the minimization of refrigerant quantity and leakage. It also relates to the installation, the service procedures, and the improvement of energy efficiency to reduce the direct emissions of carbon dioxide into the atmosphere.

In view of shortage of energy and a quest to conserve it in all possible ways energy conservation is becoming a slogan of the present decade and new methods to save energy which is otherwise wasted are being explored. Energy recovery from waste heat and/or to utilize it for useful applications to improve the system efficiency is growing concern in scientific community and hence, is in use for industrial installations now-days.

Ever present energy crises have forced the scientists and engineers all over the world to take into account the energy conservation measures in various industries. Reduction of electric power and thermal energy consumption are desirable but unavoidable in view of the fast and competitive industrial growth throughout the world. Refrigeration and air conditioning systems form a vital component for the industrial growth and affect both the food and energy problem of a country at large. RAC systems are also a major contributor to the energy consumption. Therefore it isdesirable to provide a base for energy conservation and waste heat energy recoveryfrom RAC & HP systems.

II. LITERATURE REVIEW

Selladurai, et, al [1] they perform test execution contemplate on a vapor pressure refrigeration framework with the new R290/R600a refrigerant blend and contrasted and CFC12 and HFC134a. The vapor pressure refrigeration framework was at first dealt with the in view of refrigerant R12. Exploratory outcomes demonstrated indicated somewhat bring down refrigerating limit than R12.

Kaushik, et, al [2] In this paper point by point exergy examination of a genuine vapor pressure refrigeration (VCR) cycle was broke down. For ascertaining coefficient of execution (COP), exergy productivity, exergy pulverization and effectiveness deserts a computational model has been created for R502, R404A and R507A refrigerants. Examination and examination prepare has been accomplished for evaporator and condenser.

Mohanraj et. al, [3] It speak to exploratory examination did by utilizing hydrocarbon refrigerant blend contain of R290 and R600a in the proportion of 45.2:54.8 by weight as another option to R134a. Exploratory examination completed in a 200l single evaporator local fridge.

Masjukiet. al [4] In this paper surveys of looks into in the field of exergy examination in different segments and in usable divisions where vapor pressure refrigeration frameworks are utilized.

Joybari et. al. [5] worked on analysis of exergy for the domestic refrigerator which originally manufactured for R134a. On the basis of the investigation the field of exergy examination in different parts and in usable divisions where vapor pressure refrigeration frameworks are utilized.

Boenget. al. [6] worked on the behavior of a household refrigerator. In which experimental thermodynamic analysis was performed. In those experiments simultaneously changing the refrigerant charge and the development limitation test perform.

Greco, et, al [7] In this paper relative exergetic examination, completed with exploratory tests. Examination worked performed amongst R1344a and common refrigerant liquid R744 (CO_2). R134a is a hydrofluorocarbon with a high an Earth-wide temperature boost affect (GWP), while the R744 less an unnatural weather change affect. This paper looks at R134a refrigeration plant and a model R744 framework which working in a trans-basic cycle.

Mohanraj et. al. [8] has present work on the theoretically energy performance of a domestic refrigerator with R134a and R430A as option refrigerant. In that the execution has been completed for with an extensive variety of evaporator temperatures amongst −30 and 0 °C and three diverse consolidating temperatures, particularly, 40, 50 and 60 °C. In this study, thermal analysis of vapour compression refrigeration system with R22, R404A, R407C and R410A refrigerants have been studied and the effect of condenser temperature & evaporator temperature performance parameteron COP has also been done.Thermodynamic analysis is carried out by developingcomputational model in Engineering Equation solver (EES).

III. SYSTEM MODELLING

In the “ideal” vapour compression cycle, the refrigerant exit states from the condenser and the evaporator are on respective saturation lines. Beginning with state point 1, the saturated vapour refrigerant leaving the evaporator is compressed is entropically to the desired condenser saturation pressure by inputting mechanical work (process 1-2). The discharged vapour refrigerant is de-superheated and condensed by expelling heat through the wall of the condenser to another external fluid, which is usually air or water (process 2-3). The saturated liquid refrigerant leaved the condenser and enters the expansion device where some of the refrigerant is flashed at constant enthalpy (process 3-4), causing the remaining liquid portion to be at the desired temperature and pressure needed for a particular evaporator operating condition. The price paid for this process is that the entire refrigerant is not available for the vaporization process in the evaporator (process 4-1).

The heat transferred to the refrigerant in the evaporator is called the refrigerating effect. For the purpose of rating the system's performance, for either the heating or cooling application, the efficiency term is the COP. It is, as all efficiency terms are, the desired output (e.g., the refrigerating effect) divided by the work input which, in this case, is the work input to the compressor.

Different refrigerants provide the desired product with more or less effectiveness. The desired product for a cooling application is the heat entering the evaporator. Considering the refrigeration system in the p-h diagram in Figure 3.1, the following assumptions are made:

1. Evaporation is at constant pressure (Pe) and constant temperature (Te) in the evaporator from point 4 to point 1. The heat absorbed by the refrigerant in the evaporator or refrigerating e□ect (Qevap, kJ/kg) is given as:

$$Q_{evap} = (h_1 - h_4)$$

Where, h1 is specific enthalpy of refrigerant at the outlet of the evaporator (kJ/kg), and h4 is specific enthalpy of refrigerant at the inlet of the evaporator (kJ/kg).

2. An isentropic compression process is in the compressor, from point 1 to point 2. The compressor work input (Wcomp, kJ/kg) is:

Wcomp=(h2-h1); (2)

Where, h2 is specific enthalpy of refrigerant at the outlet of the compressor (kJ/kg).

3. A de-superheating is at constant pressure (Pc), from compressor discharge temperature (T2) atpoint 2 to condenser temperature (Tc) at point 20, followed by a condensation at both constant temperature (Tc) and constant pressure (Pc) from point 20 to point 3. The heat rejected in the condenser (Qcond , kJ/kg) is:

Qcond = (h2 - h3);

Where, h3 is specific enthalpy of refrigerant at the outlet of the condenser (kJ/kg).

4. An expansion is at constant enthalpy (is enthalpy) in the throttling valve from point 3 to point 4. Therefore,

h3 = h4:

The Coefficient of Performance (COP) is the refrigerating effect produced per unit of work required; therefore, COP is obtained as the ratio of Eq. (1) to Eq. (2) for the refrigeration system and Eq. (3) to Eq. (2) for the heat pump system:

$$COP = \frac{Q_e}{W_c}$$

IV. RESULTS AND DISCUSSION

In the present work thermodynamic model has been developed in Engineering Equation Solver software and results of the analysis have been given in the following sections. For comparison simulation of cycle has been done at initial conditions i.e. at evaporator temperature of 10°C and condenser temperature of 57°C.

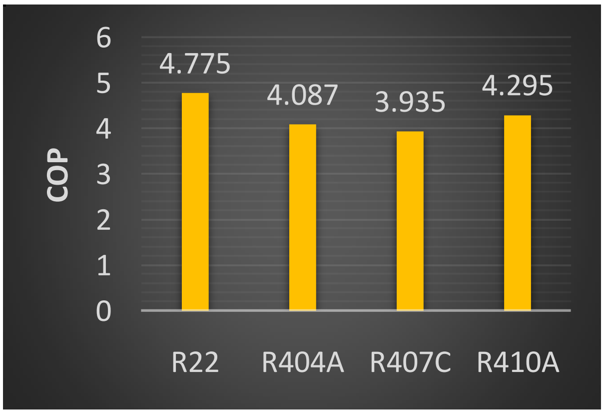

Fig 1. Comparison of COP with different refrigerant.

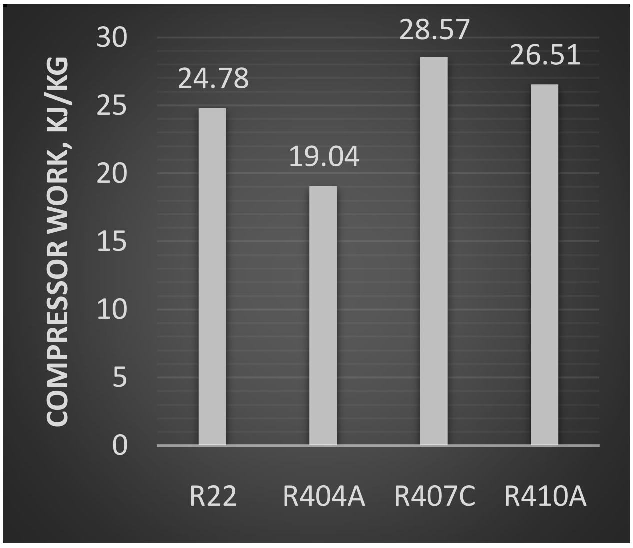

Fig 2. Comparison of compressor work with different refrigerant.

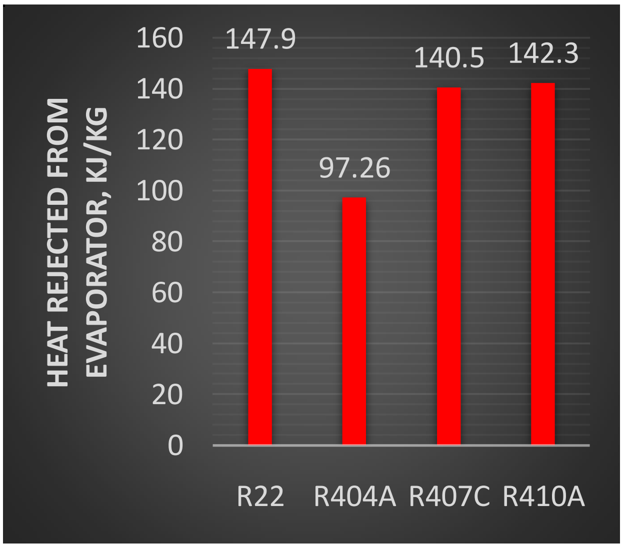

Fig 3. Comparison of heat rejected from evaporator with different refrigerant.

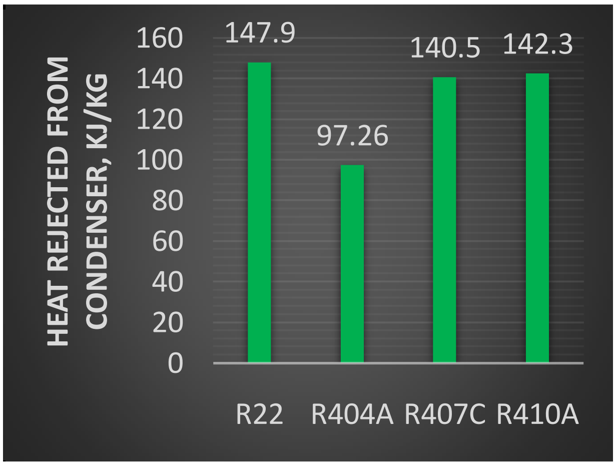

Fig 4. Comparison of heat rejected from condenser with different refrigerant.

On the basis of comparison of COP with different refrigerant, VCRS with R22 has max. COP as compared to others. Max. Compressor work with R407C is achieved i.e. 28.57 KJ/Kg. Max. Heat rejected from evaporator and condenser is achieved with 22 i.e. 147.9 KJ/Kg. Therefore, R22 can be used for achieving maximum COP with VCRS.

V. CONCLUSION

On the basis of comparison of COP with different refrigerant, VCRS with R22 has max. COP as compared to others. Max. Compressor work with R407C is achieved i.e. 28.57 KJ/Kg. Max. Heat rejected from evaporator and condenser is achieved with 22 i.e. 147.9 KJ/Kg. Therefore, R22 can be used for achieving maximum COP with VCRS. When initially evaporator temperature varied from 10°C to 28°C in the interval of 2°C keeping other parameters constant. Results indicate that COP increases with increase in evaporator temperature with different refrigerants. When initially evaporator temperature varied from 10°C to 28°C in the interval of 2°C keeping other parameters constant. Results indicate that heat rejected from condenserdecreases with increase in evaporator temperature with different refrigerants.

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