Thermodynamic Analysis of Vapour Compression Refrigeration System

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***ABSTRACT*: Refrigeration may be defined as the method to attain and keep a bounded space at a temperature lower than its nearby temperature. This is done by constant removal of heat from the enclosed space whereas the temperature is below than that of the surrounding temperature. Nowadays refrigeration is something that is very important in our daily life. Thermodynamic analysis of the vapor compression refrigeration cycle has been undertaken to enhance the COP of vapor compression refrigeration system. Comparison among the investigated refrigerants confirmed that R22 and R134a have approximately the same performance, but the best performance was obtained from the used of R152a in the system.**

***Keywords*: Refrigerant, Thermodynamic, COP, R134a, R22, R152A, R32, Condenser.**

I. INTRODUCTION

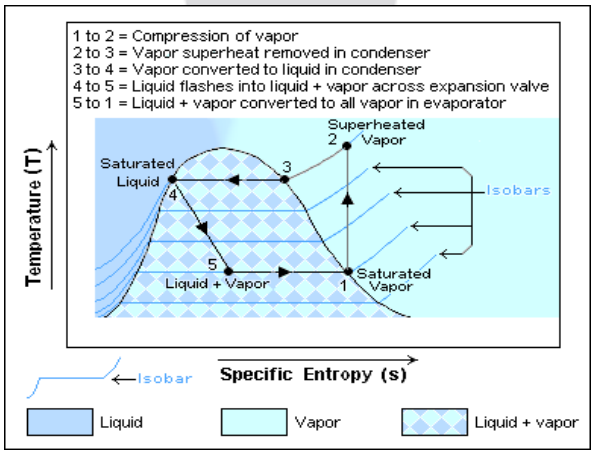
Nowadays refrigeration is something that is very important in our daily life. One of the greatest important applications is the protection of fresh foods and keeps the food in fresh condition. There is no uncertainty that food, is just like air and water are requirements for livelihoods. People frequently use refrigeration to freezing their drinks, making it tastier. In additional, refrigeration also presence used in providing thermal comfort to people by means of air conditioning process. In general refrigeration systems can be categorized in 3 main cycle systems which are vapor compression refrigeration system, vapor absorption refrigeration system, and gas cycle refrigeration system. However the vapor density refrigeration system is the most extensively used in the refrigeration process. The vapor compression refrigeration system comprises 4 main components which are compressor, condenser, expansion device, and evaporator.

The amount of refrigerant does give important effect on the performance of the refrigeration system. Theoretical study of VCRS will be done for R134a, R22, R152A, R32 refrigerant. For the same system Pc, Pe, Tc, Te limit as independent variable and COP as impartial purpose will be considered and with p-h and T-s chart. Analysis of vapor compression system will be done and from that the results for optimum COP based on calculation of parameters mentioned. Analysis will be carried out by EES software for 4 different refrigerants (R134A, R22, R152, and R32). Thermodynamic analysis of the vapor compression refrigeration cycle has been assumed to enhance the COP of vapor compression refrigeration system. Comparison among the investigated refrigerants confirmed that R22 and R134a have almost the same performance, but the best performance was obtained from the used of R152a in the system. The COP of R152a obtained was higher than those of R134a, R22, and R32. Also, R152a offers the best desirable environmental requirements; zero Ozone Depleting Potential (ODP) and very low Global Warming Potential (GWP).

II. THERMODYNAMIC ANALYSIS OF REFRIGERATION SYSTEM

The below discussion is based on the ideal vapor-compression refrigeration cycle which does not take into account real world items like frictional pressure drop in the system, slight internal irreversibility during the compression of the refrigerant vapor, or non-ideal gas behavior.

Fig 1: Temperature–Entropy diagram



The thermodynamics of the vapor compression cycle can be

investigated on a temperature against entropy diagram as depicted in Figure 1. At point 1 in the diagram, the circulating refrigerant enters the compressor as a saturated vapor. From point 1 to point 2, the vapor is isentropically compressed and exits the compressor as a superheated vapor.

From point 2 to point 3, the superheated vapor travels over part of the condenser which removes the superheat by cooling the vapor. Between point 3 and point 4, the vapor travels through the remainder of the condenser and is condensed into a saturated liquid. The condensation process occurs at essentially constant pressure.

Between points 4 and 5, the saturated liquid refrigerant passes through the expansion valve and undergoes a quick decrease of pressure. That procedure results in the adiabatic flash evaporation the adiabatic flash evaporation process is isenthalpic .

Between points 5 and 1, the cold and incompletely vaporized refrigerant travels through the coil or tubes in the evaporator where it is completely vaporized by the warm air that a fan circulates through the coil or tubes in the evaporator. The evaporator operates at essentially constant pressure. The resulting soaked refrigerant vapor returns to the compressor inlet at point 1 to complete the thermodynamic cycle.

3.1 THEORETICAL CONSIDERATION OF EXERGY

We might express the energy and exergy ideas in the following simple terms: (1) Energy is motion or ability to produce motion and (2) Exergy is work or ability to produce work. The laws of thermodynamics may be formulated accordingly: (1) Energy is always conserved in a process (First law, the law of energy conservation) and (2) Exergy is always conserved in a reversible process, but is always consumed in an irreversible process (Second law, the law of exergy). Exergy is that part of energy that is convertible into all other forms of energy. Exergy is a general concept of quality, i.e. the physical value of a system in the form of how large a quantity of purely mechanical work can be extracted from the system in its interaction with the environment.

Exergy-based thermoeconomic investigates have many applications. Power cycles, mainly power plants, are frequently investigated and optimized using exergy-based thermos economics. Energy analysis can be used in examining domestic refrigeration systems, too. Various refrigerants have been observed using methods of energy destruction to see which causes the least exergy destruction in specific components of the refrigeration cycle and for the system over all. This approach has been particularly useful for comparing alternative refrigerants to R12. For example, one study examined a refrigerator cycle and a separate freezer cycle and found that the component that destroyed the most exergy in the system was the compressor followed by the evaporator and then the condenser.

Refrigeration cycles can also be improved for a given set of operating conditions to minimize the overall exergy destruction of the system. Considering a table-top size, single compartment R-12 refrigerator, Dingeç and İleri, optimized the thermoeconomics of Turkish refrigerators.

They resolved that the optimum condenser area should be larger than that of the evaporator and that the compressor should have an isentropic efficiency of approximately 36%.They also concluded that the cost curve for the compressor has a strong effect on the optimized system design.

3.2 MATHEMATICAL MODELING

3.2.1 Assumption

1. For analysis, surrounding temperature $T_0=27^0C$
2. Degree of superheating and Degree of sub cooling are neglected during the analysis of vapor compression refrigeration cycle.

3.2.2 Governing equation

1) Compressor:

Compressor is a steady flow machine for reversible adiabatic or isentropic compression of 1 kg of vapor, the shaft work/kg input is given by

$$w_c = (h_2 - h_1)$$

Where w_c is shaft work; h2 and h1 are enthalpies at suction and delivery of the compressor respectively.

2) Condenser:

The heat removed is given by

$$q_3 = (h_3 - h_2)$$

Where q_3 is the heat removed in the condenser;h_3 is the enthalpy of liquid/kg leaving the condenser

3) Throttle valve:

Steady flow process throttle expansion is a constant enthalpy process. There is no work or heat transfer is given by

$h_3=h_2$

4) Evaporate:

Steady flow process.no work done. Heating at constant pressure. The heat absorb/kg is given by

$q_1=(h_1-h_4)$

5) co-efficient of performance:

$$COP=\frac{q_1}{W_c}$$

$$COP=\frac{h_1-h_4}{h_2-h_1}$$

3.3 ANALYSIS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM

For analysis of mentioned refrigerants with EES software, assumptions has been taken are:

1. For analysis, surrounding temperature $T_0=27^0C$
2. Degree of superheating and Degree of sub cooling are neglected during the analysis of vapor compression refrigeration cycle.

To obtain better COP for vapor compression refrigeration system from different refrigerants (R134a, R152a, R32, and R22) and for different sets of temperature of evaporator and condenser with defined range, further analysis has been done by EES software

III. RESULT AND DISCUSSION

We have done the analysis of vapor compression refrigeration system for four different refrigerant mentioned above and the result obtained is given below;

1) R134a

Table:1(a) Evaporate Temperature/s COP

T1=TE	T2'=TC	RE	WD	COP
-10	36	142.2	31.5	4.513
-11	36	141.6	32.33	4.379
-12	36	141	33.17	4.25
-13	36	140.4	34.01	4.127
-14	36	139.8	34.87	4.009

Table:2(b): Condenser Temperature v/s COP

T1=TE	T2'=TC	RE	WD	COP
-10	36	142.2	31.5	4.513
-10	37	140.7	32.08	4.385
-10	38	139.2	32.66	4.262
-10	39	137.7	33.24	4.144
-10	40	136.3	33.81	4.03

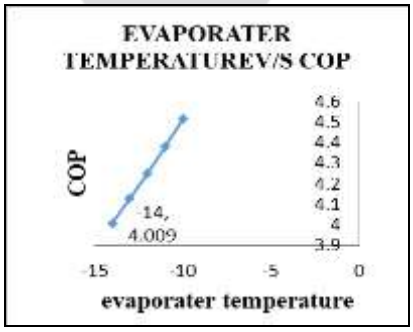


Fig:2(a) Evaporate Temperature/s COP

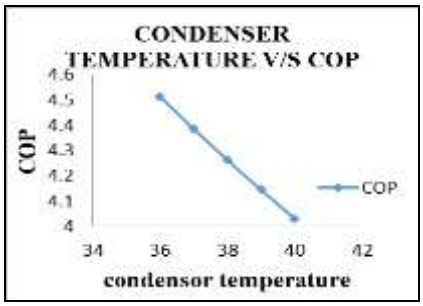


Fig: 3(b) Condenser Temperature v/s COP

2) R22:

Table:3(c) Evaporator Temperature v/s COP

T1=TE	T2'=TC	RE	WD	COP
-10	36	156.6	34.22	4.575
-11	36	156.2	35.15	4.443
-12	36	155.8	36.09	4.316
-13	36	155.3	37.04	4.194
-14	36	154.9	38	4.007

Table: 4(d) Condenser Temperature v/s COP

T1=TE	T2'=TC	RE	WD	COP
-10	36	156.6	34.22	4.575
-10	37	155.3	54.89	4.45
-10	38	153.5	35.56	4.33
-10	39	152.6	36.22	4.214
-10	40	151.3	36.88	4.102

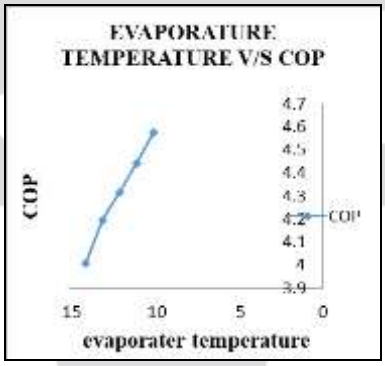


Fig: 4(c) Evaporator Temperature v/s COP

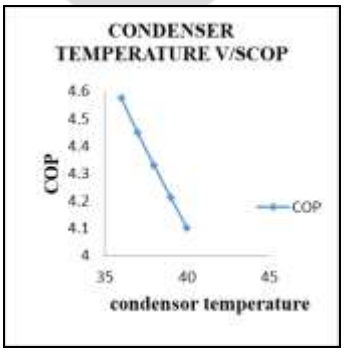


Fig: 5(d) Condenser Temperature v/s COP

3) R152a:

Table 5 (e): Evaporator Temperature v/s COP

T1=TE	T2'=TC	RE	WD	COP
-10	36	235.4	49.98	4.711
-11	36	234.7	51.31	4.575
-12	36	234	52.66	4.444
-13	36	233.3	54.01	4.319
-14	36	232.6	55.39	4.199

Table 6 (f): Condenser Temperature v/s COP

T1=TE	T2'=TC	RE	WD	COP
-10	36	235.4	49.98	4.711
-10	37	233.6	50.94	4.585
-10	38	231.7	58.89	4.465
-10	39	229.8	52.84	4.349
-10	40	227.9	53.78	4.237

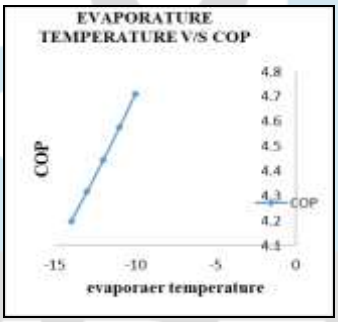


Fig: 6(e) Evaporator Temperature v/s COP

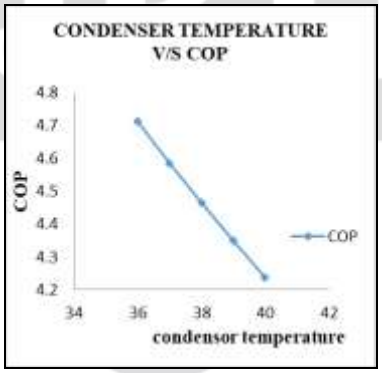


Fig: 7(f) Condenser Temperature v/s COP

4) R32

Table 7(g): Evaporator Temperature v/s COP

T1=TE	T2'=TC	RE	WD	COP
-10	36	245.7	55.61	4.417
-11	36	245.4	57.22	4.289
-12	36	245.1	58.85	4.165
-13	36	244.8	60.48	4.048
-14	36	244.5	62.15	3.935

Table 8 (h): Condenser Temperature v/s COP

T1=TE	T2'=TC	RE	WD	COP
-10	36	245.7	55.61	4.417
-10	37	243.6	56.75	4.292
-10	38	241.5	57.89	4.172
-10	39	239.5	59.03	4.057
10	40	237.4	60.16	3.946

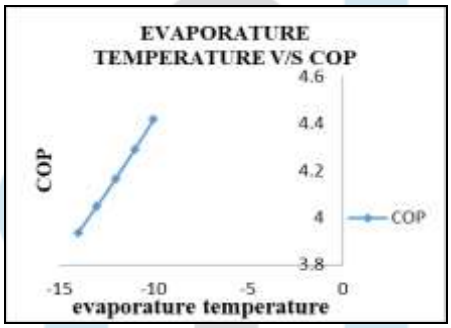


Fig.8(g): Evaporature Temperature v/s COP

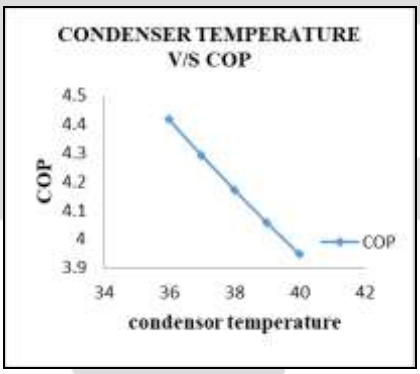


Fig 9(h): Condenser Temperature v/s COP

1. Effect of evaporate temperature on COP for fixed condenser temperature TC=36ºC is decrease in COP with decrease in evaporate temperature

2. Effect of condenser temperature on COP for fixed evaporate temperatures=-10ºC is decrease in COP with increase in condenser temperature.

V. DISCUSSION

5.1 ADVANTAGES

- Very mature technology.
- Relatively inexpensive.

- Can be driven directly using mechanical energy (water, car/truck motor) or with electrical energy.
- Effective up to 60% of Carnot's theoretical limit based on some of the best compressors produced by Danfoss,

5.2 CONCLUSION

The analysis has been done for refrigerants R134a, R152a, R22, and R32. From that we came to obtain optimum COP for R152a compare to other refrigerants. Comparison among the investigated refrigerants confirmed that R22 and R134a have approximately the same performance, but the best performance was obtained from the used of R152a in the system. As a result, R152a could be used as a drop-in replacement for R134a in vapour compression refrigeration system. The COP of R152a obtained was higher than those of R134a, R22, and R32. Also, R152a offers the best required environmental supplies; zero Ozone Depleting Potential (ODP) and very small Global Warming Potential (GWP).

5.4 FUTURE SCOPE

Further if the work is done or more advancement is carried out for vapor compression refrigeration system, higher COP can be obtain with increase in evaporator temperature as well as decrease in condenser temperature.

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