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An Experimental Investigation and Performance Evaluation of VCRS system by Varying Mass Flow Rate and Ambient Temperature of Refrigerants R-12 and R-134a

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Abstract—*From a long time improving COP of vapour compression refrigeration system and optimising its performance has been a major challenge for the engineers. Now we are trying to solve the problem by capacity modulation (variable refrigerant flow) technique. In this paper we worked on two different refrigerants at two different ambient temperatures, one being 25°C and the other 30°C. The first refrigerant was R-12 and the second was R-134a. Each of the refrigrants had two different mass flow rates as 0.0028kg/s and 0.0053kg/s. For R-12 the COP was found to be 2.66 and 2.19 at ambient temperatures of 25°C and 30°C respectively corresponding to mass flow rate of .0028 kg/sec. Similarly the COP was found to be 3.30 and 2.64 at ambient temperatures of 25°C and 30°C respectively for mass flow rate of .0053 kg/sec.*

For refrigerant R-134a the COP was found to be 2.30 and 1.93 at ambient temperatures 25°C and 30°C respectively corresponding to flow mass rate .0028 kg/sec. Similarly the COP was found to be 2.72 and 2.43 at ambient temperatures 25°C and 30°C respectively for mass flow rate .0053kg/sec. Hence it was observed that the COP increased with increasing the mass flow rate of the refrigerant. Also, at the same mass flow rate and same ambient temperature COP of R-12 was found to be better than COP of R-134a.

Keyword*: Vapour Compression Refrigeration System, variable refrigerant flow rate, air cooled condenser, COP, refrigerants (R-12 & R-134a).*

1. INTRODUCTION

Refrigeration is the science of producing and maintaining temperatures below that of the surrounding atmosphere, this means removing of heat from a substance which is to be cooled. Refrigeration or air conditioning is a kind of heat pump whose function is to remove heat from a lower temperature. Out of all refrigeration systems the vapour compression refrigeration system (VCRS) from the view point of commercial and domestic utility, it is the most practical form of refrigeration.

In this paper we are using two different refrigerants R-12 and R-134a. Here, we are mainly focusing on flow rate of refrigerants, by controlling the mass flow rate (capacity modulation technique) we are trying to enhance the performance of VCRS system and reducing the power consumption. Nowadays capacity modulation technique is emerging trend in the air conditioning industry for both residential and commercial application. There are two technologies that can provide capacity modulation inverter and digital scroll.

For R-12 with the increase in refrigerant mass flow rate, there is increase in COP of about 24%. And for R-134a with the increase in refrigerant mass flow rate there is increase in COP of about 18% which further decreases the power consumption.

Wang and Hihara (2003) [1] proposed an equivalent dry-bulb temperature (EDT) method to analyse the cooling and dehumidifying performance of refrigeration and air-conditioning systems. This method could predict the totally dry, wet and partially wet cooling modes. The simulation model was validated by experimental data and the deviation was found to be within 10%.

Ma et al (2005) [2] conducted the experiments and developed a correlation to predict the mass flow co-efficient for the flow of refrigerantsR22, R407C and R410A through EEVs of six different geometries made of copper. By choosing the parameters such as EEV head geometry, EEV inlet conditions, EEV outlet conditions and refrigerant properties and using Buckingham pi Theorem, the correlations for the refrigerant mass flow coefficient (CD) for EEV was predicted. The performance of the EEVs with several half taper and inner diameter combinations for R22 and its alternatives R407C and R 410 A were experimentally investigated. The mass flow rates of R407C are greater by 4.25 %, and those of R410A are greater by 22.70 % on average, than those of R22. R410A shows the highest flow co efficient (CD) 30 for given condensing temperatures mainly because of its higher saturation pressure than the other fluids.

Chen (1999) [3] conducted a performance analysis of VCR systems by computer simulation for R12 and R134a. The test results indicated that the COP of R134a was less than that of R12. Though the refrigeration capacity of R134a was more than that of R12, because of the increased power consumption of R134a the COP decreases.

Zhang et al (2006) [3] developed a dimensionless correlation on the basis of experimental data to predict the mass flow rate of R22 and its alternative R407C through an EEV. The mass flow rate was measured at a series of condensing temperatures, evaporating temperatures and degree of sub cooling at the EEV inlet with five opening setting degrees of the EEV such as 100, 200, 300, 400 and 500 pulses. By analyzing the experimental data and found that the operating conditions, flow area and the thermo physical properties of the refrigerant would affect the mass flow rate through the EEV. The predicted correlations based on Buckingham pi Theorem, can be used to predict the mass flow rate through EEVs whose biggest flow area is less than 2.544 mm^2.

K. Mani and V. Selladurai [5], have analyzed a vapour compression refrigeration system with the new R290/R600a refrigerant mixture as drop-in replacement was conducted and compared with R12 and R134a. The VCRS was initially designed to operate with R12.The results showed that the refrigerant R134a showed slightly lower COP than R12. The discharge temperature and discharge pressure of the R290/R600a mixture was very close to R12. The R290/R600a (68/32 by wt %) mixture can be considered as a drop-in replacement refrigerant for R12 and R134a.

Zhiyuan et al (2010) conducted a series experiments and theory studies on EEVs and found that the refrigerant mass flow rate through EEV is increasing with increase in sub cooling of refrigerant, increase in condenser temperature and increase in number of pulses and decreasing with increase in evaporator temperature. Also, refrigerant mass flow rate is depending up on the method of EEV connection (i.e. shaft in and side out method or side in and shaft out method).

2. EXPERIMENTAL SETUP AND WORKING

The experimental setup consists of four main parts. These are compressor, condenser, expansion valve and evaporator (shown in Fig. below).The vapour at low temperature and pressure enters the compressor where it is compressed isentropically and subsequently its temperature and pressure increase considerably. The vapour after leaving the compressor enters the condenser where it is condensed into high pressure liquid and from condenser it is passes through the expansion valve here it is throttled down to a lower pressure and a lower temperature. Through expansion valve it finally passes onto evaporator where it extracts heat from the surrounding to be cooled.

Fig. 1: Fig. showing experimental setup.

The setup consists of the following components:

Compressor: Here the working fluid (refrigerant) is isentropically compressed to a superheated state and then moved to the condenser. Hermetic sealed type compressor used in the setup. Compressor operates in a sealed space with lubricating oil.

Specification: Hermitically sealed gas compressor with electrical accessories

Model: KCJ44HAG-B220H

Rated Power Supply: 230V50Hz1PH

Rated Power Consumption: 450W

Output Rated Cooling Capacity: 932 kcal/h

Condenser: Condenser is an important device used in high pressure side of refrigeration system. Its function is to remove heat of the vapour refrigerant discharged from the compressor. Here the superheated vapour is condensed isothermally to the saturated liquid state. Forced convection air cooled type condenser is used in this setup.

Specifications:

Diameter of condenser pipe=3/8”

Length of pipe= 13”

Material of pipes-Copper

Capillary tube or expansion valve: The capillary tube is used as an expansion device in small capacity domestic refrigerators. Here the condensed fluid is throttled and expanded with an isenthalpic process.

Specifications:

Diameter: 0.5mm to 2.5mm

Length: 0.5m to 5 m

Capillary tube used: 40 No. capillary

Evaporator: The evaporator is an important device used in low pressure side of refrigeration system. The evaporator is used to absorb heat from the surrounding location or medium which is to be cooled by means of refrigerant.

Specifications:

Making of evaporator: Copper pipes of following making were selected

Size: 3/8”*0.56mm*50’

Standard: ASTMB68

The dimensional features of the evaporator assembly are as follows:

Container: 20L capacity

Instruments used: The following equipments are used to assist the experiment.

Energy meter: Two energy meters are used to measure the power consumption of the compressor and the heater respectively. A 1phase, ac, 50 Hz, 0-5 Amp energy meter is used.

Ammeter and voltmeter: A voltmeter and an ammeter is used to monitor the power input to the compressor. The experiment may be delay.

Specification:

Ammeter: 0-5 Amp

Voltmeter: 0-300 volt

Pressure gauges: Two pressure gauges are used for the measurement of suction and discharge pressure. Bourdon tube pressure gauge are used.

Specification of pressure gauges:

Range:

Discharge- 0 to 300 psi

Suction- 0 to 50 psi

Rotameter: It is used for measuring the volume flow rate of the refrigerant.

Thermometers: For temperature measurement four thermometers are used.

3. FORMULAE USED AND SYMBOLS USED

P_{eva} : Evaporator absolute temperature.

P_{con} : Condenser absolute temperature.

T_1: Evaporator exit temperature.

T_2: Condenser inlet temperature.

T_3: Condenser exit temperature.

T_4: Evaporator inlet temperature.

I : Operating current value.

V: Operating voltage value.

$COP_{theoretical} = (h_1-h_4)/(h_2-h_1)$,

h_1 = enthalpy of refrigerant at inlet of compressor in kJ/kg

h_2 = enthalpy of refrigerant at exit of compressor in kJ/kg

h_3 = enthalpy of refrigerant at exit of the condenser kJ/kg

h_4 = enthalpy of refrigerant at entry of evaporator in kJ/kg

$COP_{carnot} = T_1/(T_2-T_1)$,

4. OBSERVATION TABLES AND GRAPHS

Table 1: Result obtained at two different flow rates of R-134a

Symbol	Unit	Ambient temp.= 25^o	Ambient temp. = 30^o	Ambient temp.= 25^o	Ambient temp. = 30^o
		Mass flow rate=.0028 kg/s	Mass flow rate=0.0028 kg/s	Mass flow rate=0.0053 kg/s	Mass flow rate=0.0053 kg/s
P_{eva}	psi	15	14	25	23
P_{con}	psi	140	137	142	139
T_1	°C	18	20	14	17
T_4	°C	13	15	-15	-12
T_3	°C	44	48	40	44
T_2	°C	64	68	60	64
I	Ampere	1.8	2.0	1.8	2.0
V	Volts	210	220	210	220

Table 2: COP_s of R-134a at different ambient temperatures

Parameter	Ambient temp.= 25^o	Ambient temp. = 30^o	Ambient temp.= 25^o	Ambient temp. = 30^o
	Mass flow rate=.0028kg/s	Mass flow rate=0.0028kg/s	Mass flow rate=.0053kg/s	Mass flow rate=0.0053kg/s
COP_{carnot}	6.23	6.1	6.32	6.17
$COP_{theoretical}$	2.3	1.93	2.72	2.43

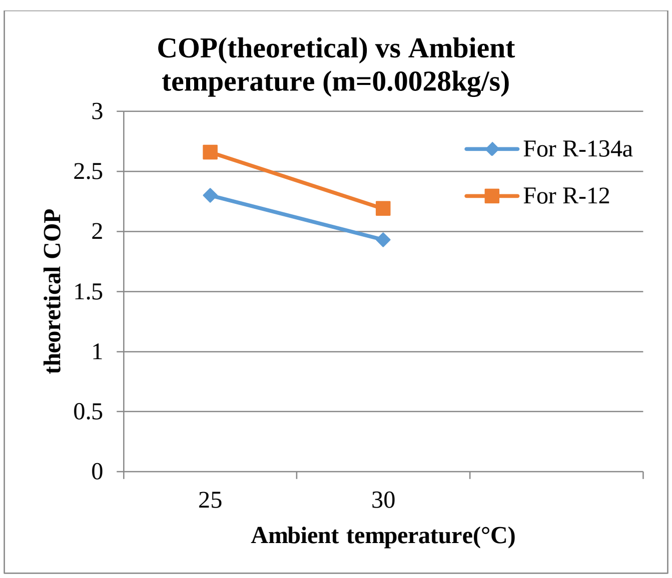
Table 3: Result obtained at two different flow rates of R-12

Symbol	Unit	Ambient temp.= 25°	Ambient temp. = 30°	Ambient temp.= 25°	Ambient temp. = 30°
		Mass flow rate=.0028kg/s	Mass flow rate=0.0028 kg/s	Mass flow rate=0.0053kg/s	Mass flow rate=0.0053kg/s
P_{eva}	psi	16	15	26	24
P_{con}	psi	142	139	143	140
T_1	°C	10	12	8	10
T_4	°C	5	7	-18	-15
T_3	°C	34	39	32	35
T_2	°C	52	58	48	54
I	Ampere	1.8	2.0	1.8	2.0
V	Volts	210	220	210	220

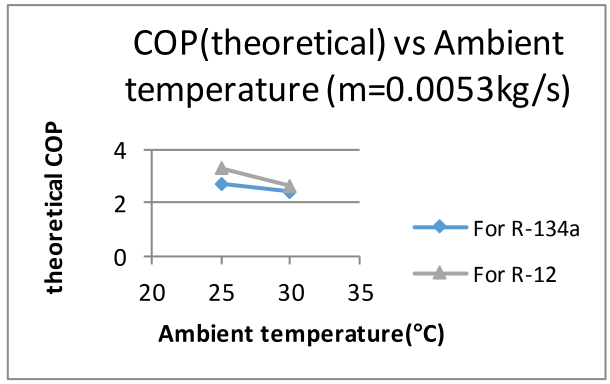
Table 4: COP_s of R-12 at different ambient temperatures

Parameter	Ambient temp.= 25°	Ambient temp. = 30°	Ambient temp.= 25°	Ambient temp. = 30°
	Mass flow rate=0.0028 kg/s	Mass flow rate=0.0028 kg/s	Mass flow rate=0.0053 kg/s	Mass flow rate=0.0053kg/s
COP_{carnot}	6.73	6.19	7.02	6.43
COP_{theo}	2.66	2.19	3.3	2.64

The above tables show that under the same conditions of ambient temperatures and mass flow rates, the performance of the refrigerant R-134a is better than R-12.



The above graph show that theoretical COP decreases with increase in the ambient temperature, whereas for same ambient temperature COP of R-12 is higher than R-134a.



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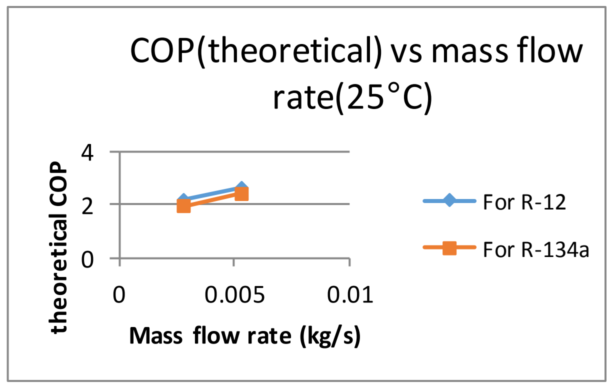

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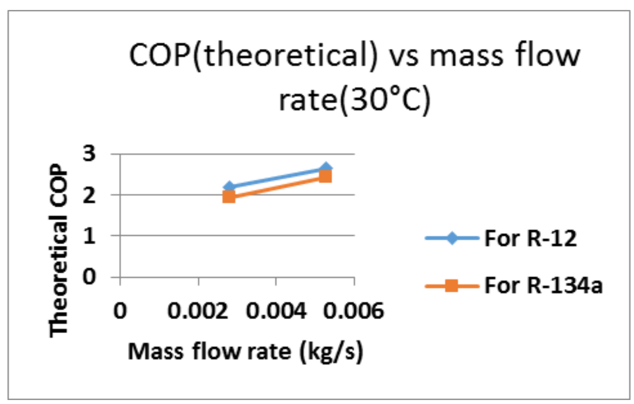

The above graph show that with increase in mass flow rate theoretical COP increases, whereas for the same mass flow rate COP of R-12 is higher than R-134a

5. CONCLUSION

A Vapour Compression Refrigeration System (VCRS) is experimentally investigated. Results show that there is a considerable change in the COP of the VCRS when we vary the mass flow rate of the refrigerant, also the COP changes as the ambient conditions change. But when we compare the COP of R-12 and R-134a at the same mass flow rate and same ambient temperature, we find that the COP of R-12 is better than that of R-134a.

The COP is more at mass flow rate= 0.0053kg/s for both the refrigerants, also the COP is more at the ambient temperature of 25^{o}C than at 30^{o}C. Hence we conclude that the COP increases with an increase in the mass flow rate and decreases as the ambient temperatures increase. Also the performance of the refrigerant R-12 is better than R-134a at the same mass flow rate and the same temperature.

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