"Performance Evaluation of R290 as Substitution to R22 & Mixture of Them in Vapour Compression Refrigeration System"

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Abstract— Use of natural refrigerant R290 can play a vital role in fulfilling the objectives of the international protocols like Montreal and Kyoto. Because of environmental problems such as ozone depletion and global warming, R22 needs to be phased out on urgent basis. This paper analyzes the possibilities of R290 as a potential substitute to the R22.Thermodynamic performance analysis of refrigerants R290 and R22 was carried out using standard vapor compression cycle, with an evaporating temperature range of - 25°C to 10°C for the condensing temperature of 45°C, based on analytical calculations. Refrigerant properties were obtained from. Performance parameters like, discharge temperature, volumetric refrigerating capacity and required mass flow of refrigerant were found to be lower with R290 when compared to R22.Coefficient of performance with R290 is slightly lower than that of with R22.However, higher COP can be expected by especially designed system pertaining to the properties of R290.Overall, R290 can be a better substitute to R22 in real applications because of its excellent environmental and thermos physical properties.

Keywords— ***COP, Mass flow rate, Refrigeration effect, specific work***

I-INTRODUCTION

Refrigeration technology has forever played an important role in improving the human standard of living. Inventions such as the refrigerator and air-conditioner have become a necessity for comfortable living. However, right from its inception, the refrigeration industry has been constantly tackling the issues of safety and environmental impact of refrigerants. Despite the constant effort from the researchers, the industry has still been a major contributor towards environmental degradation.

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A refrigerant may be a single chemical compound or a mixture (blend) of multiple compounds. Azeotropic didn't change their volumetric composition or saturation temperature when they evaporate or condense at a constant pressure these are blends of multiple components of volatilities (refrigerants) that evaporate and condense as a single substance.

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Blends- Two or more chemical compounds of mixtures of refrigerants are blends. They have multiple chemical compounds compared to a single compound is that the required properties of the blend can possibly be achieved by varying the fractional composition of the components.

II- LITERATURE REVIEW

G. M P Yadav, P. R Prasad, G. Veeresh- Because of simplicity and low cost, capillary tubes are used as the expansion device in most small refrigeration and air conditioning systems. Another advantage is that capillary tubes allow high and low side pressures equalize during the off-cycle, thereby reducing the starting torque required by the compressor. In this application the liquid line is usually placed in contact with the suction line, forming a counter flow heat exchanger. The liquid line is welded to the suction line in the lateral configuration. The temperature of the vapor refrigerant coming out from the evaporator is less than the temperature of the liquid coming out of the condenser. Before the expansion process, heat is transferred from the liquid line to the suction line. As a consequence, this in turn reduces the refrigerant quality at the inlet of the evaporator and therefore increases the refrigerating capacity. The suction line exit temperature also increases, eliminating suction line sweating and preventing slagging of the compressor. The main objective of this project is to evaluate the performance of refrigerating with liquid line suction line heat exchange for different lengths of heat exchange by using R134a and R404a as refrigerants and compare with different lengths of liquid line- suction line heat exchanger.

Prof. Jignesh K. Vaghela The main aim of the research is to evaluate the different alternative refrigerants as a drop in substitute of R134a theoretically. For this purpose, thermodynamic properties of different alternative refrigerants i.e. R290, R600a, R407C, R410A, R404A, R152a and R1234yf are compared to R134a. Thermodynamic evaluation of the standard rating cycle of vapor compression refrigeration system is carried out. Engineering equation solver and refprop softwares have been used for the thermodynamic analysis purpose. From the thermodynamic analysis, it is derived that R1234yf is best suitable alternative refrigerants as a drop in substitute of R134a. R1234yf has the lowest coefficient of performance as compared to R134a; however, it is best suitable alternative refrigerants as a drop in substitute because it has a very low global warming potential and can be substituted in the existing automotive air conditioning system with minimum modification.

Sharmas Vali Shaik, T. P.Ashok Babu- The present paper describes the theoretical thermodynamic performance of vapor compression refrigeration system using HFC and HC blends as an alternative to replace the refrigerant R22. In this study thermodynamic analysis of window air conditioner with R431A, R410A, R419A, R134a, R1270, R290 and fifteen refrigerant mixtures consist of R134a, R1270 and R290 was carried out based on actual vapor compression cycle. All the investigated refrigerant mixtures are ozone friendly in nature and they possess GWP in the range of 0.0244 to 1.685 times the GWP of R22. Thermodynamic performance analyses of all the investigated refrigerant mixtures were evaluated at the condensing and evaporating temperatures of 54.4oC and 7.2oC respectively. The results show that COP for the refrigerated mixture R134a/R1270/R290 (50/5/45 by mass percentage) is 2.10% higher among the R22, R431A, R410A, R419A, R134a, R1270, R290, and fifteen studied refrigerant mixtures. The compressor discharge temperatures of all the studied refrigerants were lower than that of R22 by 4.8oC-22.2oC. The power consumption per ton of refrigeration for the refrigerated mixture R134a/R1270/R290 (50/5/45 by mass percentage) is 2.01% lower among R22, R431A, R410A, R419A, R134a, R1270, R290, and fifteen studied refrigerant mixtures. Overall the thermodynamic performance of refrigerant mixture R134a/R1270/R290 (50/5/45 by mass percentage) is better than that of R22 with reasonable savings in the energy and hence it is an appropriate ecological energy efficient alternative refrigerant to substitute R22 used in air conditioning applications.

Tejaswi Saran Pilla, Pranay Kumar Goud Sunkari -Mixed refrigerant systems are reported to be thermally efficient. However, the mechanical input required by the compressor is not investigated in the literature. Hence, in the present work, two refrigerants are chosen (R-290 and R-600a) to evaluate the mechanical performance of compressor of domestic refrigerators. The refrigeration cycle consists of four major processes. The isentropic compression in the compressor, isobaric heat rejection in the condenser, isenthalpic reduction in pressure and isobaric heat addition in the evaporator. The present work aims at investigation of mechanical performance of the compressor with mixed refrigerants (R-290 and R-600a).

The boiling point of the each of the refrigerant is different and hence the specific volume occupied by each is different. This in turn affects the work input required. Hence, the present work is aimed at evaluating the compressor performance with mixed refrigerants. The temperature distribution during the cycle operation process is estimated. This in turn enables the effective design of the compressors for domestic refrigeration systems for effective operation.

III- Methodology

Table 1 Environmental property of refrigerants R22 and R290

Refrigerant	Chemical formula	Atmospheric life in years	Global warming potential	Ozone depletion potential
R22	$CHClF_2$	12	1700	0.055
R290	C_3H_8	0.041	20	0.000

Table 2.Physical properties of refrigerants R22 and R290

Refrigerant	Molecular weight (kg/Kmol)	Normal boiling point (°C)	Critical temperature (°C)	Critical pressure (MPa)	Latent heat of evaporation (kJ/kg)
R22	86.47	-40.75	96.2	4.99	233.7
R290	44.10	-42.2	96.7	4.25	425.4

Table-3 Thermo –Physical properties of R-22 & R-290 at nominated operating conditions

PROPERTY	TEMP (°C)	STATE	REFRIGERANTS	
			R290	R22
SATURATION PRESSUER(MPa)	-20	LIQUID	0.24454	0.2453
	35	VAPOUR	1.2181	1.3548
DENSITY(kg/m3)	-20	LIQUID	554.51	1346.5
	35	VAPOUR	26.616	57.988
VISCOSITY(μPa-s)	-20	LIQUID	154.81	269.71
	35	VAPOUR	8.669	13.055
THERMAL CODUCTIVITY(W /m °C)	-20	LIQUID	0.11666	0.1037
	35	VAPOUR	0.0205	0.01232
SPECIFIC HEAT(kJ/kg °C)	-20	LIQUID	2.3696	1.1227
	35	VAPOUR	2.1632	0.9485
INTERNAL ENERGY	-20	LIQUID	150.74	176.86
	35	VAPOUR	564.7	391.98

Figure-1 Experimental setup

IV- Result and Discussion

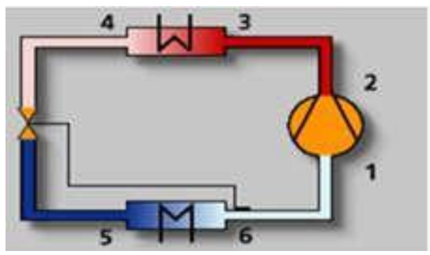

Figure-2 Single-stage process

Table 3.Performance valuation of R22 and R290

Refrigerants	Discharge Temperature (T_2 in K)	Refrigeration Effect	Specific Work	COP	Mass flow rate	HP/Ton of Refrigeration
R 290	315.97	259.01	75.54	3.42	0.814	1.392
R 22	334.32	154.01	43.25	3.56	1.37	1.337

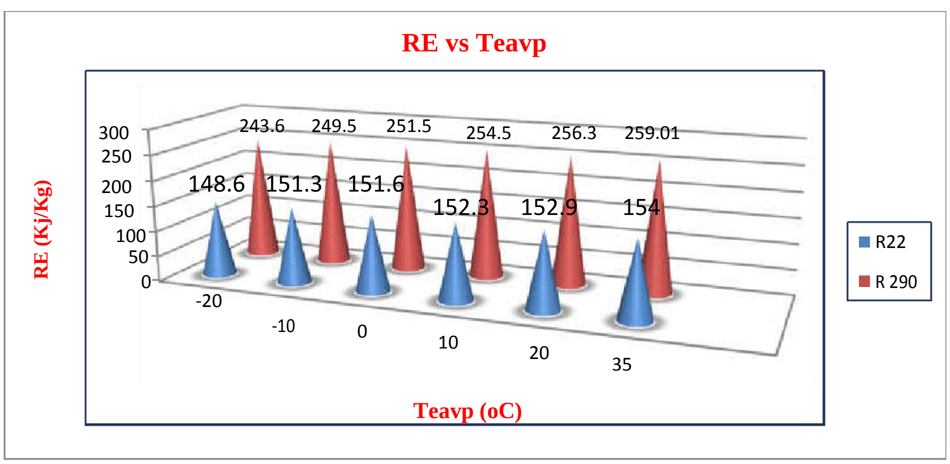

Figure-3 Refrigeration effect Vs evaporation temp

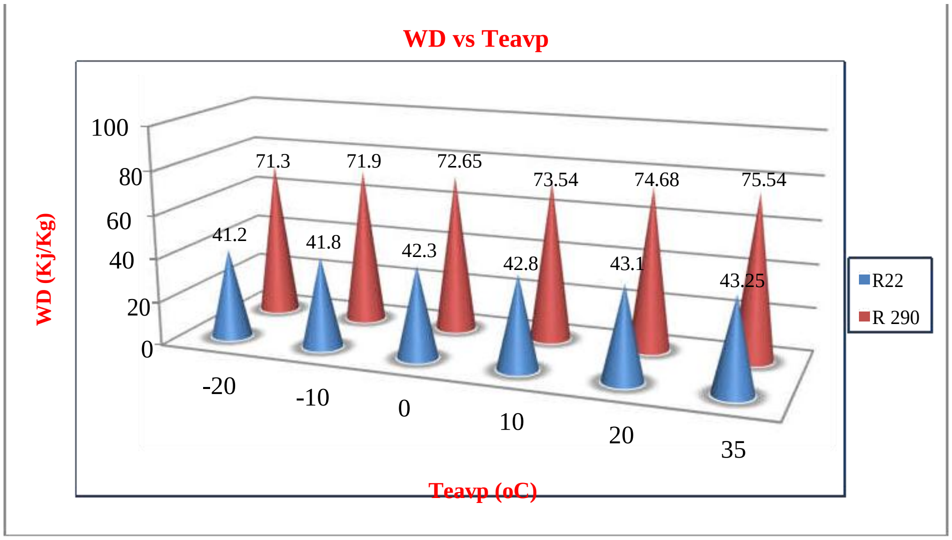

Figure-4 Work done Vs evaporation temp

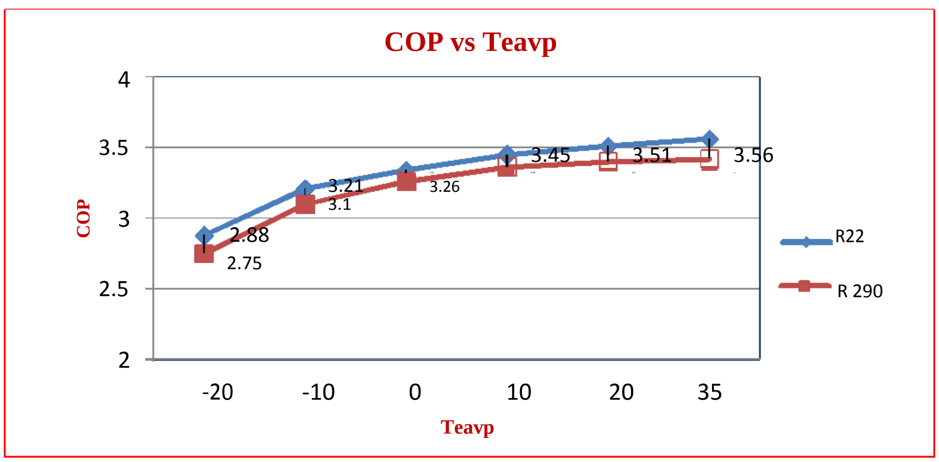

Figure-5 COP Vs evaporation temp

Table 4.Performance valuation of Mixture of R22 and R290

R-22/ R-290	Discharge Temperature (T_2 in K)	Refrigeration Effect	Specific Work	COP	Mass flow rate	HP/Ton of Refrigeration
90/10	328	247.456	75.246	3.28	0.8526	1.069
70/30	338	267.38	75.503	3.54	0.7891	0.993
50/50	318	263.498	75.597	3.48	0.8007	1.008
30/70	330	270.98	77.252	3.51	0.7785	1.002
10/90	332	272.641	77.131	3.53	0.7739	0.994

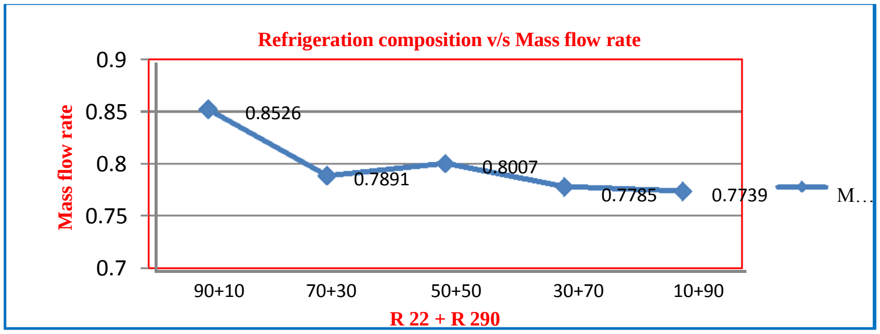

Figure-6 Mass flow rate Vs mixture of refrigerants

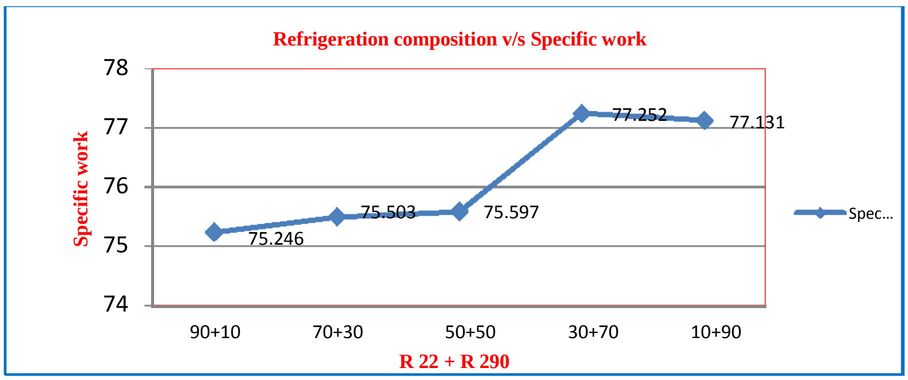

Figure-7 Specific work Vs mixture of refrigerants

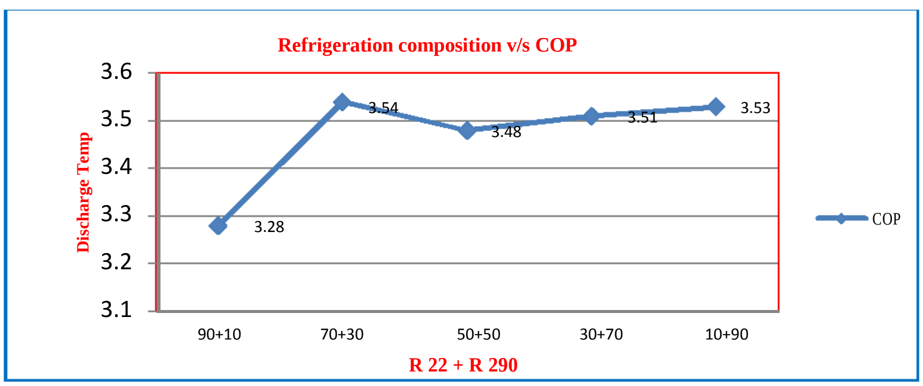

Figure-8 COP Vs mixture of refrigerants

V-CONCLUSION

In the present study analysis of R22 and R 290 refrigerants as well as mixtures consists of front and propane investigated based on actual vapour compression refrigeration cycle. As the study of following conclusions is drawn.

- The COP of refrigerant mixture (3.54) showed the nearest to that of the COP of R22 (3.54) among five investigated refrigerant mixtures when compared to R22 and R 290.
- Discharge temperature of compressor for all the investigated refrigerant mixtures were reduced in the range of 3.68 -22.03$_{0}$ C when compared to reference refrigerant R22 and R 290. The lower compressor discharge temperature increases the life of motor windings. Thus R 290 is beneficial to compare to others.
- The power per ton of refrigeration of R22 (1.37 kW/TR) with R 290 (1.32 kW/TR) have maximum among the five studied refrigerant mixtures.

- Overall the refrigerated mixture (R22/R290 70/30 by mass %) is an appropriate eco-friendly alternative refrigerant to replace R22 among the five investigated refrigerant mixtures from the standpoint of COP, discharge temperature and power per ton of refrigeration.

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