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Theoretical analysis of a vapour compression refrigeration system with R134a, R290, R600a & various ratio of R290/R600a

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Abstract: Though the global warming up potential of HFC134a is relatively high, it is affirmed that it is a long term alternative refrigerants in lots of countries. The different environmental friendly refrigerants of either HC & HFC class.HCs have zero ODP and very low GWP whereas HFCs have zero ODP but a higher GWP. When R-134a was replaced with blending of HCs refrigerant the COP of the system improved. In this paper consider the Theoretical analysis of R134a, R290, R600a & various ratios of R290/R600a refrigerants. The present investigation has been done for evaporator and condenser temperatures in the range of-10^{o}c and 40^{o}c respectively. The results indicate that the refrigerant blend (R600a/R290) with 70/30 mass fraction was found to be the most suitable alternative among refrigerants tested for R134a.
Key words: GWP, ODP, HC Refrigerants, HFC Refrigerants

I. INTRODUCTION

Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures.

A.S. Dalkilic and S. Wongwises (2010) analysed a performance comparison of vapour-compression refrigeration system using various alternative refrigerants A theoretical performance study on a traditional vapour-compression refrigeration system with refrigerant mixtures based on HFC134a, HFC152a, HFC32, HC290, HC1270, HC600, and HC600a was done for various ratios and their results are compared with CFC12, CFC22 and HFC134a as possible alternative replacements. B.O.Bolaji *et al.*(2011) analysed the performances of the three ozone Hydro fluorocarbon (HFC) refrigerants (R32, R134a and R512a) in a vapour compression refrigeration system were investigated experimentally and compared. The results obtained showed that R32 yielded undesirable characteristics, such as high pressure and low co-efficient of performance (COP). Comparison among the investigated refrigerants confirmed that R152a 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 refrigerant system. The COP of R152a obtained was higher than those of R134a and R32 by 2.5% and 14.7% respectively. Also, R152a offers the best desirable environmental requirements; zero ozone potential and very low global warming potential. A.Baskaran et al. (2012) analysed on a VCR system with various refrigerants mixture of R152a, RE170, R600a, and R290 were done for various mixture ratios and their results were compared with R134a as possible alternative replacement. Considering the comparison of (COP) and pressure ratio of the tested refrigerants and also the main environ-mental impacts of ozone layer depletion and global warming, refrigerant blend R435A [RE170 (80%), R152a (20%)] were found to be the most suitable alternative among refrigerants tested for R134a. Bi *et al*. (2011) conducted an experimental study on the performance of a domestic refrigerator using TiO2-R600a Nano refrigerant as working fluid. They showed that the TiO2-R600a system worked normally and efficiently in the refrigerator and an energy saving 9.6%. They also reported freezing velocity of Nanorefrigerating system was more than that with pure R600a system. Shengshan *et al* (2011) conducted an experimental study on the performance using TiO2–R600a with 0.1 g/lit and 0.5 g/lit of TiO2 nano particles concentrations. The performance was compared with pure R-600a. The design temperatures were obtained at a quicker rate with TiO2–R600a nano refrigerant. The energy consumptions were reduced by 5.94% and 9.60% with the concentrations as 0.1 g/lit and 0.5 g/lit of TiO2 nano particles respectively. All the results obtained exhibited that TiO2–R600a nano refrigerant worked safely and normally in the refrigerator with better performance than pure R–600a system. Thus TiO2–R600a nano refrigerant may be used in domestic refrigerator with better performance and lower energy consumption without any alteration of the system. R. Saidur *et al*. (2011) conducted experiment with hfc–134a in domestic refrigerator with tio2 nano particles. The results showed that this nano refrigerant gave better performance. The energy consumption of hfc–134a refrigerant using mineral oil and nano particles mixture as lubricant was lesser than with pure hfc–134a and it saved 26.1% energy with 0.1% mass fraction tio2 nano particles compared to the hfc–134a. 60% hfc–134a with mineral oil and 0.1% wt al2o3 nano particles gave optimal performance. The power consumption was reduced by 2.4% and the COP was improved by 4.4%. Senthilkumar and Elansezhian (2012) conducted an experimental study on the performance of a domestic refrigerator using Al2O3-R134ananorefrigerant as working fluid. They found that the Al2O3-R134a system performance was better than pure lubricant with R134a working fluid with 10.30% less energy used with 0.2%V of the concentration used and also heat transfer coefficient Increases with the usage of nano Al2O3. Rejikumar and Sridhar (2013) conducted an experimental studyon the performance of a domestic refrigerator using TiO2 – R600a nanorefrigerant as working fluid. They found that the energy consumption reduced by 11% and coefficient of performance increases by 19.6%.

II. PROBLEM DEFINITION

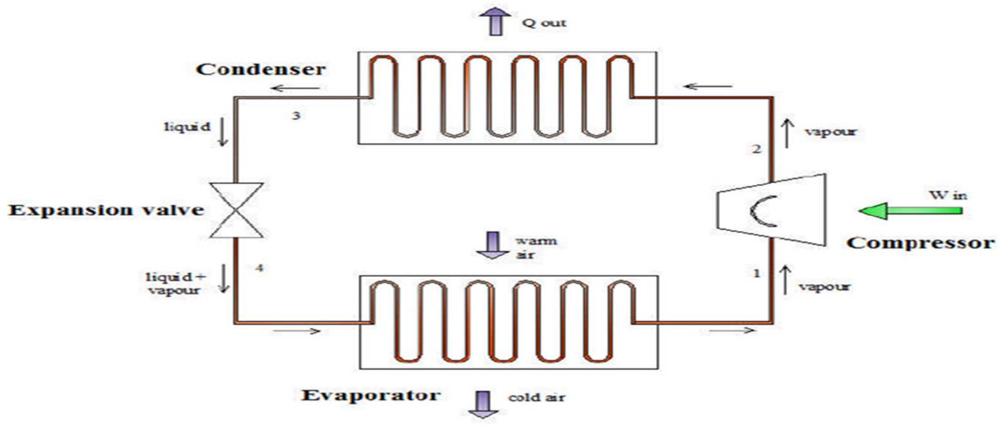
The Global Warming Potential (GWP) of currently used R134a is high as1300. The Montreal and Kyoto Protocol of United Nations suggests minimizing of Hydro Fluro carbons (HFCs) to use as refrigerants. European countries have already banned R134a.Blending of R134a with other HFC is a problem. R-22 and R134a will be phased out due to environmental issues. To overcome the above problem, refrigerant blending of (R600a/R290) is proposed in the present study because (R600a/R290) has Zero Ozone Depleting Potential and a very less value of 120 as Global Warming Potential (GWP) when compared to other refrigerants. The atmospheric life span for (R600a/R290) is 1.4 years .Pure substance (R600a/R290) offers excellent thermodynamic properties nontoxic and compatibility with the conventional oil in compressor. (R600a/R290) has been already approved for use in automobile applications as an alternative to R134a by US Environmental Protection Agency

III. MATERIALS AND METHODS

There are four main components in vapour compression refrigeration system.

Compressor
Condenser
Expansion valve
Evaporator

Figure 3.1 standard vapour compression refrigeration cycle



Process 1-2: Isentropic compression of saturated vapour in compressor
Process 2-3: Isobaric heat rejection in condenser
Process 3-4: Isenthalpic expansion of saturated liquid in expansion device
Process 4-1: Isobaric heat extraction in the evaporator

The system was charged with the help of charging system and evacuated with the help of vacuum pump to remove the moisture. After charging each refrigerant, data were collected and different evaporator temperatures using equation. The following parameters were obtained using the above equations. a) Vapour pressure b) compressor input power c) co-efficient of performance and d)

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pressure ratio. Initially a performance test is made with the system loaded with pure R134a. The data is treated as the basis for the comparison with the refrigerant mixtures. After that the system was charged with R290 and then R600a respectively for the performance analysis of the system. By addition to that these trials combination of both these refrigerants (R290/R600a) was considered as another experimental trail to identify alternative refrigerant mixed with various mass proportions. Finally, the mixture composed of (R290/R600a) was considered as an alternative to R134a. This mixture is further referred in this work as HCM. Blend mixtures HCM of (R290/R600a) by mass in the proportion of HCM

20:80 (20% weight of R290 and 80% weight of R600a),
30:70 (70% weight of R290 and70% weight of R600a),
50:50 (50% weight of R290 and 50% weight of R600a),
60:40 (60% weight of R290 and 40% weight of R600a),
70:30 (70% weight of R290 and 30% weight of R600a) &
80:20 (80% weight of R290 and 20% weight of R600a)

Were charged through the charging port in the compressor and the performance tests were conducted. The results of the performance comparison of the investigated mixture of the refrigerants (R600a/R290) in the vapour compression refrigeration system are given below.

IV. RESULTS AND DISCUSSIONS

The theoretical trial conducted with pure R134a, pure HC refrigerants such as R290, R600a and also with various HC mixtures in various mass fractions. The theoretical performance and operating parameters for the various trails with obtained results were tabulated as follows.

Table 4.1 comparison of operating parameters of base fluids & new alternative refrigerants

REFRIGERANTS	OPERATING PARAMETERS				
	W_C	R.E	COP	m_r	P_{comp}
R134a	32.67	130.55	3.994	0.0269	0.8788
R290	62.29	244.08	3.918	0.0143	0.8907
R600a	67.34	244.72	3.633	0.0143	0.9629
R290/R600a(20/80)	61.16	247.70	4.050	0.01412	0.8635
R290/R600a(30/70)	62.49	245.61	3.930	0.01425	0.8904
R290/R600a(50/50)	61.14	249.75	4.085	0.01401	0.8565
R290/R600a(60/40)	60.18	247.81	4.117	0.01412	0.8497
R290/R600a(70/30)	59.60	251.40	4.218	0.0139	0.8284
R290/R600a(80/20)	61.73	253.63	4.108	0.0137	0.8512

The theoretical trial for various combinations and various mass proportions has shown different picture respective to their influence on refrigerant system. The initial trail loaded with R134a considered as base testing results for the existing system. The COP obtained for this initial trail with R134a was 3.994 with 0.0269 mass flow rates. The next trail with R290 & R600a has the COP of 3.918 & 3.633 respectively which was low compared R134a. Refrigerating effect (R.E = 244.08 & 244.72) given by these two trials are higher than R134a (130.55). The increase in compressor work input has reduces the COP of these trails compared to R134a but with lower mass flow rates of 0.0143. To overcome these issues with HC refrigerants additional trails with various mass fractions like R 290/R600a (20/80), R 290/R600a (30/70), R 290/R600a (50/50), R 290/R600a (60/40), R 290/R600a (70/30), R 290/R600a (80/20) were conducted which shows some enhanced performance of the system. The mass fractions R 290/R600a (50/50), R 290/R600a (60/40), R 290/R600a (70/30) and R 290/R600a (80/20) were obtained with increased COP level 4.085, 4.117, 4.218 and 4.108 respectively compared to R134a. The higher and opted COP level obtained from this experimental trial was 4.218 with the mass fraction of R 290/R600a (70/30). The power required to run the compressor is one of the major operating parameter in any refrigeration system. Lower compressor power with high COP was the desired requirement for the refrigerating system. Here, in this work the power needed for the system to run loaded with R134a was 0.8788. When the system loaded with various HC combinations of R 290/R600a which require less compressor power compared to R134a such as like 0.8565, 0.8497, 0.8284 and 0.8512 referred from the Table.5.1.

V. CONCLUSIONS

The methodology proposed in this project work to identify the alternative refrigerant for R134a has effectively contributed towards the objective of this work. After the various number of combinations, mixture ratios and theoretical trials finally R 290/R600a (70/30) has identified and suitable alternative for R134a which satisfies the most requirement of ideal refrigerant. While considering the comparison of performance coefficients (COP) and power consumption of the tested refrigerants and also the main environmental impacts like Ozone Layer Depletion and Global Warming Potential, the refrigerant blend (R600a/R290) with 70/30 mass fraction was found to be the most suitable alternative among refrigerants tested for R134a. This fixed alternative has shown the improved COP by 5.608% when compared R134a COP. And as for energy saving concern it saves 6.084% compared to R134a.

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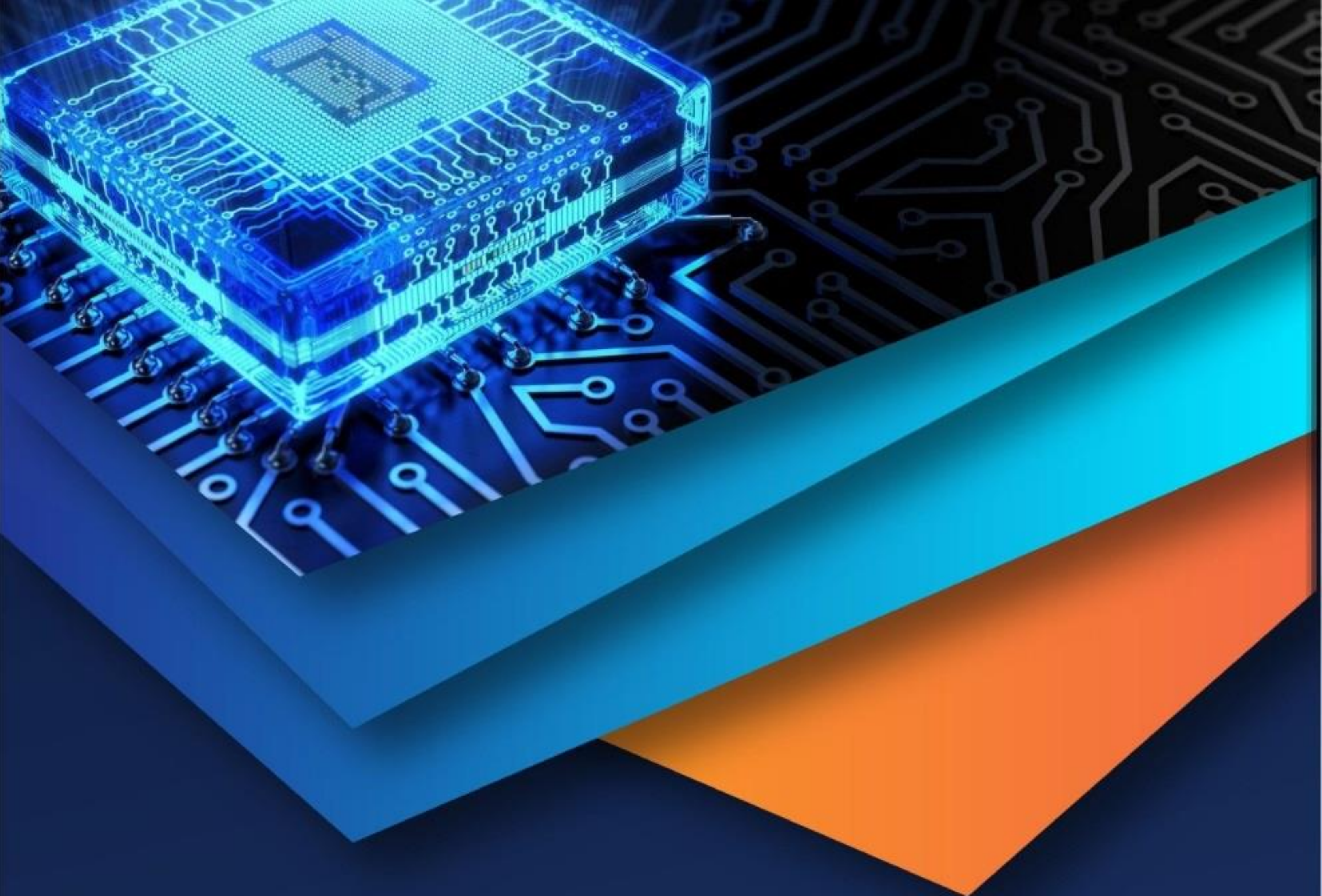

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