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Potential of R1234yf Nano refrigerant to Replace R134a in a Domestic Refrigerator - A Review

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***Abstract-* Ever growing need of refrigeration system is one of the major reason of expanding pattern of energy consumption, thus energy saving is one of the best approach to overcome this issue. Due to various environmental convention manufacturing sector encountering more and more pressure from the legislature not only on energy consumption but also on environmental concern, therefore while selecting a refrigerant it needs to consider both of energy saving and environmental cost. In this paper, a comprehensive review is carried out investigate performance potential of nano-R1234yf. Nanorefrigernt (special type of Nano fluid) shows potential of upgrading thermodynamic performance of refrigeration system. This review contains much amount of information regarding the environmental pollution produced by working fluids of air-conditioning, heat pump and commercial refrigeration applications. The replacement of R134a with R1234yf gives clean and green environment, with zero ozone depleting potential (ODP) and less global warming potential (GWP).**

***Index Terms*-Environmental protection, Nano refrigerant, Performance potential, R1234yf.**

1. INTRODUCTION

Refrigerants are the working fluids in refrigeration, air-conditioning, and heat pump systems (UNEP, 1994). They absorb heat from one area, such as an air-conditioned space, and reject it into another, such as outdoors, usually through evaporation and condensation. Working fluids escaped through leakages from cooling equipment during normal operation (filling or empting) or after accidents (damages) gather in significant quantities at high levels of the atmosphere (stratosphere). In the stratosphere, through catalytically decompounding, pollution from working fluid leakage depletes the ozone layer that normally is filtering the ultraviolet radiation from the sun, which is a threat to living creatures and plants on earth.

Stratospheric ozone depletion has been linked to the presence of chlorine and bromine in the stratosphere. In addition, refrigerants contribute to global warming (also called global climate change) because they are gases that exhibit the greenhouse effect when in the atmosphere.

As per Montreal Protocol 1987, the use of CFCs was completely stopped in most of the nations. However, HCFCs refrigerants can be used until 2040 in developing nations and developed nations should phase out by 2030 (Richard, 2002). To meet the global demand in refrigeration and air- conditioning sector, it is necessary to look for long-term alternatives to satisfy the objectives of international protocols. Over the last two decades, hydrofluorocarbon R134a has been the most important and dominant refrigerant for household appliances, air conditioning and chillers. However, this refrigerant has a high global warming potential, GWP, of approximately 1300, which contributes significantly for the greenhouse effect (Drake et al. 2011). As from January 2015, Europe's UE regulation N°517/2014 restricts the use of hydro fluorocarbons, HFCs, with a GWP of 150 or more (European Parliament and the Council, 2014). In this regard, it exists two important alternatives to replace the HFCs for refrigeration systems: natural refrigerants (CO2, hydrocarbons and ammonia), and synthetic refrigerants. Each group of refrigerants presents advantages and drawbacks; for example, the use of hydrocarbons, HCs, offers a good drop-in replacement for halogenated refrigerants in terms of environmental impacts and energy consumption (Harby, 2017). In the field of domestic refrigeration, several studies have been carried out with HCs and mixtures of them to replace R134a (Wongwises and Chimres, 2005; Mohanraj et al. 2009; Liu et al. 2015). However, due to their high flammability, technical restrictions have been applied for its use in domestic refrigerators, from which its sales have been prohibited in several countries of Latin America, the USA, as well as in some Asian countries.

As an alternative to the HCs, R1234yf synthetic refrigerant from the family of the hydro fluoroolefins, HFOs, has emerged recently as a replacement fluid for R134a (Minor et al. 2010). Some of the main advantages of using R1234yf are its thermodynamic properties and its low level of toxicity. In addition, its ozone depletion potential, ODP, is zero, and its GWP is less than 4.4 [sarbu & bancea 2009].

Within specialized literature, some studies have analyze the feasibility of replacing R134a with R1234yf (Brown 2013; Kedzierski et al. 2015). Yataganbaba et al. (2015), studied two evaporator refrigeration cycles through a model based on an exergy analysis and they concluded that R1234yf and R1234ze were adequate alternatives to replace R134a. Karber et al. (2012) worked with two different refrigerators, one of them with basic technology and the other with more advanced technology. The authors used AHAM standard HRF-1 to evaluate and compare the energy performance among R1234yf, R1234ze and R134a. They concluded that R1234yf represented a maximum increment of 2.7% in the energy consumption, indicating that it is a suitable replacement for R134a. Based on the above, R1234yf is shown as an ideal refrigerant to replace R134a. In most results, small increases in energy consumption were obtained when using R1234yf in comparison with R134a. Recently scientists used nanoparticles in refrigeration systems because of its remarkable improvement in thermos-physical and heat transfer capabilities to enhance the efficiency and reliability and to reduce energy consumption of refrigeration and air conditioning system.

In order to continue and to extend previous studies, this paper presents potential of R1234yf to replace R134a. In this work, we emphasize the use of R1234yf, prioritizing the replacement of the refrigerant with use of Nano refrigerant and without making any modifications to the vapor compression system.

2. ENVIRONMENTAL IMPACT OF REFRIGERANTS

The design of the refrigeration equipment depends strongly on the properties of the selected refrigerant. Refrigerant selection involves compromises between conflicting desirable thermo-physical properties. A refrigerant must satisfy many requirements, some of which do not directly relate to its ability to transfer heat. Chemical stability under conditions of use is an essential characteristic. Safety codes may require a non-flammable refrigerant of low toxicity for some applications.

The environmental consequences of refrigerant leaks must also be considered. Cost, availability, efficiency, and compatibility with compressor lubricants and equipment materials are other concerns [15].

Safety properties of refrigerants considering flammability and toxicity are defined by ASHRAE Standard 34 (2007). Toxicity classification of refrigerants is assigned to classes A or B (Table 1). Class A signifies refrigerants for which toxicity has not been identified at concentrations less than or equal to 400 ppm by volume, and class B signifies refrigerants with evidence of toxicity at concentrations below 400 ppm by volume. By flammability refrigerants are divided in three classes. Class 1 indicates refrigerants that do not show flame propagation when tested in air (at 101 kPa and 21 C). Class 2 signifies refrigerants having a lower flammability limit (LFL) of more than 0.10 kg/m3 and a heat of combustion less than 19,000 kJ/kg. Class 3 indicates refrigerants that are highly flammable, as defined by an LFL of less than or equal to 0.10 kg/m3 or a heat of combustion greater than or equal to 19,000 kJ/kg.

New flammability class 2L has been added since 2010 denoting refrigerants with burning velocity less than 10 cm/s.

Table 1 Safety classification of refrigerants

Flammability	Safety code	
	lower toxicity	higher toxicity
higher flammability	A2	B2
lower flammability	A2L	B2L
No flame propagation	A1	B1

Minimising all refrigerant releases from systems is important not only because of environmental impacts but also because charge losses lead to insufficient system charge levels, which in turn results in suboptimal operation and lowered efficiency.

The average global temperature is determined by the balance of energy from the sun heating the earth and its atmosphere and of the energy radiated from the earth and the atmosphere into space. Greenhouse gases (GHGs), such as CO2 and water vapour, as well as small particles trap heat at and near the surface, maintaining the average temperature of the Earth's surface at a temperature approximately 34 K warmer than would be the case if these gases and particles were not present (greenhouse effect).

Global warming is a concern because of an increase in the greenhouse effect from increasing concentrations of GHGs attributed to human activities. Thus, the negative environmental impact of the working fluids, especially the effect of halogenated refrigerants on the environment, can be synthesised by two effects [5]:

- depletion of the ozone layer;
- contribution to global warming at the planetary level via the greenhouse effect.

The measure of a material's ability to deplete stratospheric ozone is its ozone depletion potential (ODP), a relative value to that of R11, which has an ODP of 1.0.

The global warming potential (GWP) of a GHG is an index describing its relative ability to collect radiant energy compared to CO2, which has a very long atmospheric lifetime. Therefore, refrigerants will be select so that the ozone depletion potential will be zero and with a reduced GWP.

The most utilised halogenated refrigerants are the family of chemical compounds derived from the hydrocarbons (HC) (methane and ethane) by substitution of chlorine (Cl) and fluorine (F) atoms for hydrogen (H) (Fig. 1), whose toxicity and flammability scale according to the number of Cl and H atoms. The presence of halogenated atoms is responsible for ODP and GWP.

Table 2 presents the principal characteristics of halogenated refrigerants (pure and mixtures), with the symbol for refrigerant, chemical formula, as well as their application domains.

Group	Refrigerant	Chemical formula	Chemical name	Evaporation Temp		Applications
0	1	2	3	4	5	6
CFC	R11	CCl_3F	Threechlorofluoromethane	0	60	Air-conditioning, Heat pumps
	R12	CCl_2F_2	Dichlorodifluoromethane	–40	10	Domestic and commercial refrigeration
				10	40	Air-conditioning, Heat pumps
	$R12B_1$	$CClBrF_2$	Bromochlorodifluoromethane	0	50	Air-conditioning, Heat pumps
	R13	$CClF_3$	Chlorotrifluoromethane	–100	-60	Cascade refrigeration systems
	$R13B_1$	$CBrF_3$	Bromotrifluoromethane	–80	–40	Mono-, two stage- and in cascade refrigeration systems, for industries
	R113	$C_2Cl_3F_3$	Trichlorotrifluoroethane	0	15	Air-conditioning
				15	50	Heat pumps
	R114	$C_2Cl_2F_4$	Dichlorotetrafluoroethane	–20	10	Air-conditioning,
				10	80	Heat pumps
HCFC	R21	$CHCl_2F$	Dichlorofluoromethane	–20	20	Air-conditioning, Heat pumps
	R22	$CHClF_2$	Chlorodifluoromethane	–50	10	Industrial-, food-, commercial refrigeration, Air-conditioning
	R142b	$C_2H_3ClF_2$	Chlorodifluoroethane	–20	10	Air-conditioning
				10	60	Heat pumps
HFC	R23	CHF_3	Threefluoromethane	–100	–60	Cascade refrigeration systems for industrie and laboratory
	R32	CH_2F_2	Difluoromethane	–60	–10	Industrial and commercial refrigeration
	R125	C_2HF_5	Pentafluoroethane	–50	10	Industrial and commercial refrigeration, Air-conditioning
	R134a	$C_2H_2F_4$	Tetrafluoroethane	–30	20	Domestic-, commercial-, industrial refrigeration, Air-conditioning
	R152a	$C_2H_4F_2$	Difluoroethane	–30	10	Industrial and commercial refrigeration, Air-conditioning
Mixtures	R500	(R12/R152a)	–	–40	10	Household and industrial refrigeration, Heat pumps
	R502	(R22/R115)	–	–60	–20	Industrial and commercial refrigeration
	R507	(R125/R134a)	–	–50	–10	Industrial and commercial refrigeration
	R410A	(R32/R125)	–	–50	0	Industrial and commercial refrigeration
	R407C	(R32/R125/R134a)	–	–40	0	Industrial and commercial refrigeration
	R404A	(R125/R143a/R134a)	–	–40	0	Industrial and commercial refrigeration

Table 2 Application domains of halogenated refrigerants

During the last century, the halogenated refrigerants have dominated the vapour compression-based systems due to its good thermodynamic and thermo-physical properties. Thermodynamic properties of pure refrigerants are listed in Table 3 [6]. But the halogenated refrigerants are having poor environmental properties with respect to ODP and GWP.

The second generation of refrigerants, CFCs replaced classic refrigerants in early 20th century. Refrigerants as CFCs (R12, R11, and R13) have been used since the 1930s because of their superior safety and performance characteristics. However, their production for use in developed countries has been eliminated because it has been shown that they deplete the ozone layer [7]. The CFCs and HCFCs represented by R22 and mixture R502 dominated the second generation of refrigerants [37].

The HCFCs also deplete the ozone layer, but to a much lesser extent than CFCs. HCFCs production for use as refrigerants is scheduled for elimination by 2030 for developed countries and by 2040 for developing countries [8].

Therefore, the traditional refrigerants (CFCs) were banned by the Montreal Protocol because of their contribution to the disruption of the stratospheric ozone layer [38]. The Kyoto Protocol listed HCFCs as being with large GWPs.

With the phasing out of the use of CFCs, chemical substances such as the HCFCs and the HFCs, were proposed and have been used as temporary alternatives. The HFCs do not deplete the ozone layer and have many of the desirable properties of CFCs and HCFCs. They are being widely used as substitute refrigerants for CFCs and HCFCs.

Table3: Thermodynamic properties of pure refrigerants

Refri-gerant	Molecular mass, M [g/mol]	Critical Temp. tcr [°C]	Critical pressure, Pcr [MPa]	Boiling point, t0n [°C]
R11	137.37	198	4.41	23.7
R12	120.9	112	4.14	-29.8
R22	86.47	96.2	4.99	-41.4
R23	70.01	25.9	4.84	-82.1
R32	52.02	78.2	5.8	-51.7
R41	34.03	44.1	5.9	-78.1
R123	152.93	82	3.66	27.8
R124	136.48	122.3	3.62	-12
R125	120.02	66.2	3.63	-54.6
R134a	102.03	101.1	4.06	-26.1
R142b	100.49	137.2	4.12	-9
R143a	84.04	72.9	3.78	-47.2
R152a	66.05	113.3	4.52	-24
R161	48.06	102.2	4.7	-34.8
R170	30.07	90	4.87	-88.9
R218	188.02	71.9	2.68	-36.6
R290	44.1	96.7	4.25	-42.2
R600	58.12	152	3.8	-0.5
R600a	58.12	134.7	3.64	-11.7
R717	17.03	132.3	11.34	-33.3
R744	44.01	31.1	7.38	-78.4
R1270	42.08	92.4	4.67	-47.7

The environmental impact of an HVAC&R system is due to the release of refrigerant and the emission of greenhouse gases for associated energy use. The total equivalent warming impact (TEWI) is used as an indicator for environmental impact of the system for its entire lifetime. TEWI is the sum of the direct refrigerant emissions, expressed in terms of CO2 equivalents, and the indirect emissions of CO2 from the system's energy use over its service life [15].

Environmentally preferred refrigerants have:

- low or zero ODP;
- relatively short atmospheric lifetimes;
- low GWP;
- ability to provide good system efficiency;
- appropriate safety properties;
- ability to yield a low TEWI.

In Table 4 is listed the environmental properties of refrigerants [15]. Because HFCs do not contain chlorine or bromine, their ODP values are negligible and represented by 0 in this table. Ammonia, HCFCs, most HFCs, and HFOs have shorter atmospheric lifetimes than CFCs because they are largely destroyed in the lower atmosphere by reaction with OH radicals. A shorter atmospheric lifetime generally results in lower ODP and GWP values.

3. NANOREFRIGERANT

A nanorefrigerant is a special class of refrigerant in which the nanoparticles are suspended and well-dispersed in the base refrigerant. The concept of dispersing the solid particles into a fluid was first introduced by Maxwell (1873) [10]. He dispersed millimetre and micrometre sized particles into the base fluid in order to improve the thermophysical properties of the fluid. But this genre of fluids suffered few major setbacks due to issues like stability, clogging and erosion. With the advent of nanotechnology, Choi (1995) [11] introduced a new concept of dispersing nanoparticles in the base fluid and called it as nanofluids .The purpose behind the development of nanofluids is to enhance the heat transfer performance of various heat transfer fluids and lately, this concept has been extended to the refrigerants as well. The key points regarding nanorefrigerants are:-

-The use of nanorefrigerants will lead to smaller and lighter refrigeration systems.

-The refrigeration systems functioning on nanorefrigerants will consume less compressor power i.e. they will be more energy efficient.

The above mentioned points are the direct consequences due to the superior thermophysical properties of nanorefrigerants in comparison to the base refrigerants. The majority of researchers observed an increase in the effective thermal conductivity of the base fluid due to the addition of nanoparticles [11, 12, 13]. As expected, same trend was observed in the refrigerant based nanofluids as well, for instance, the thermal conductivity values increased by as much as 104% by addition of CNT nanoparticles in R113 [17]. The study of nanofluids is not just limited to the thermal conductivity, in fact, many researchers have studied other thermophysical properties as well such as viscosity, specific heat and surface tension.

The boiling heat transfer is a major area of research when it comes to refrigerants. The study of boiling heat transfer is already involves complexities and these complexities are only going to increase due to the addition of nanoparticles in the refrigerant. The researchers have observed mixed results for boiling heat transfer measurements of nanofluids and nanorefrigerants but that should not deject researchers by any means. In past, various results have been published in which the boiling heat transfer performance for nanorefrigerants was found to be higher in comparison to that of the base refrigerant without nanoparticles.

The research work on nanorefrigerants is still in its infancy. Every work, study and experiment, no matter how big or small, is important for the advancement of research in the field of nanofluids and nanorefrigerants. This paper presents a review on recent development of possible substitutes for non-ecological refrigerants employed in HVAC&R equipment based on thermodynamic, physical and environmental properties. Overall, it is useful for those readers who are interested in current status of alternative refrigerant development related to vapour compression-based refrigeration, air-conditioning and heat pump units. The study describes the selection of refrigerants adapted to each utilisation based on the thermodynamic, physical and environmental properties, the technological behaviour and the use constraints as the principal aspects of the environmental protection.

Group	Fluid	ODP	GWP (R11=1)	GWP (CO2=1)	Atmospheric Lifetime [years]
CFC	R11	1	1	4000	50…60
	R12	1	2.1…3.05	10600	102…130
	R113	0.8-1.07	1.3	4200	90…110
	R114	0.7-1.0	4.15	6900	130…220
	$R12B_1$	3-13	-	1300	11…25
	$R13B_1$	10-16	1.65	6900	65…110
HCFC	R21	0.05	0.1	-	<10
	R22	0.055	0.034	1900	11.8
	R123	0.02	0.02	120	1.4…2
	R142b	0.065	0.3…0.46	2000	19…22.4
HFC	R23	0	6	14800	24.3
	R32	0	0.14	580	6…7.3
	R125	0	0.58…0.85	3200	32.6
	R134a	0	0.28	1600	14…15.6
	R143a	0	0.75…1.2	3900	55…64.2
	R152a	0	0.03…0.04	140	1.5…8

HFO	R1234yf	0	-	<4.4	0.029
NH_3	R717	0	-	0	<0.02
CO_2	R744	0	-	1	>50
Azeotropic mixtures	R500(R12/R152a)	0.63-0.75	2.2	6000	-
	R501(R12/R22)	0.53	1.7	4200	-
	R502(R22/R115)	0.3-0.34	4.01...5.1	5600	>100
	R507(R125/R143a)	0	0.68	3800	-
Near azeotropic mixture	R404A(0.44R125/0.52R143a/ 0.04R134a)	0	0.6...0.94	3750	-
	R410A(0.5R32/0.5R125)	0	0.5	1890	-
	R428(0.775R125/0.2R134a/0.019R600a/0.006R290)	0	-	3500	-
	FX40(0.1R32/0.45R125/0.45R143)	0	0.6	3350	-
Zeotropic mixtures	R407A(0.2R32/0.4R125/0.4 R134a)	0	0.14...0.45	1920	-
	R407B(0.1R32/R0.7R125/0.2R134a)	0	0.1...0.5	2560	-
	R407C(0.23R32/0.25R125/0.52R134a)	0	0.29...0.37	1610	-
	R417A(0.466R125/0.5R134a/0.034R600)	0	-	2300	-
	R422A(0.851R125/0.115R134a/0.034R600a)	0	-	3100	-
	R424(0.505R125/0.47R134a/0.009R600a/0.01R600/0.006R60)	0	-	2400	-
	R427A(0.15R32/0.25R125/0.1R143a/0.5R134a)	0	-	2100	-

Table 4 Environmental properties of refrigerants

4. LITERATURE REVIEW

Choi S.U.S. et al [1995] suggested the concept of nanofluid metallic or non-metallic particles. Recently some studies have been reported on nanoparticles in refrigeration system because of its capability to improve heat transfer characteristics, hence efficiency enhancement.

Pawel et al. [2005] conducted studies on nanofluids and found that there is the significant increase in the thermal conductivity of nanofluid when compared to the base fluid and also found that addition of nanoparticles results in significant increase in the critical heat flux.

Bi et al. [2007] conducted studies on a domestic refrigerator using nanorefrigerants. In their studies R134a was used the refrigerant, and a mixture of mineral oil TiO2 was used as the lubricant. They found that the refrigeration system with the nanorefrigerant worked normally and efficiently and the energy consumption reduces by 21.2%. When compared with R134a/POE oil system.

Bi et al. [2008] found that there is remarkable reduction in the power consumption and significant improvement in freezing capacity. They pointed out the improvement in the system performance is due to better thermo-physical properties of mineral oil and the presence of nanoparticles in the refrigerant.

Barbara Minor et al. [2008] conclude that HFO-1234yf has excellent potential as a new low global warming refrigerant for automotive air conditioning and potentially for stationary applications. It has excellent environmental properties which can have a long term favourable impact on climate change and meet current and future climate regulations. Significant toxicity tests have been completed with encouraging results. It is compatible with existing R-134a technology which can allow for a smooth and cost effective transition. The mild flammability properties of HFO-1234y have shown its high potential for use in direct expansion applications, pending completion of risk assessments.

Jwo et al. [2009] conducted studies on a refrigeration system replacing R-134a refrigerant and polyester lubricant with a hydrocarbon refrigerant and mineral lubricant. The mineral lubricant included added Al2O3 nanoparticles to improve the lubrication and heat-transfer performance. Their studies show that the 60% R-134a and 0.1 wt % Al2O3 nanoparticles were optimal. Under these conditions, the power consumption was reduced by about 2.4%, and the coefficient of performance was increased by 4.4%.

Thomas J. Leck [2009] evaluate that HFO-1234yf as a Potential Replacement for R-134a in Refrigeration Applications. This paper presents results of work to develop a Martin Hou equation of state model for calculation of thermos-physical properties of this new molecule. And he conclude that the vapour pressures are essentially the same at about 40 ºC. At lower temperatures the vapour pressure of HFO-1234yf is higher than that of R-134a, and above 40 ºC the HFO-1234yf drops to less than that of R-134a.

Bi et al. [2011] conducted an experimental study on the performance of a domestic refrigerator using TiO_2-R600a nanorefrigerant as working fluid. They showed that the TiO_2-R600a system worked normally and efficiently in the refrigerator and an energy saving of 9.6%.

Senthilkumar and Elansezhian [2012] conducted an experimental study on the performance of a domestic refrigerator using Al_2O_3-R134a nanorefrigerant as working fluid. They found that the Al_2O_3-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 Al_2O_3.

Krishna sabareesh et.al [2012] conducted an experimental study on the performance of a domestic refrigerator using TiO_2 - R12 nanorefrigerant as working fluid. They found that the freezing capacity increased and heat transfer coefficient increases by 3.6 %, compression work reduced by 11% and also coefficient of performance increases by 17% due to the addition of nanoparticles in the lubricating oil.

Kyle M. Karber et al. [2012] found that R-1234yf is more suitable than R-1234ze to replace R-134A and he two refrigerator setup for refrigerant. In Refrigerator 1 and 2, R-1234yf had 2.7% and 1.3% higher energy consumption than R-134a this indicates that R-1234yf is a suitable for replace R-134a.In Refrigerator 1 and 2, R-1234ze had 16% and 5.4% lower energy consumption than R-134a. Thus R-1234ze might not be suitable for drop-in replacement.

Reji kumar and Sridhar [2013] conducted an experimental study on the performance of a domestic refrigerator using TiO_2 – R600a nanorefrigerant as working fluid. They found that the energy consumption reduced by 11% and coefficient of performance increases by 19.6.

Ioan Sarbu [2014] conclude that a possible solution for environmental protection is the use of inorganic refrigerants (NH_3, CO_2) and hydrocarbon refrigerants (propane, isobutene, ethylene, propylene) for industrial applications, household cooling and in air-conditioning or food storage. The hydrocarbon refrigerant represents a high risk of flammability and explosion, these substances will not be often used as refrigerants compared with CO_2 or NH_3. The refrigerant mixtures having lower environmental impacts with higher energy efficiency are considered to be fourth generation refrigerants. The HFO mixtures represent a very active research and development area today and may hold a solution for selection of alternative refrigerants in the future

D.Sendil Kumar, R. Elansezhian [2014] performed analysis in his paper ZnO nanorefrigerant in R152a refrigeration system for energy conservation and green environment, and concluded that the system works safely with replacing of R152a with the conventionally used R134a.No modification in the system was required for the retrofitting process which is a major advantage of the work. The COP increases with the increase in nano concentration of ZnO. Maximum COP of 3.56 was obtained with 0.5%v of ZnO. The suction temperature decreases with the increase in nano concentration. The input power decreases with increases in nano concentration. The pull-down temperature of the evaporator decreases with time. The usage of R152a with very low GWP ensures safe and clean environment with low power consumption. The pressure ratio decreases with then increase in nano ZnO concentration.

A. Senthilkumara, R. Praveenb [2015] investigated in his paper, Performance analysis of a domestic refrigerator using cuo –r600a nano – refrigerant as working fluid and concluded that CuO - R600a can work normally and efficiently in refrigerator and the freezing velocity of CuO - R600a was more quickly than the pure R600a system. So the above works have demonstrated that CuO - R600a can improve the performance of the domestic refrigerator.

] R. S. Mishra, Rahul Kumar Jaiswal [2014] performed analysis in his paper Thermal Performance Improvements of VCRS Using Eco Friendly Based Nanorefrigerants in Primary Circuit and concluded that use of nanoparticles enhances thermal performance of vapour compression refrigeration system from 8% to 35 % using nanorefrigerant in primary circuit. With use of nanoparticles increase in the thermal performance of vapour compression refrigeration system from 7 to 21 % using nano fluid in secondary circuit was observed. Maximum enhancement in the performance was observed using R134a/ Cu nano-refrigerant in primary circuit and water in secondary circuit of VCRS. Lowest enhancement in performance was observed using R404A/TiO2 nanorefrigerant in primary circuit and water in secondary circuit of VCRS.

Hooman Yarmand et.al [2014] numerically investigated the effect of different Reynolds numbers in the on heat transfer characteristics of nanofluids flowing through the channel. The Nusselt number increases gradually with the increase of the volume fraction of nanoparticles and Reynolds number. Effect of Reynolds number is more dominant than concentration effect of nanoparticles on heat transfer to nanofluids. CFD software (Fluent) could provide fair and agreeable result from experimental correlations.

T. Coumaressin and K. Palaniradja [2014] investigate numerically the effect of using CuO-R134a in the vapour compression system on the evaporating heat transfer coefficient, and concluded that evaporating heat transfer coefficient increases with the usage of nanoCuo.

Rahul.K. Jaiswal , R.S. Mishra [2015] investigated in his paper First Law Efficiency Improvement Of Vapour Compression Refrigeration System Using Nano Particles Mixed With R-404a Eco friendly Refrigerant and concluded that the use of nanorefrigerant instead of pure refrigerant in vapour compression refrigeration cycle increase the thermal performance of nanorefrigerant enhances significantly and also the performance of refrigeration systemand also nano particle suspended in pure refrigerant enhance the thermal conductivity from 10 to 95 %, convective heat transfer coefficient from 10 to 80 % and heat transfer enhancement factor ranges from 1.4 to 2.5. Performance enhancement of VCRS C.O.P from 3 to 15 %, Exergy efficiency 2 to 5 % observed and exergy destruction ratio of the system reduces by adding nano particle into pure refrigerant.

Zhaogang Qi [2015] performed analysis in his paper Performance improvement potentials of R1234yf mobile air conditioning system", and concluded that R1234yf system COP and cooling capacity were lower than that of R134a system. Increasing sub-cooling temperature from 1K to 10K could improve system COP and cooling capacity by 15%. The effect of superheat on COP and cooling capacity was tiny and was adverse for larger refrigerant mass flow rate. Improving compressor efficiency would be better options in the future R1234yf MAC system Enhancement.

Alptug Yataganbaba et.al [2015] conducted an experimental study for Exergy analysis of R1234yf and R1234ze as R134a replacements in a two evaporator vapour compression refrigeration systemand concluded that the exergy efficiency was greatly affected by changes in the evaporator and condenser temperature. Though the values of performance parameters for HFO-1234yf are smaller than that of HFC-134a, but the difference is small, so it can be a good alternative to HFC- 134a because of its environmentally friendly properties. The greater portion of exergy destruction takes place in the compressor.Mixing chamber has lower exergy destruction compared to other components. The highest exergy efficiencies are obtained with R1234ze and R134a.

D. Sánchez et.al [2016] conducted an experiment to evaluate energy performance of low GWP alternatives to R134a and concluded that the hydrocarbon R290 (propane) obtains the best results in terms of cooling capacity and COP. However, it requires an important increment in power consumption (up to 44.8%). In consequence, it is not suitable for use as a direct drop-in alternative. The hydrofluorocarbon R152a presents an average reduction in cooling capacity and power consumed by the compressor and it can be considered a suitable direct drop-in alternative to R134a, taking into account the corresponding safety requirements. The HFO refrigerant R1234yf introduces a decrease in terms of cooling capacity it can be considered a direct drop-in alternative to R134a with an appreciable COP reduction. The hydrofluoroolefin R1234ze (E) yields a notable reduction in cooling capacity and power consumption, and it is not suitable for use as a direct drop-in alternative. R600a is not appropriate for use as a direct drop-in alternative to R134a. R1234yf and R152a are two potential drop-in alternatives to R134a considering the energy consumption and the cooling capacity of the refrigerating facility.

J. M. Belmen-Flores et.al [2017] conducted an experimental study on domestic refrigerator for replacement of R134a and concluded that there was an increase of 4% in the energy consumption when using R1234yf with respect to R134a. A TEWI analysis was performed, showing that R1234yf is 1.07% higher than R134a

H.U. Helvaci, Z.A. Khan [2017] in his numerically study concluded that increasing nanoparticle concentration decreases the temperature differences between the wall and bulk temperature of nanofluids. Growth in Reynolds number for both the base fluid and the nanofluids diminishes the thermal irreversibility whereas enhances the frictional entropy generation.

5. DISCUSSION

In response to various environmental convention, more environmentally friendly refrigeration systems have been investigated in recent years [20, 26, 27, 28]. Two aspects are of particular concern, namely the use of ecological (environmentally friendly) refrigerants and the energy consumption issue.

Because the thermodynamic and thermo-physical proprieties of refrigerants influences the energetically performances of the system and while exerting an environmental impact, they must be carefully analysed and taken into account during the conception and design of the cooling systems.

Recently, R1234yf was proposed as an alternative of R134a in Refrigeration and automotive air-conditioning systems [20]. R1234yf has an ODP of 0, and its GWP is only 4 [29]. Hence, R1234yf satisfies the recent environmental requirements and polices quite well. This refrigerant has been classified as a very low flammable working fluid (A2L safety group [5]). In addition, the thermo-physical properties of R1234yf are quite similar to those of R134a [30]. The working pressure of the R1234yf system is very close to that of the R134a system under the working conditions of automotive air-conditioning systems.

Nanorefrigerants are going to have a promising future but there are few challenges. Because of their improved heat transfer attributes and improve-ment in COP and energy saving, it is safe to assume that nanorefrigerants will be utilized as a part of numerous modern refrigeration system and gadgets sooner rather than later.

6. CONCLUSION

In response to various environmental conventions, more environmentally friendly refrigeration systems have been investigated in recent years. Two aspects are of particular concern, namely the use of ecological (environmentally friendly) refrigerants and the energy consumption issue. This study contains a good amount of information regarding ecological refrigerant trend and nanorefrigerant. The blend of nanoparticles with ecological refrigerant has a promising future and R1234yf nanorefrigerant has potential to replace R134a.

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