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Comparative Analysis on Performance of Refrigeration Systems using Nano Refrigerants

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ABSTRACT: Refrigeration systems are widely used around the world, taken together- they are one of the factors for climate change. Amid global debate on climate change, there have been researches on enhancing performance of refrigeration systems. Scientists have been using nanoparticles, as additives to conventional refrigerants in different refrigeration systems and they have shown remarkable thermal properties and heat transfer capabilities. This paper presents comparative study on performance of refrigeration systems while using nanoparticles like SiO₂, Al₂O₃, TiO₂ and CuO as additives to conventional R134a refrigerant. Impact of using nanorefrigerants on Coefficient of Performance (COP), heat transfer capabilities and parameters (like temperature and pressure) of refrigeration systems (i.e. experimental setups) are extracted from already published research. IMST-ART software is used to simulate and calculate the performance characteristics of refrigeration system using base fluid i.e. pure R134a refrigerant. Comparison of data shows increase in heat conductivity and heat transfer coefficient of Nano-refrigerants than the conventional R134a refrigerant. It also indicated significant increase in Coefficient of Performance (COP) of refrigeration systems using nanorefrigerants in comparison to systems using traditional R134a.

KEYWORDS: Nanorefrigerants, Nanoparticle, Refrigeration System, Coefficient of Performance (COP)

I. INTRODUCTION

Refrigeration is a process in which heat is removed from a low-temperature reservoir and transferred to a high-temperature reservoir. It can be defined as the process of producing and maintaining temperatures that are below room temperature. A refrigerant is pumped through coils which extracts the heat from the space to-be refrigerated. All refrigeration systems generally work on the same principle. Most common refrigeration systems are based on Vapour Compression cycles. Over time, there has been research on using nanofluids as additives to the traditional refrigerants.

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NANOFLUIDS: Nanofluids are a new class of fluids which consist of a base fluid with along with the Nano-sized particles (1-100nm) suspended within them. These particles are generally metal or metal oxides, they have increased conduction and convection coefficients, enhanced heat transfer capabilities than ordinary fluids. Some readily used nanofluids are ethylene glycol-based copper nanofluids, water-based copper oxide nanofluids etc.

NANO REFRIGERANTS: Nano refrigerants are a new class of engineered refrigerants- which are synthesized, when nanoparticles are suspended in the conventional refrigerants. Nano refrigerants have improvised properties as compared to traditional refrigerants. They have enhanced thermophysical properties and heat transfer characteristics which results in improvement in performance of refrigerating system.

II. RELATED WORK

Jiang et al. [1] studied the thermal conductivities of CNT-R113 nanorefrigerants and after having measurement found that the measured thermal conductivities of four kinds of 1.0 vol.% CNT R113 nanorefrigerants got significantly increased to 82%, 104%, 43% and 50%, respectively.

Wang et al. [2] performed experiments on boiling heat transfer characteristics of Al₂O₃ nanoparticles which were dispersed in R22 refrigerant, and found that there was increase in heat conductivity of nanorefrigerants as compared to traditional refrigerants.

Wu et al. [3] studied the pool boiling heat transfer of the R11-TiO₂ i.e. mixture of R11 and TiO₂ and the results showed that there was an increase of heat transfer capabilities.

Park et al. [4] performed experiments on flow-boiling of SiO₂/R134a nanofluid in a horizontal tube. The result data indicated that there was decrease in heat transfer coefficient for the mixture of silica nanoparticles and R134a in comparison to the pure R134a.

Kedzierski and Gong [5] investigated the impact of CuO-R134- a pool boiling heat transfer. They found that due to nanoparticles, there was significant enhancement in the heat transfer by 50-275% as compared to base fluid R134a/polyol ester (99.5/0.5).

METHODOLOGY: IMST-ART software is used to simulate and calculate performance characteristics of refrigeration systems using traditional R134a refrigerant. Inputs to IMST-ART software are extracted from already published literature of using nanorefrigerants in refrigeration systems. Performance characteristics of refrigeration systems using traditional R134a and Nanorefrigerants (Al₂O₃-R134a, TiO₂-R134a, etc) are compared. We also reviewed heat transfer performance of different nanoparticles dispersed in various fluids.

III. THERMAL CONDUCTIVITY

Traditionally improving the heat transfer capability of refrigerants has been an area of great interest for many researchers because thermal conductivity of these fluids plays a pivotal role in development of energy-efficient systems. It is a well-established fact that crystalline solids have higher thermal conductivity than fluids. For example, the thermal conductivity of Cu at room temperature is about 600 times that of water. Similarly, even oxides like (Al₂O₃) which act as insulators have thermal conductivity relatively higher than water. Therefore, fluids containing suspended solid particles

are expected to show enhanced heat transfer properties than those of pure fluids. On the bases of this fact, it has been proposed in various research works that on suspending Nano sized particles in traditional refrigerants, a new superior category of engineered fluids (Nano-Fluids) with enhanced thermal conductivity can be produced.

Tae-Keun [6] et al. found that on adding 0.55 vol.% of Fe Nano crystalline powder in ethylene glycol the thermal conductivity enhanced by 18% with respect to corresponding base fluid.

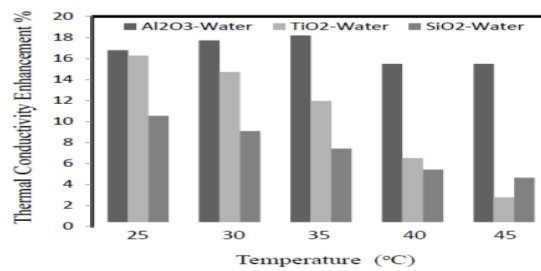
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Similarly, experimental study on enhancement of thermal conductivity of Copper suspended in water was done by S. Lee [7] et al, they reported that the addition of CuO at a volume fraction of 0.04 (4 vol.%) to ethylene glycol system, improved thermal conductivity by more than 20 percent. A.M Hussain [8] et al measured the thermal conductivity of three different nanoparticles (Al₂O₃, SiO₂, & TiO₂) suspended in distilled water and showed that in all the three cases thermal conductivity showed an increasing trend from (0.5 to 20%).



(a) Percentage of thermal conductivity enhancement

Figure 1

Figure (1) shows graph of Percentage of thermal conductivity [8]. Ding.G [9] et al also added that enhancement in thermal conductivity of Nano fluids depends on type of nanoparticle added, nanoparticle size and temperature.

IV. COMPARATIVE ANALYSIS OF COEFFICIENT OF PERFORMANCES (COP)

Kumar et al [10] added Al₂O₃ nanoparticles (0.2% concentration) to refrigeration system by adding them to the lubricant in the compressor of the refrigeration system. The size of Aluminium oxide (Al₂O₃) nanoparticles is between 40-50 nm. Also, experiment was fabricated in chamber filled with N₂ gas at 5 bar to 7 bar pressure- which is maintained for three-fourth of an hour. The performance test is done with 150 gm of R134a. Author repeats experiment 5 times. Further his experiments showed that Coefficient of Performance got enhanced maximum up to 3.5. While simulating on IMST-ART with same parameters and conditions we got following results for pure R134a

	Units	Case 1
Condensation Temp.	°C	50.00
Evaporation Temp.	°C	0.00
Condensation Press.	kPa	1318.27
Evaporation Press.	kPa	292.83
Condenser pressure drop	kPa	0.00
Evaporator pressure drop	kPa	0.00
Condenser SubCooling	K	0.00
Total SubCooling	K	0.00
Evaporator Superheat	K	5.00
Total SuperHeat	K	5.00
COP		3.04
EER		10.37
Total carnot eff.	%	55.57
COP(HPA)		3.99
EER(HPA)		13.61
TCE (HPA)	%	61.67
Cooling Capacity	kW	1.91
Heating Capacity	kW	2.51
Condenser glide	K	0.00
Evaporator glide	K	0.00
Mass Flowrate	kg/s	0.015
Inlet Flowrate	m ³ /h	3.71
Swept Volume	m ³ /h	10.00
Power Input	kW	0.63
Isentropic Eff.	%	78.13
Compressor Eff.	%	74.23

Figure 2

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refrigeration system. Figure (2) shows Screen grab of IMST-ART software showing different performance characteristics of Refrigeration System with R134a as refrigerant using conditions and parameters as used by Kumar[10]. On comparing COP of refrigeration system using traditional R134a and Nano refrigerant (0.2 % concentration of Al₂O₃ with R134a as base fluid) we observed enhancement of COP significantly by 13.10%.

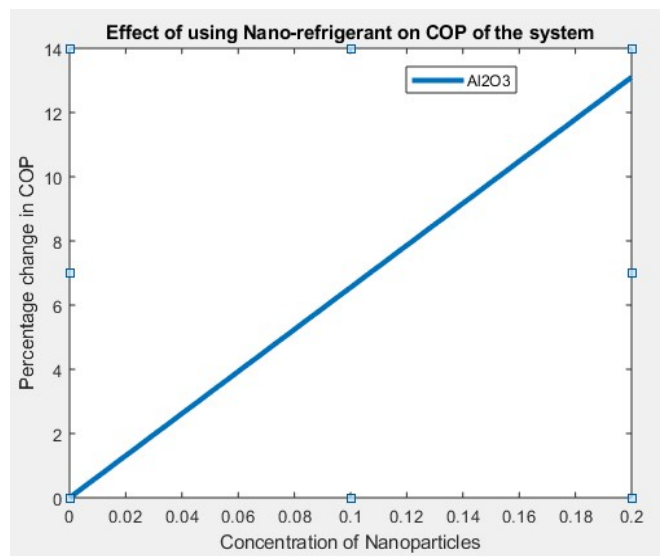


Figure 3

Figure (3) shows impact of adding Al₂O₃ to R134a on COP of the refrigeration system. This graph is between concentration of Al₂O₃ Nanoparticles added to refrigeration system with traditional R134a refrigerant and percentage change in Coefficient of Performance (C.O.P) of the system. Desai et al, [11] added SiO₂ nanoparticles in different concentrations (0.1%, 0.2% and 0.25% by volume) to R134a (base fluid) in Vapour Compression Cycle. SiO₂ nanoparticle is added to compressor of refrigeration system of 500-watt capacity. The chamber is filled with N₂ gas at 5 bar to 7 bar pressure and it is maintained for 45 minutes. During experiment, 150 gm of charge is used. Experiment is repeated for multiple times, after every trail, 15 minutes are given for the stabilization the system. We used IMST ART software with same parameters and conditions for pure R134a refrigerants.

	Units	Case 1
Condensation Temp.	°C	50.00
Evaporation Temp.	°C	0.00
Condensation Press.	kPa	1318.27
Evaporation Press.	kPa	292.83
Condenser pressure drop	kPa	0.00
Evaporator pressure drop	kPa	0.00
Condenser SubCooling	K	0.00
Total SubCooling	K	0.00
Evaporator Superheat	K	5.00
Total SuperHeat	K	5.00
COP		3.66
EER		12.52
Total carnot eff.	%	67.08
COP (HPA)		4.61
EER (HPA)		15.76
TCE (HPA)	%	71.40
Cooling Capacity	kW	1.72
Heating Capacity	kW	2.17
Condenser glide	K	0.00
Evaporator glide	K	0.00
Mass Flowrate	kg/s	0.013
Inlet Flowrate	m ³ /h	3.34
Swept Volume	m ³ /h	10.00
Power Input	kW	0.47
Isentropic Eff.	%	94.31
Compressor Eff.	%	89.60

Figure 4

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Figure (4) shows screen grab of IMST-ART software showing different performance characteristics of Refrigeration System with R134a as refrigerant using conditions and parameters as used in experiments by Desai et al, [11]. Here COP of refrigeration cycle with R134a is 3.66. When 0.1% concentration of SiO₂ is added to R134a, its COP gets increased to 3.19 i.e. by 7.6%. When 0.2% of SiO₂ is added to R134a, its COP gets increased to 4.176 i.e. by 14.10%. When 0.25% of SiO₂ are added to R134a, its COP gets increased to 4.095 i.e. by 11.90%.

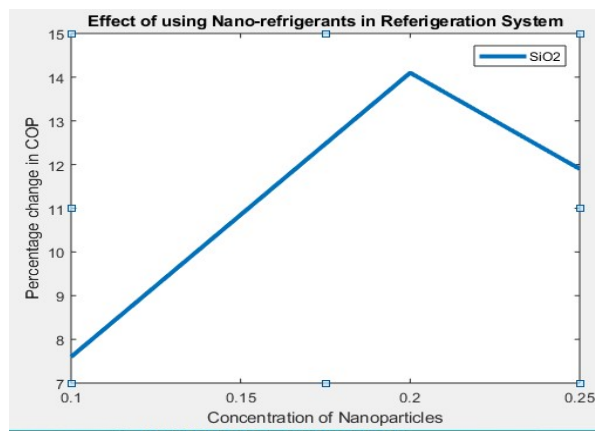


Figure 5

Figure (5) shows impact of adding SiO₂ to R134a on COP of the refrigeration system. Babu et al [12] used TiO₂ nanoparticle with R134a refrigerant. Experimental set-up is designed with following characteristics: Power input to compressor is 0.222 kW/hr, refrigeration effect of the set-up i.e. vapour compression cycle is 0.444 kW/hr. Also, refrigerant temperature at Entry of Compressor is 27 C. Refrigerant Temperature at Exit of Compressor is 35 C. Refrigerant Temperature at Exit of Condenser is 33 C. Refrigerant Temperature at Entry of Evaporator is 24 C. Water Temperature inside Evaporator Tank is 25 C. All these details regarding experimental setup and other parameters are fed into IMST-ART software.

	Units	Case 1
Condensation Temp.	°C	33.00
Evaporation Temp.	°C	24.00
Condensation Press.	kPa	839.01
Evaporation Press.	kPa	645.95
Condenser pressure drop	kPa	0.00
Evaporator pressure drop	kPa	0.00
Condenser SubCooling	K	0.00
Total SubCooling	K	0.00
Evaporator Superheat	K	5.00
Total SuperHeat	K	5.00
COP		1.99
EER		6.81
Total carnot eff.	%	6.04
COP (HPA)		2.91
EER (HPA)		9.95
TCE (HPA)	%	8.56
Cooling Capacity	kW	0.44
Heating Capacity	kW	0.65
Condenser glide	K	0.00
Evaporator glide	K	0.00
Mass Flowrate	kg/s	0.003
Inlet Flowrate	m ³ /h	0.31
Swept Volume	m ³ /h	10.00
Power Input	kW	0.22
Isentropic Eff.	%	7.04
Compressor Eff.	%	6.47

Figure 6

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Figure (6) Screen grab of IMST-ART software showing different performance characteristics of Refrigeration System with R134a as refrigerant using conditions and parameters as used in experiments by Babu et al [12]. Coefficient of Performance (COP) for the pure R134a refrigerant under above parameters and conditions is 1.99. When 0.1 gm/L of TiO₂ is added to R134a, COP gets increased to 2.26, i.e. there is increase of 11.95% in COP. When 0.2 gm/L of nanoparticle is added to R134a, COP of the vapour compression refrigeration gets increased to 2.404 i.e. there is increase of 17.08% in COP.

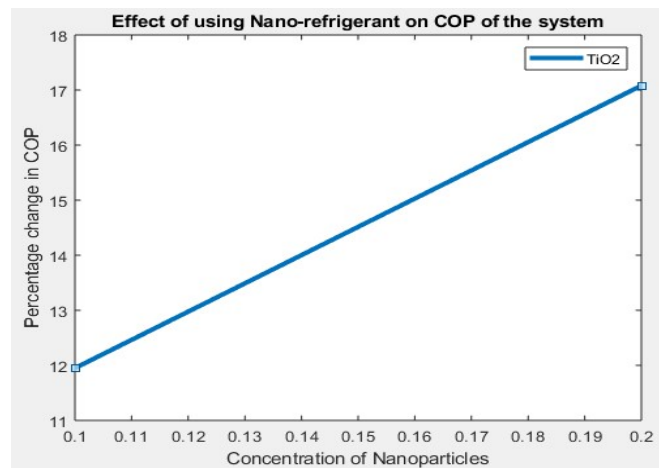


Figure 7

Figure (7) shows Graph shows impact of adding TiO₂ to R134a on COP of the refrigeration system. Ahmed [13] used three concentrations (0.1%, 0.25%, 0.4%) of CuO-R134a nanorefrigerants. The test rig system used for experiment is first evacuated. Pressure gauges and thermocouples are placed at different places of the test-rig for the measurement of different pressures and temperatures during the experiment. Refrigeration system has thermal load of 600 KJ. Ambient temperature of the refrigeration system is 35 C. All these details were fed to IMST-ART software for R134a.

	Units	Case 1
Condensation Temp.	°C	50.00
Evaporation Temp.	°C	0.00
Condensation Press.	kPa	1318.27
Evaporation Press.	kPa	292.83
Condenser pressure drop	kPa	0.00
Evaporator pressure drop	kPa	0.00
Condenser SubCooling	K	0.00
Total SubCooling	K	0.00
Evaporator Superheat	K	4.00
Total SuperHeat	K	4.00
COP		1.88
EER		6.43
Total carnot eff.	%	34.44
COP(HPA)		2.80
EER(HPA)		9.57
TCE (HPA)	%	43.35
Cooling Capacity	kW	2.04
Heating Capacity	kW	3.04
Condenser glide	K	0.00
Evaporator glide	K	0.00
Mass Flowrate	kg/s	0.016
Inlet Flowrate	m ³ /h	3.98
Swept Volume	m ³ /h	10.00
Power Input	kW	1.09
Isentropic Eff.	%	50.10
Compressor Eff.	%	46.09

Figure 8

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Figure (8) shows screen grab of IMST-ART software showing different performance characteristics of Refrigeration System with R134a as refrigerant using conditions and parameters as used in experiments by Ahmed [13]. Ahmed charges refrigeration system with 200 gm of nanorefrigerant by adding CuO lubrication oil suspension to the compressor of the refrigeration system- and he does so for three different concentrations of the Nano-refrigerants i.e. 0.1%, 0.25% and 0.4%. When 0.1% concentration of CuO is added, the COP is increased to 2.06 i.e. COP gets increased by 8.73%. When 0.2% concentration of CuO nanoparticle are added, COP is increased to 2.10 i.e. COP gets increased by 10.47%. COP of the refrigeration system is increased to 2.13, when 0.4% concentration of the CuO nanoparticles are added to the system i.e. COP gets increased by 11.73%.

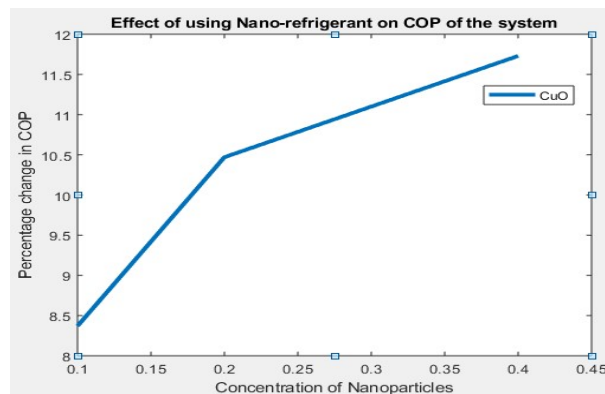


Figure 9

Figure (9) shows graph shows impact of adding CuO to R134a on COP of the refrigeration system.

V. CONCLUSION

- Various experiments and researches as cited above in the paper suggest there is an extensive increase in heat conductivity and heat transfer coefficient of Nano refrigerants as compared traditional refrigerants.
- On Comparing COP of refrigeration systems using traditional refrigerants and Nano refrigerants, it was observed that there was significant increase in COP of the refrigeration systems using Nano refrigerants- which reduces the power consumption of system and makes it more energy efficient.
- It was observed when concentration of Nano particles in refrigerants are increased, it results in increase of COP of the refrigeration system up to certain threshold, as in case of adding 0.2% of SiO₂ to R134a, COP gets increased by 14.10%. while as when 0.25% of SiO₂ is added to R134a, COP gets increased. by 11.90% i.e. 2.2% less than 0.2% of SiO₂.

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Figure (10) shows relation between percentage change in Coefficient of Performance (COP) and concentration of different nanoparticles added to refrigerant in Vapour Compression Refrigeration System. Figure (11) shows graph shows relation between percentage change in Coefficient of Performance (COP) and concentration of different nanoparticles added to refrigeration system.

Z	Nanoparticles	Concentration	%age change in COP
R134a	Al ₂ O ₃	0.2	13.10
R134a	SiO ₂	0.1	7.6
R134a	SiO ₂	0.2	14.10
R134a	SiO ₂	0.25	11.90
R134a	TiO ₂	0.1	11.95
R134a	TiO ₂	0.2	17.08
R134a	CuO	0.1	8.73
R134a	CuO	0.2	10.47
R134a	CuO	0.4	11.73

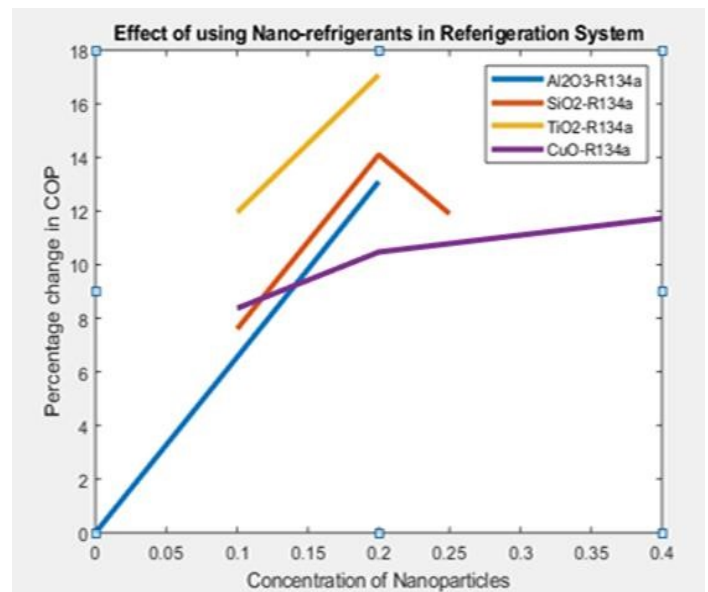


Table 1

REFERENCES

- [1] Weiting Jiang, Guoliang Ding, Hao Peng, Measurement and model on thermal conductivities of carbon nanotube nanorefrigerants, Int. J. Therm. Sci. 48 (6) (2009) 1108–1115.
- [2] Kai-Jian Wang, Guo-Liang Ding, W.T. Jiang, Nano-scale thermal transporting and its use in engineering, Proceedings of the 4th Symposium on Refrigeration and AirCondition, Southeast University, 2006.
- [3] W.U. Xiao-Min, L.I. Peng, L.I. Hui, W.A.N.G. Wei-Cheng, Investigation of pool boiling heat transfer of R11 with TiO₂ nano-particle, J. Eng. Thermophys. 28 (2008) 124–126.
- [4] Y. Park, A. Sommers, L. Liu, G. Michna, A. Joardar, A. Jacobi, Nanoparticles to enhance evaporative heat transfer, The 22nd Int. Congress of Refrigeration, Beijing, China, in CD-ROM, Paper Number: ICR07B1-709, 2007.
- [5] M.A. Kedzierski, M. Gong, Effect of CuO nanolubricant on R134a pool boiling heat transfer, Int. J. Refrig. 32 (5) (2009) 791–799.
- [6] TK Hong, Yang HS, Choi CJ. “Study of the enhanced thermal conductivity of Fe Nano-fluids” Journal of Applied Physics 2005;97(6).]
- [7] S. Lee S, U.-S. Choi, J. A. Eastman, S. Li “Measuring Thermal Conductivity of Fluids Containing Oxide Nanoparticles” Journal of Heat Transfer MAY 1999, Vol. 121 / 289]
- [8] Adnan M. Hussein^{1,4}, R.A. Bakar^{1,2}, K. Kadirgama^{1,2} and K.V. Sharma³, “EXPERIMENTAL MEASUREMENT OF NANOFLUIDS THERMAL PROPERTIES” International Journal of Automotive and Mechanical Engineering (IJAME) ISSN: 2229-8649 (Print); ISSN: 2180-1606 (Online); Volume 7, pp. 850863, January-June 2013]
- [9] D. Sendil Kumar and Dr. R. Elansezhian, 2012, “Experimental Study on Al₂O₃-R134a Nano Refrigerant in Refrigeration System” International Journal of Modern Engineering Research (IJMER) www.ijmer.com Vol. 2, Issue. 5, Sep.-Oct. 2012 pp-3927-3929 ISSN: 2249-6645
- [10] Desai et al, “Application of SiO₂ Nanoparticles as Lubricant Additive in VCRS: An Experimental Investigation” Asian Review of Mechanical Engineering ISSN: 2249 - 6289 Vol. 4 No. 1, 2015, pp. 1-6 © The Research Publication.
- [11] Jiang W, Ding G, Peng H. Measurement and model on thermal conductivities of carbon nanotube Nano refrigerants. International Journal of Thermal Sciences 2009;48:1108–15
- [12] ManojBabu, S. Nallusamy, K. Rajan, “Experimental Analysis On Vapour Compression Refrigeration System Using Nano lubricant With HFC-134a Refrigerant”, Nano Hybrids Vol. 9 (2016) pp 33-43 Submitted: 2015-09-22
- [13] Ahmed J. Hamad, “Experimental investigation of vapor compression refrigeration system performance using Nano-refrigerant”, Wasit Journal of Engineering Science, Vol. (2), No. (2), 2014.