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RESEARCH ARTICLE

Methods for Improving Thermodynamic Performance of Variable Speed Vapour Compression Refrigeration Systems Using Nanorefrigerent in Primary Circuit

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ABSTRACT

The use of nanorefrigerant/refrigerant as a primary fluid in variable vapour compression refrigeration systems was studied and computational simulation program was developed to solve the non linear equations of the system model. The investigation includes the thermal conductivity, dynamic viscosity, and heat transfer rate of the nanorefrigerant/refrigerant with complete system geometry of VCRS. Simulation results have shown that for the same geometric characteristics of the system 1st Law enhancement about 7-30 % and heat transfer rate 10-30 % and nanorefrigerant thermal conductivity enhancement 1500-3000 %. These advanced thermo physical properties increased the heat transfer rate in the heat exchanger. The nanorefrigerant/refrigerant could be better working fluid to be used in the refrigeration and air conditioning system to increase the heat transfer performance of that system and overall system performance and save the energy usage.

Key words: *Exergy-Energy Analysis, Performance Improvement Nano materials, Ecofriendly refrigerants, VCRS*

INTRODUCTION

Now a day's refrigeration based equipment are most important for industrial and domestic applications. Those systems utilize more energy compare to other appliances. The refrigeration systems have been severely investigated to reduce the energy consumption in many research articles. Hence, nanoparticle based refrigerant has been introduced a superior properties refrigerant that increased the heat transfer performance of base refrigerant of the refrigeration system. Many types of solid and oxide materials could be used as the nanoparticles to be suspended into the conventional refrigerants. In this study, the effect of the suspended copper oxide (CuO), Titanium Oxide (TiO2), Aluminum Oxide (Al2O3), into the R134a, R407c and R404 ecofriendly refrigerant is investigated by using mathematical modeling. Ultrahigh-performance cooling is one of the most vital needs of many industrial technologies. However, inherently low thermal conductivity is a primary limitation in developing energy-efficient heat transfer fluids that are required for ultrahigh-performance cooling. Modern nanotechnology can produce metallic or nonmetallic particles of nanometer dimensions. Nanomaterials have unique mechanical, optical, electrical, magnetic, and thermal properties. Nanofluids are engineered by suspending nanoparticles with average sizes below 100 nm in traditional heat transfer fluids such as water, oil, refrigerant and ethylene glycol. A very small amount of guest nanoparticles, when dispersed uniformly and suspended stably in host fluids, can provide dramatic improvements in the thermal properties of host fluids. Nanofluids (nanoparticle fluid suspensions) is the term coined by Choi [1] to describe this new class of nanotechnology-based heat transfer fluids that exhibit thermal properties superior to those of their host fluids or conventional particle fluids suspensions.

Nanofluid technology, a new interdisciplinary field of great importance where nanoscience, nanotechnology, and thermal engineering meet, has developed largely over the past decade. The goal of nanofluids is to achieve the highest possible thermal properties at the smallest possible concentrations (preferably <1% by volume) by uniform dispersion and stable suspension of nanoparticles (preferably <10 nm) in hot fluids. To achieve this goal it is vital to understand how nanoparticles enhance energy transport in liquids. Since Choi [1] conceived the novel concept of nanofluids in 1993, by discovering unexpected thermal properties of nanofluids, but also in proposing new mechanisms behind enhanced thermal properties of nanofluids, developing unconventional models of nanofluids, and identifying unusual opportunities to develop next-generation coolants such as smart coolants for computers, Industrial appliances and safe coolants for nuclear reactors. As a result, the research topic of nanofluids has been receiving increased attention worldwide. The recent growth of work in this rapidly emerging area of nanofluids is most evident from the exponentially.

Although lots of researches have been done and going on based on the performance evaluation of various metallic/ nonmetallic nanoparticle suspended into the conventional fluid to enhance the heat transfer property of base fluid. Also some theoretical analysis of suspension of nanoparticle Al_2O_3 in conventional refrigerant. On the other hand the performance of vapour compression cycle based chiller facility using nanorefrigerant yet to be analyzed with different type, concentration and diameter of nanoparticle. Such as TiO_2, CuO nanoparticle suspension into conventional refrigerant with different concentration and diameter are yet to be analyzed and also effect of variation of concentration and nanoparticle diameter on the performance of vapour compression refrigeration system is yet to be analyzed. The effect of changing input parameter of VCRS using nanorefrigerant also required. The idea of Suspension nanoparticle into conventional refrigerant and theoretical analysis of VCRS using nanorefrigerant is proposed after going through the research work and literature review. The experiment was conducted on the operating the test rig has been developed in the DTU as shown in Fig-1.

Fig.1 (a): variable-speed vapour compression refrigeration systems

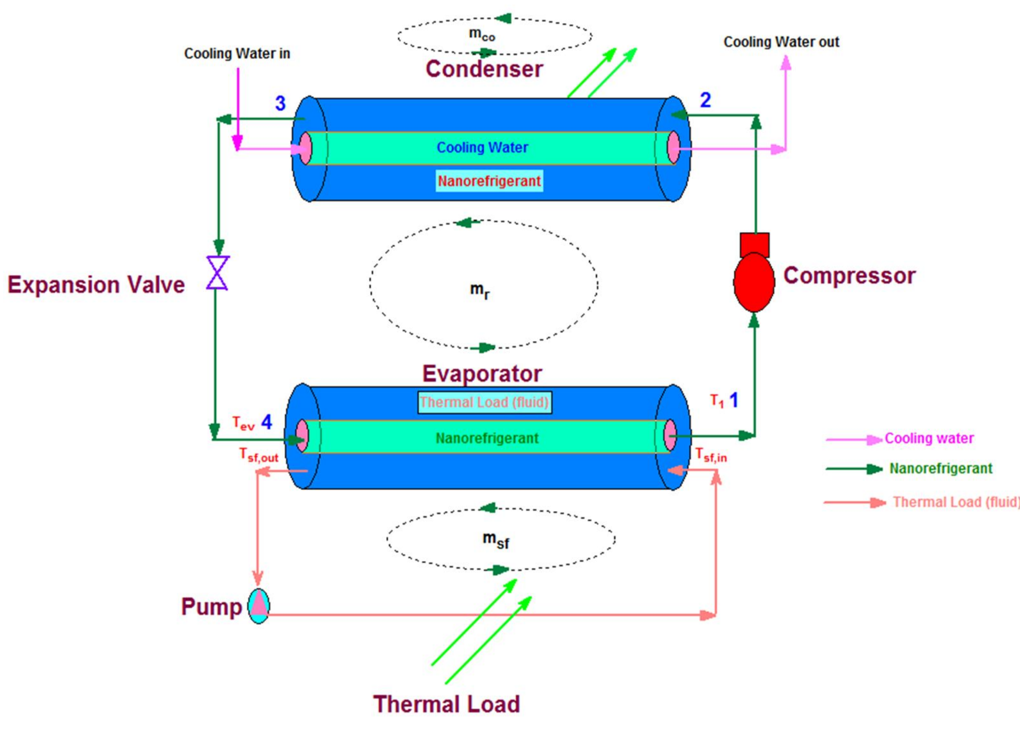


Fig-1(b): Experimental set of variable-speed vapour compression refrigeration systems

In the modeling of vapour compression refrigeration system, first all we write all the heat balance equation for design of the components in the system. and then substituting inputs as per developed model and for output we assumed some guess values in the software then solved the equations one after one components. First we designed evaporator, then, then condenser. For design evaporator we "comment" the other components and check the Number of equations is equal to Numbers. of variables and then solve the formulation, if there is some error while solving then, we update our guess nearest values of our design. The design of the components set all the inputs like, size of the evaporator and condenser, mass flow rate of brine and water, compressor speed, Temperature of brine and water. So, as per our objective to have constant our inputs data and then we use various nearest replacement of eco-friendly refrigerants on the same configuration and then compare the outputs as per ecofriendly refrigerants used (i.e. R134a, R404a, R407c, R290.shown in the Table-1

MODEL VALIDATION

The validation of the model using experimental measurements of different steady states is presented. To this end, three sets of steady state experiments have been undertaken. Each set of experiments consists of a group of tests where the facility is working at a defined set of inputs Table 5.1. The experimental result validation is done without using nanofluid or nanorefrigerant. Table 1(a) to 1(h) expresses the result without using nanofluid. And for initial condition the condenser and evaporator concentric tube type. With condenser outer tube diameter is 5/8" and inside tube diameter is 3/8"evaporator outer tube diameter is 5/8" and inside tube diameter is 3/8"

Table 1(a): Inputs of the design and experimental test rig

S. No	m_b (kg/s)	m_w (kg/s)	Condenser size (m)	Evaporator size (m)	N (rpm)
1.	0.006	0.008	1.2	0.8	2900

Table 1 (b): Inputs of the design and experimental test rig for system without nano materials

S. No	m_b (kg/s)	m_w (kg/s)	Tb_{in} (°C)	Tw_{in} (°C)	N (rpm)
1.	0.006	0.008	25	25	2900

For the experiment we use refrigerant is R134a. In table 1(a)-1(b) the initial input to for the computational and for test Rig. In table 1(c) is the computational or predict data, table1(d) is the experimental data.

Table 1 (c): Inputs measured for the test rig without nano materials

S. No	m_b (kg/s)	m_w (kg/s)	Tb_{in} (°C)	Tw_{in} (°C)	N (rpm)
1.	0.006	0.008	25	25	2900
2.	0.008	0.008	25	25	2900
3.	0.006	0.006	25	25	2900

Table 1(d): computational output data obtained from model for system for system without nano materials

S. No	m_b (kg/s)	m_w (kg/s)	Condenser size (m)	Evaporator size (m)
1.	0.006	0.008	1.2	0.8
2.	0.008	0.008	1.2	0.8
3.	0.006	0.006	1.2	0.8

Table 1 (e): Computational data obtained for system without nano materials

S. No	Te (°C)	Tk (°C)	Tb_{out} (°C)	Tw_{out} (°C)
1.	-1.501	48.25	12.9	37.01
2.	0.277	49.17	15.29	37.69
3.	-0.78	51.32	13.19	40.82

Table 1(f): Computational or predict data for system without nano materials

S. No	Te (°C)	Pe (bar)	Pk (bar)	COP
1.	-1.501	2.774	12.62	2.978
2.	0.277	2.96	12.91	3.131
3.	-0.78	2.847	13.63	2.827

Table 1(g): computational results obtained for system without nano materials

S. No	Te (°C)	Tk (°C)	Tb_{out} (°C)	Tw_{out} (°C)
1.	-1.8	42.10	13.1	34.70
2.	-0.7	43.60	14.3	36.10
3.	1.1	46.30	16.4	35.20

Table 1 (h): computational results obtained for system without nano materials

S. No	Te (°C)	Pe (bar)	Pk (bar)	COP
1.	-1.8	2.86	12.90	2.67
2.	-0.7	2.56	11.80	2.75
3.	1.1	2.80	12.64	2.84

Table 2(a): Physical and environmental characteristics of selected refrigerants

Properties	R134A	R404A	R407C	R290
Molecular Weight (kg / Kmol)	102	97.6	86.20	44.1
B.P. at 1.013 bar (°C)	-26.1	-51.4	-43.6	-42.2
Critical temperature (°C)	101.1	72.15	85.8	96.68
Critical pressure (bar)	40.60	37.35	46.00	42.47
ODP	0	0	0	0
GWP_{100}	1300	3260	1800	3

A comparison between the measured and predicted values for the parameters in three sets is presented. It has been observed that the predicted values of the parameters are within the 20% of the measured values. The most widely used fluorocarbon refrigerants in the world. These include the environmentally friendly hydrocarbon (HFC) refrigerants R134a, R404A, R407C and R290.
In a simple reciprocating system which can simulate the performance of actual system as closely as possible, has been used to compare the characteristics of various refrigerants R134a, R404A, R407C and R290. Similarly table 2(b) show the comparison between most commonly used refrigerant R134a, R404A, and R407cand R290. It was observed that that R134a have highest C.O.P. than other refrigerant for the same geometry and input parameter of the VCRS. It is because compressor work reduces about 20-30 % than other refrigerant by using R134a in VCRS. Also working pressure ratio is little lower than the other refrigerant. So that R134a is most commonly used in HVAC and automobile AC system.

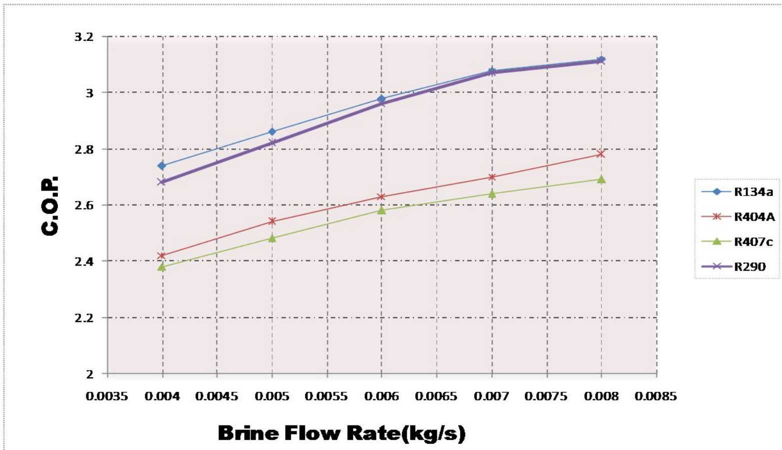
Table 2(b): Comparison of performance parameters for different ecofriendly refrigerants using model

Parameters	R134A	R404A	R407C	R290
COP	2.978	2.638	2.574	2.959
Compressor work (W)	102	131.4	127.8	121.2
Refrigerating effect (W)	303.7	346.5	329	358.4
Mass flow rate (kg/s)	0.00236	0.0047	0.0027	0.00157
Condenser pressure (bar)	12.62	27	23.27	17.16
Evaporator pressure (bar)	2.774	5.788	4.208	9.148
Condenser Temperature (°C)	48.25	56.94	52.49	51.26
Evaporator Temperature (°C)	-1.501	-1.338	-2.272	-4.326
Brine outlet temperature (°C)	12.9	11.19	11.89	10.72
Water outlet temperature (°C)	37.01	39.16	38.47	39.23

R407C exhibits a relatively high temperature glide compared to the other refrigerants, which have almost no glide. It also offer '0' ODP, low global warming potential. European market embraced R407C and currently offers a wide R407C AC product range. Further, a change to polyester lubricant is also required. R404A has been in the market place for more than 10 years.
Table-2(b) shows the C.O.P. value of R134a and R290 is quite similar but R404A and R407C have very less value of C.O.P than R134a and R290. Thus the R134 and R290 are more efficient considering 1st law of thermodynamics. But due to their different thermo physical property it is used in different application. Similarly the compressor work for different refrigerant respectively and it can be seen that compressor work is also high of R407C and R404A than the R134a and R290 so that its performance reduces 1st law of thermodynamics.
The refrigeration effect R134a, R290, R404A and R407C respectively and from the Fig shown it is very clear that refrigeration effect of R134a is less than the R290 but due to higher compressor

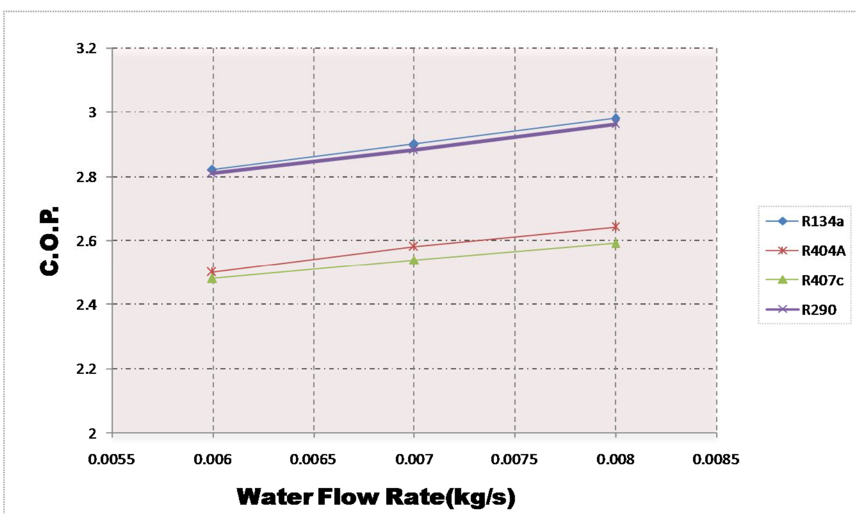
work of R290 than R134a the C.O.P. value of R290 is lower than the R134.fig also show that refrigeration effect of R404A is higher than the R407C. The characteristic performance curves of vapor-compression refrigeration systems are defined as a plot between the inputs of the system by using refrigerants R134a, R404A, R407C and R290 to the coefficient of performance (COP) of the system.

Fig. 2(a): COP vs. Brine flow rate of different refrigerants



In Fig-2(a) the performance curve is shown between COP and Brine flow rate of different refrigerants. When brine mass flow rate 0.004 to 0.008 kg/s (100%) then change in COP for R134a is 14.10 %, R404a is 13.94%, R407c is 14.39% and R290 is 17.06%.

Fig. 2(b): COP vs. condensing water flow rate of different refrigerants



In Fig 2(b) the performance curve is shown between COP and Water flow rate of different refrigerants. When water mass flow rate 0.006 to 0.008 kg/s (33.3%) then change in COP for R134a is 5.54%, R404a is 5.65%, R407c is 3.58% and R290 is 5%. In Fig-2(c) the performance curve is shown between COP and condensing water inlet temperature of different refrigerants. When condensing water inlet temperature 18 to 30 ^{o}C (66.67%) then change in COP for R134a is 20.27%, R404a is 16.13%, R407c is 12.50% and R290 is 16.32%.

Fig. 2(c): COP vs. condensing water inlet temperature of different refrigerants

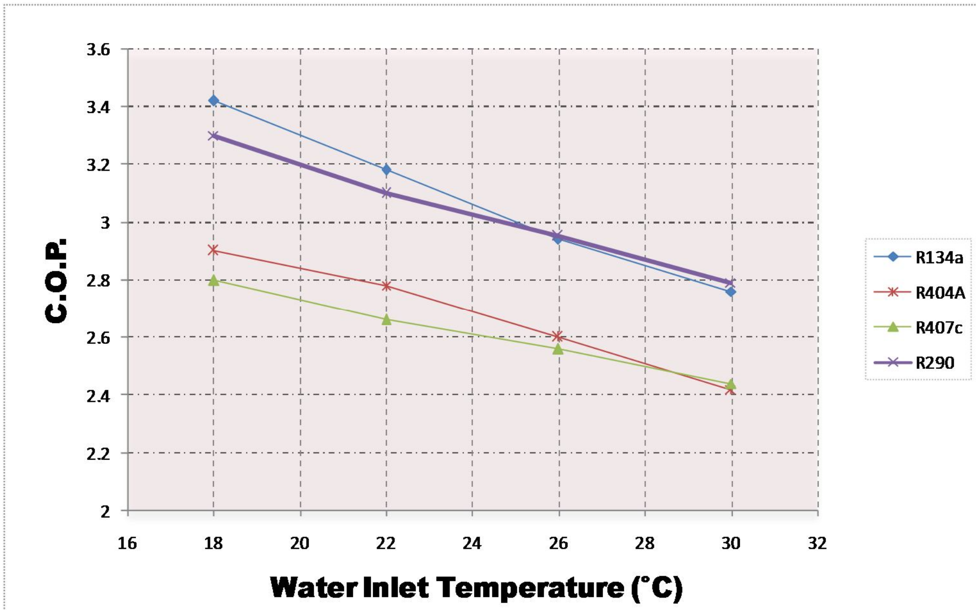
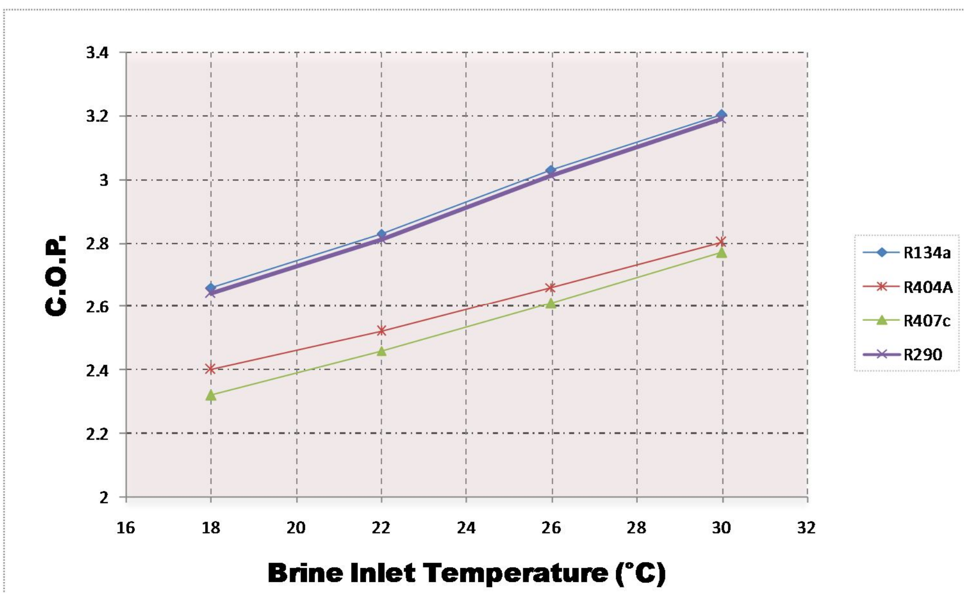


Fig. 2(d): COP vs. Brine inlet temperature of different refrigerants

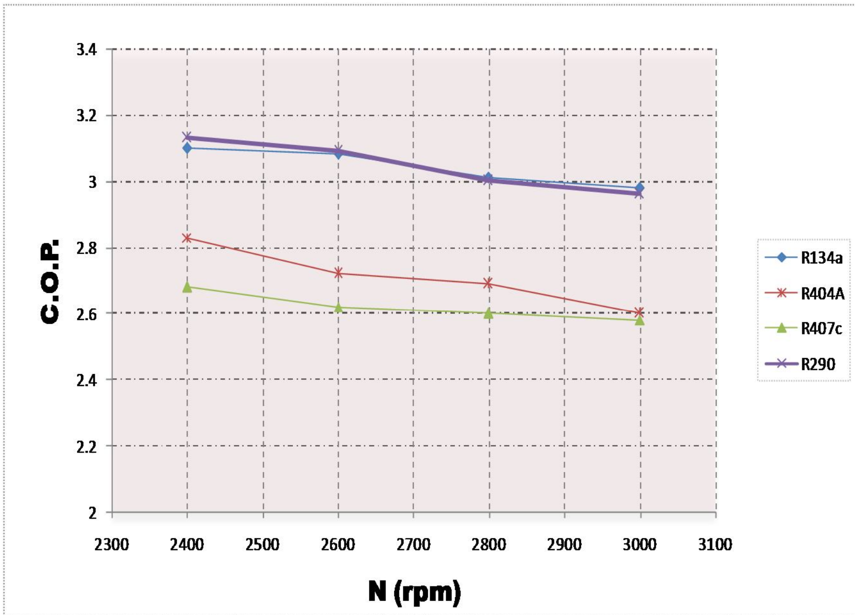


In Fig 2(d) the performance curve is shown between COP and Brine inlet temperature of different refrigerants. When brine inlet temperature 18 to 30 ^{o}C (66.67%) then change in COP for R134a is 20.46%, R404a is 17.15%, R407c is 18.47% and R290 is 20.54%.

In Fig 2(e) the performance curve is shown between COP and speed of the compressor N (rpm) of different refrigerants. When Compressor speed is from 2400 to 3000 rpm (25%) then change in COP for R134a is 5.55%, R404a is 7.38%, R407c is 5.08% and R290 is 6.98%.

The performance evaluation of vapour refrigeration system using nano particles mixed in the ecofriendly refrigerants in the primary circuit has been carried out. nanorefrigerantat the same input and geometric parameter of VCRS and result are shown below.

Fig. 2(e): COP vs. Compressor speed (N) of different refrigerants



THERMO PHYSICAL PROPERTY OF NANOREFRIGERANT

In this section variation of thermo physical property of base refrigerant using nanoparticle suspended into base refrigerant at 5 Vol % are shown below.

1. Thermal conductivity of nanorefrigerant with different nanoparticle and base refrigerant

Fig. 3.1.(a): Temperature vs Thermal conductivity of R134a with different nanoparticle

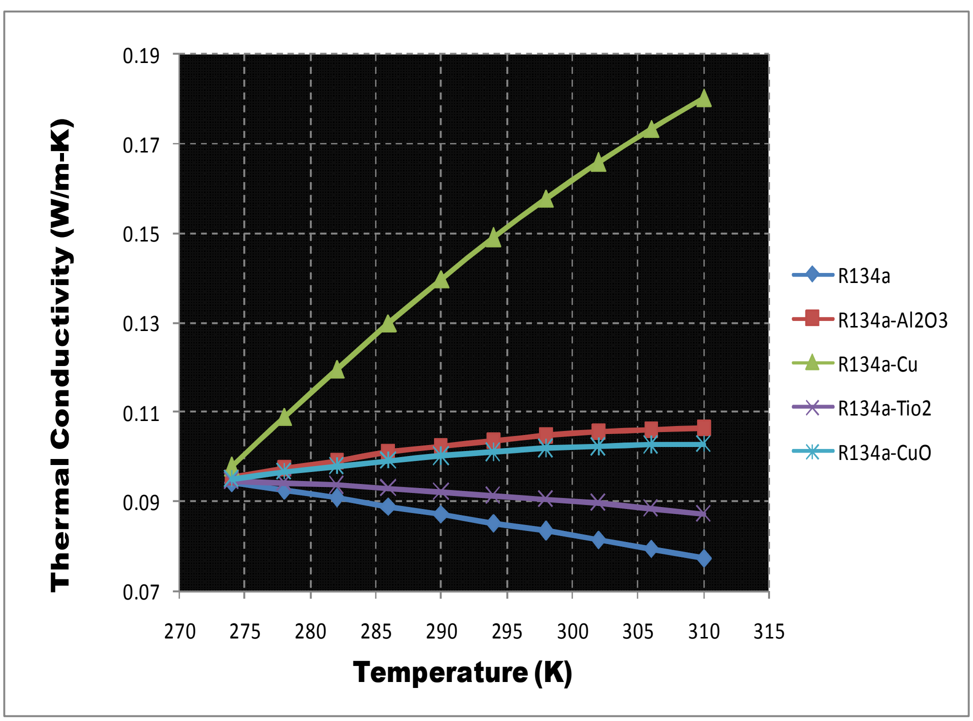


Fig. 3.1(b): Temperature vs Thermal conductivity of R407c with different nanoparticle

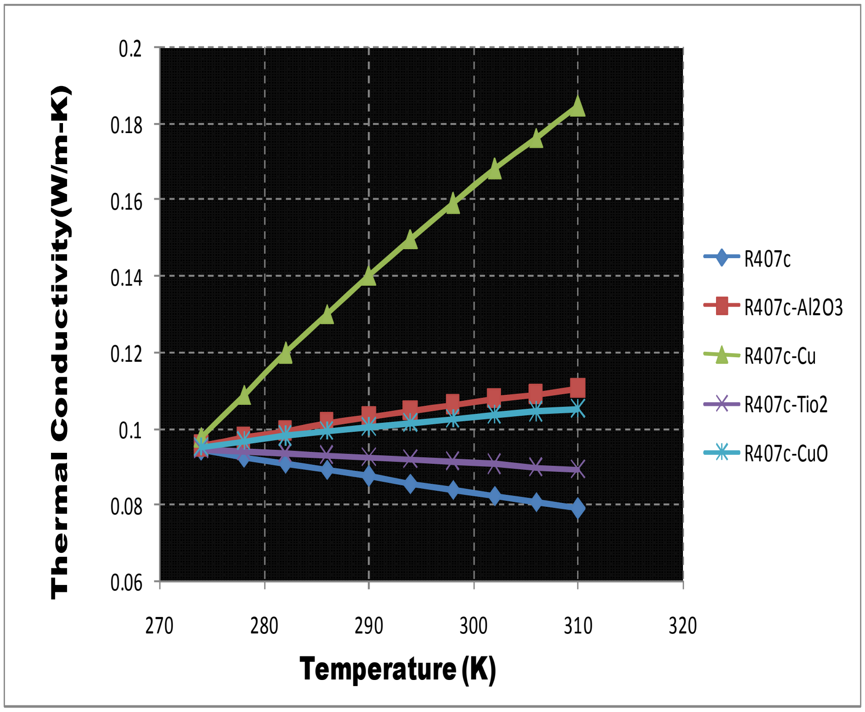


Fig. 3.1(c): Temperature vs Thermal conductivity of R404A with different nanoparticle

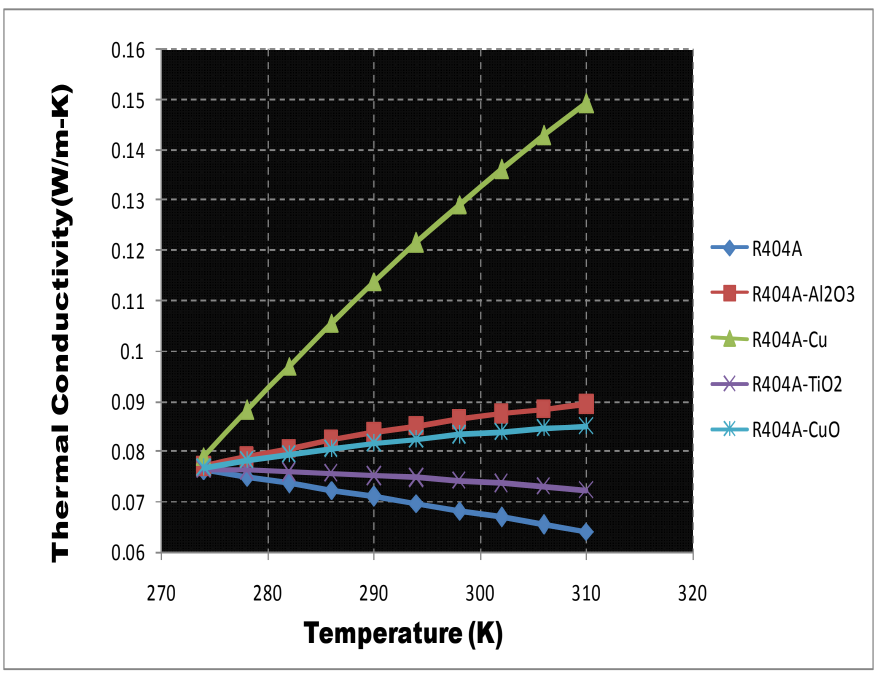


Fig. 3.1(a) -3.1(c) shoe the enhancement in thermal conductivity of pure when different kind of nanoparticle is suspended into the host refrigerant. The enhancement factor varies from 0.06 to 2 for different nanoparticle from the fig we can see that cu nanoparticle have more EF at higher temperature which value is approx 2.

2. Density of nanorefrigerant with different nanoparticle and base refrigerant

Fig. 3.2 (a): Temperature vs Density of R134a with different nanoparticle

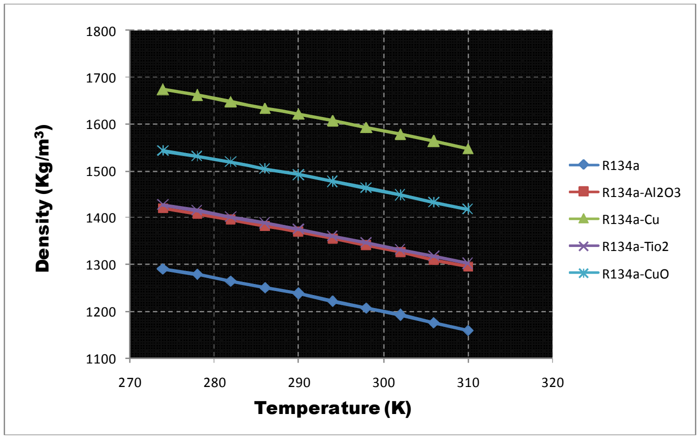


Fig. 3.2(b): Temperature vs Density of R404Aa with different nanoparticle

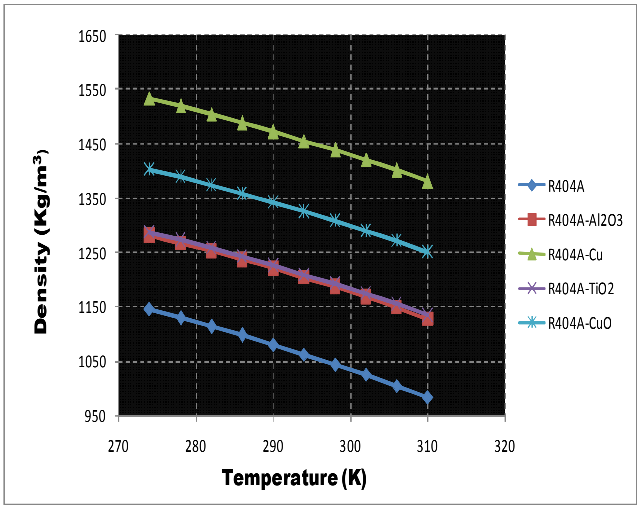


Fig. 3.2(c): Temperature vs Density of R407c with different nanoparticle

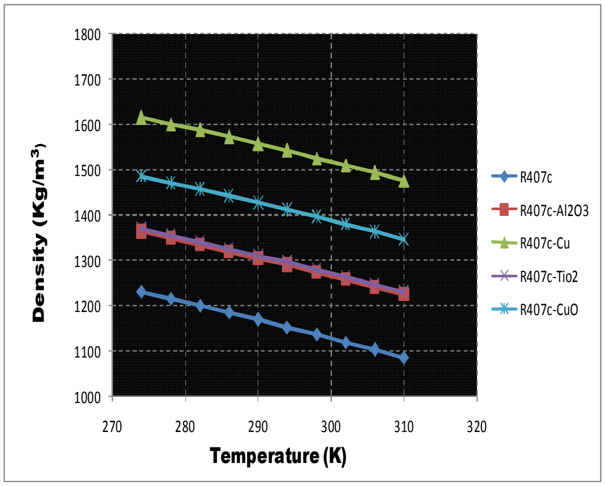


Fig. 3.2(a) -3.2(c) shows variation in density of nanorefrigerant subject to temperature variation. Fig shows that density variation of nanorefrigerant is similar to pure refrigerant as higher temperature low density and lower temperature high.

3. Dynamic viscosity of nanorefrigerant with different nanoparticle and base refrigerant

Fig. 3.3(a): Temperature vs Dynamic viscosity of R404A with different nanoparticle

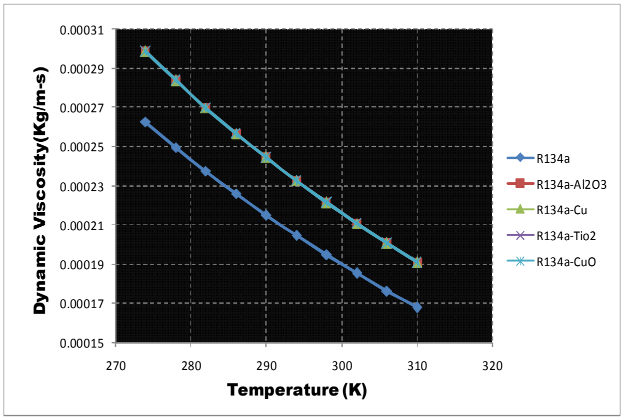


Fig. 3.3(b): Temperature vs Dynamic viscosity of R407c with different nanoparticle

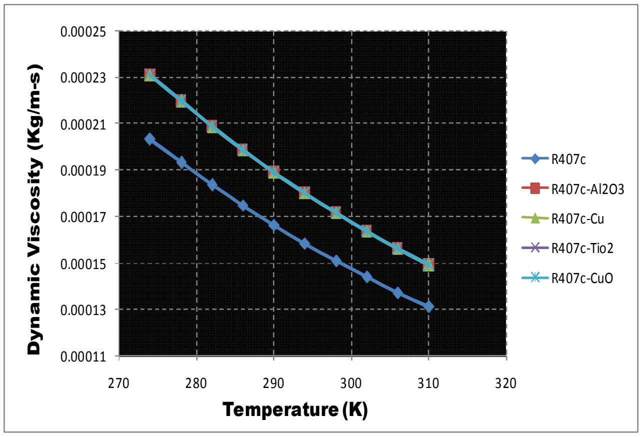


Fig. 3.3(c): Temperature vs Dynamic viscosity of R404A with different nanoparticle

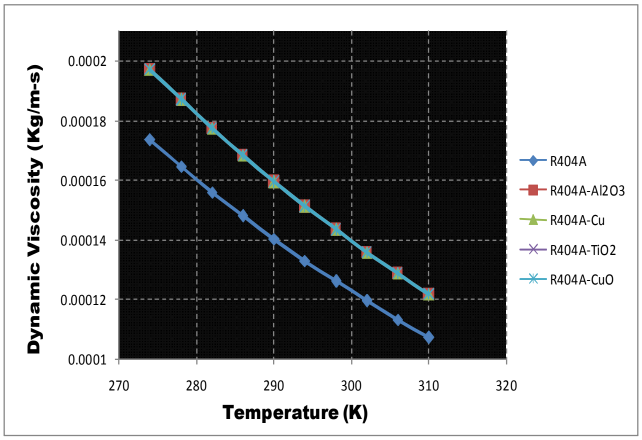


Fig. 3.3(a) to fig. 3.3(c) shows variation in Dynamic viscosity of nanorefrigerant subject to temperature variation. Fig shows that Dynamic viscosity variation of nanorefrigerant is similar to pure refrigerant as higher temperature low viscosity and lower temperature high.

4. Specific heat of nanorefrigerant with different nanoparticle and base refrigerant

Fig. 3.4(a): Temperature vs Specific heat of R407c with different nanoparticle

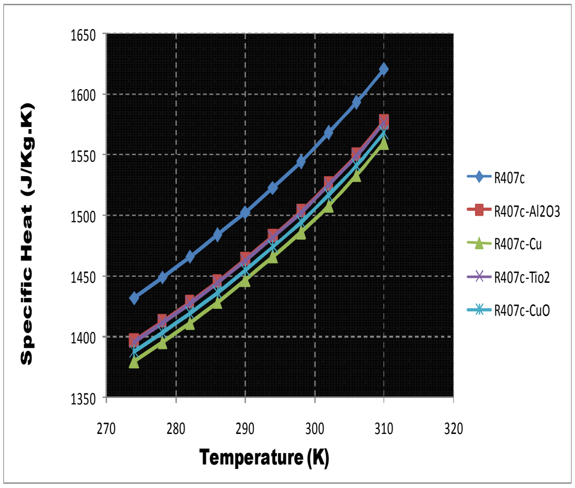


Fig. 3.4(b): Temperature vs Specific heat of R134a with different nanoparticle

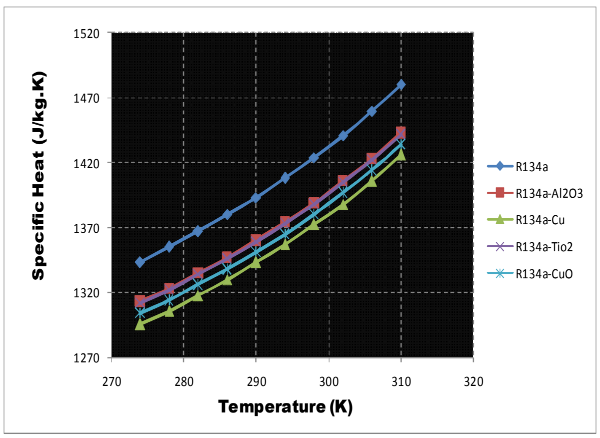


Fig. 3.4(c): Temperature vs Specific heat of R404A with different nanoparticle

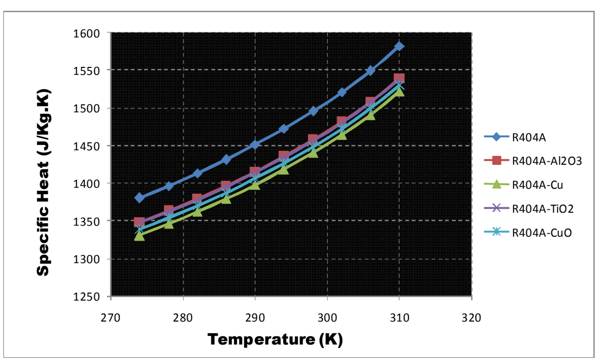


Fig.-3.4(a)-3.4(c) shows variation in Specific heat of nanorefrigerants with variation of temperature it was found that the specific heat variation of nanorefrigerant is increasing as temperature is increasing and also the similar to pure refrigerant as higher temperature High Specific heat and lower temperature low. But when we go for higher vol % concentration of nanoparticle specific heat will reduce.

5. Effect of volume concentration on Thermo physical property of nanorefrigerant with different nanoparticle and base refrigerant (at 280K temperature)

Fig. 3.5(a): Vol % concentration of nanoparticle(ϕ) vs Density of R407c with different nanoparticle

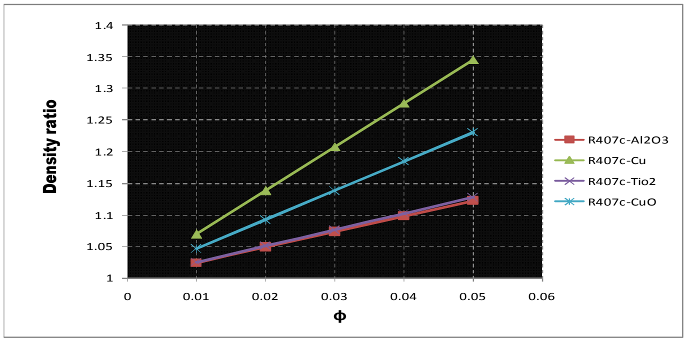


Fig. 3.5(b): Vol % concentration (ϕ) vs Density of R134a with different nanoparticle

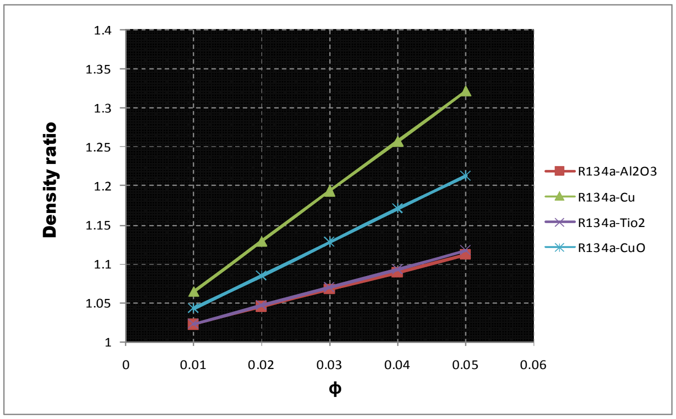


Fig. 3.5(c): Vol % concentration (ϕ) vs Density of R404A with different nanoparticle

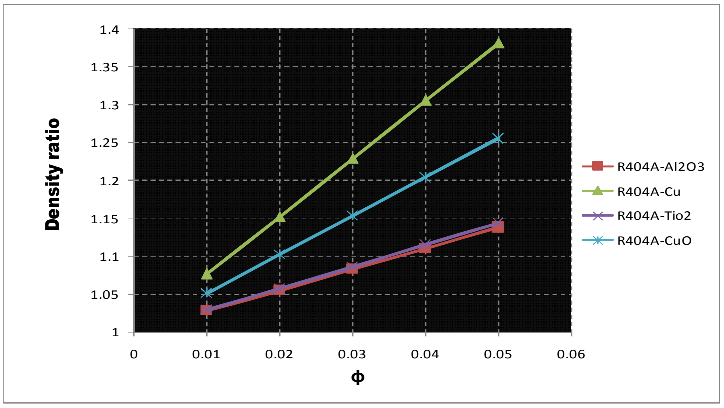


Fig. 3.5(d): Vol % concentration (ϕ) vs Cond. Ratio of R407c with different nanoparticle

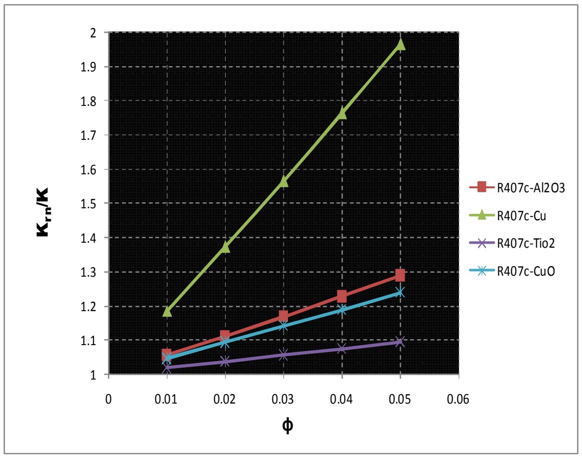


Fig. 3.5(e): Vol % concentration (ϕ) vs Cond. Ratio of R134a with different nanoparticle

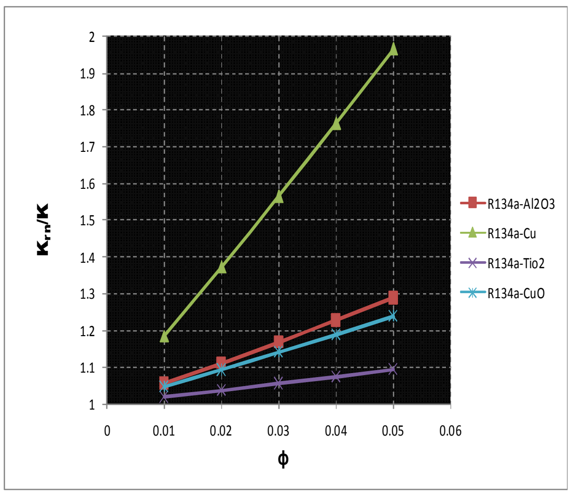


Fig. 3.5.(f): Vol % concentration (ϕ) vs Cond. Ratio of R404A with different nanoparticle

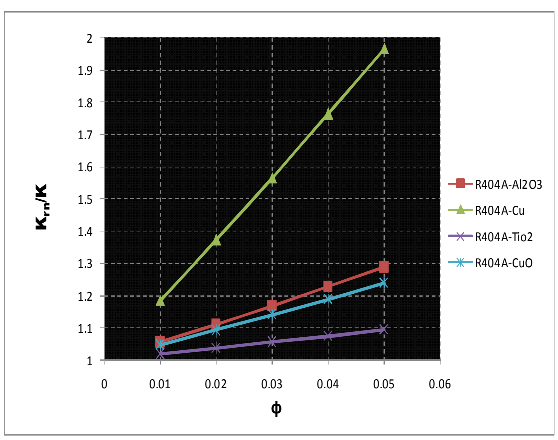


Fig 3.5(a).- 3.5(c) showed the density variation with Vol % concentration (ϕ) and it was observed that density in increases as Vol % concentration (ϕ) increases for all ecofriendly refrigerants.

Similarly showed the cond ratio variation with Vol % concentration (ϕ) and it was observed that cond ratio increases as Vol % concentration (ϕ) increases for all ecofriendly refrigerants as shown in Figs. 3.5(d)-3.5(j) respectively. It was observed that the Cond. Ratio of R404A with different nanoparticle Vol % concentration (ϕ) vs Cond. Ratio of R404A with different nanoparticle conductivity ratio of pure refrigerant to nanorefrigerant increases with increasing concentration of nanoparticle into the host refrigerant. It was observed that that Cu nanoparticle based nanorefrigerant have higher cond. Ratio than other nanoparticle and have approx two times higher than base refrigerant at 5 vol % concentration.

Fig. 3.5(g): Vol % concentration (ϕ) vs Specific heat ratio of R407c with different nanoparticle

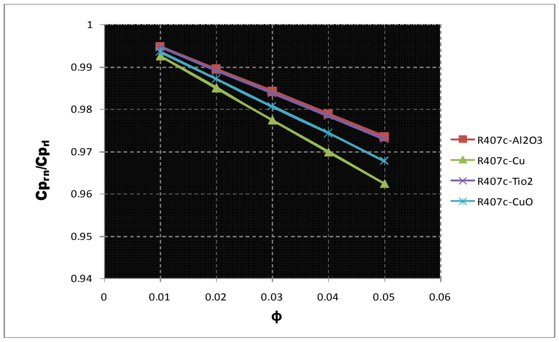


Fig. 3.5(h): Vol % concentration (ϕ) vs Specific heat ratio of R404A with different nanoparticle

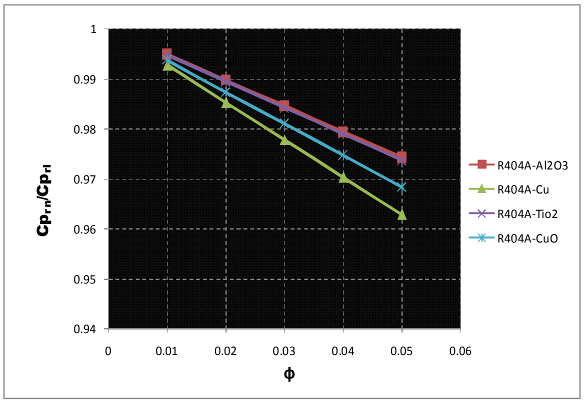


Fig. 3.5(i): Vol % concentration (ϕ) vs Specific heat ratio of R134a with different nanoparticle

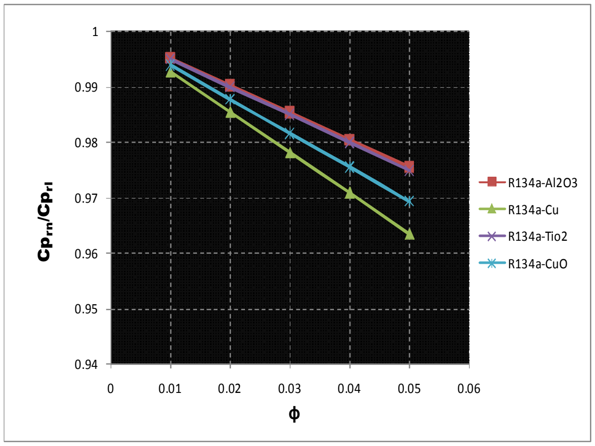


Fig. 3.5(j): Vol % concentration (ϕ) vs Viscosity ratio of R407c, R134a and R407c with different nanoparticle

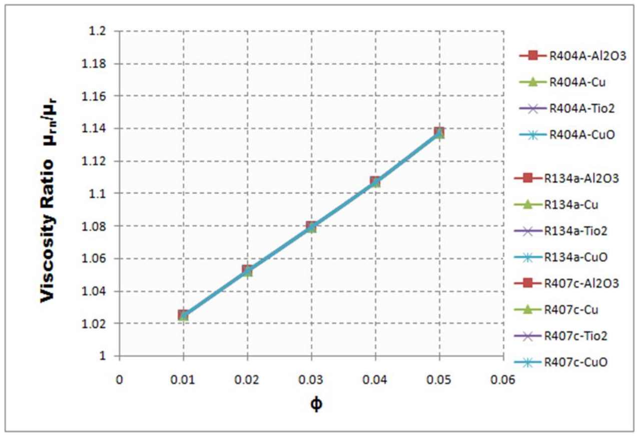


Fig. 3.5(k): Vol % concentration (ϕ) vs Convective heat transfer coefficient ratio of R407c with different nanoparticles

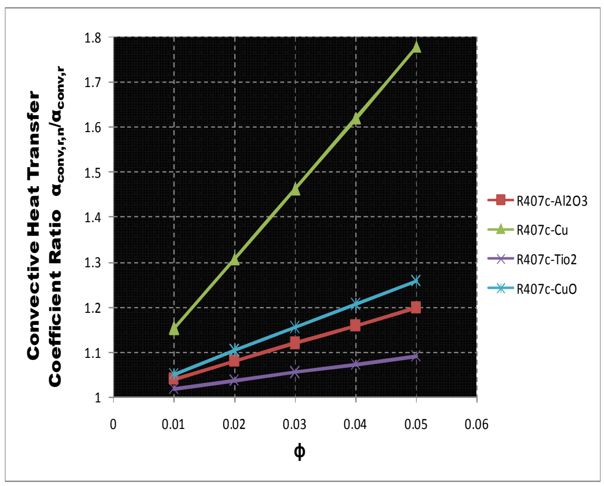


Fig. 3.5(l): Vol % concentration (ϕ) vs Convective heat transfer coefficient ratio of R404A with different nanoparticle

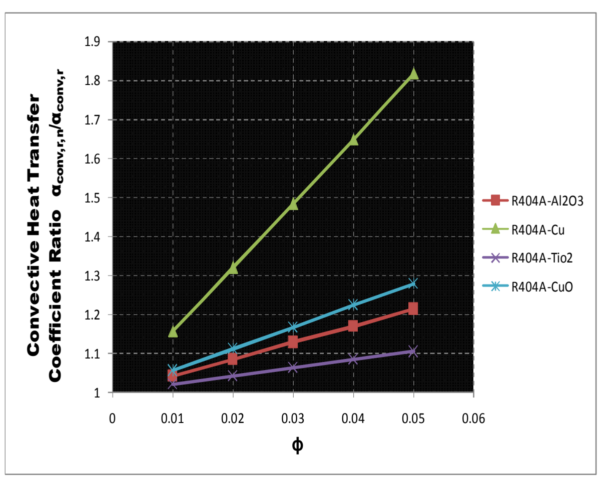


Fig. 3.5(m): Vol % concentration (ϕ) vs Convective heat transfer coefficient ratio of R134a with different nanoparticle

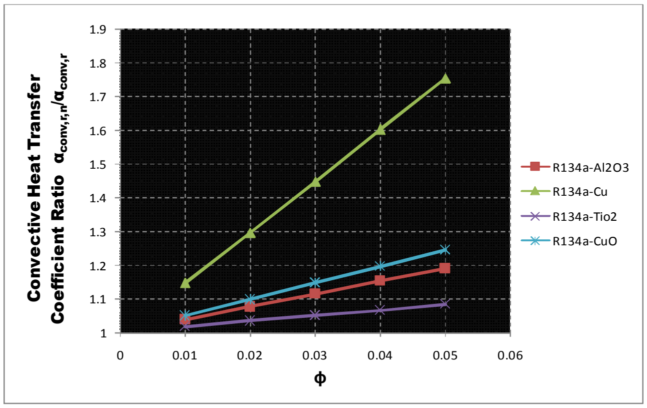


Fig 3.5(k) - 3.5(m) shows the convective heat transfer coefficient factor increases by increasing the concentration of nanoparticle. And copper nanoparticle based nanorefrigerant have highest convective heat transfer coefficient ratio than other particle its value ranges from 1 to 1.7.

Fig. 3.5(n): Vol % concentration (ϕ) vs Heat transfer enhancement factor R134a with different nanoparticles

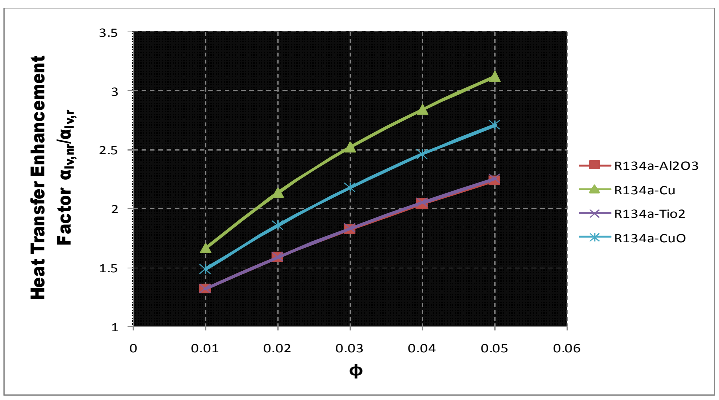


Fig. 3.5 (O): Vol % concentration (ϕ) vs Heat transfer enhancement factor R404A with different nanoparticle

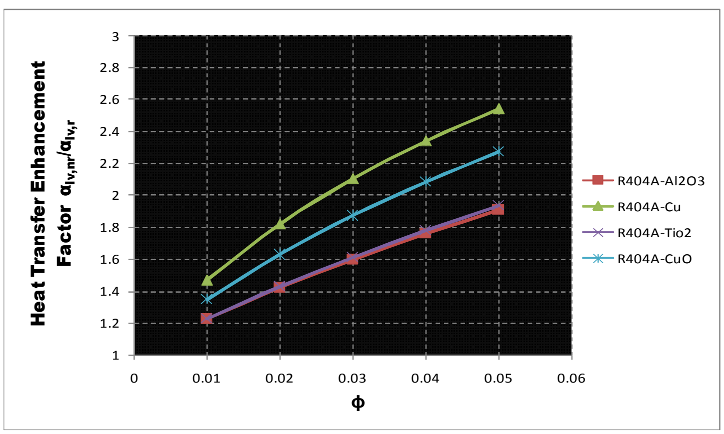


Fig. 3.5(p): Vol % concentration (ϕ) vs Heat transfer enhancement factor R407c with different nanoparticle

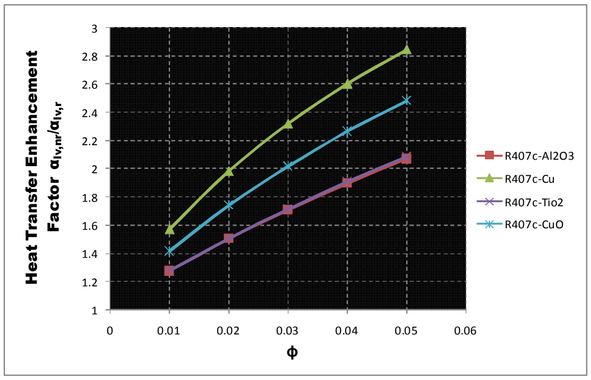


Fig.3. 5(n) -3.5(p) show the heat transfer enhancement factor of nanorefrigerant with different nanoparticle and it was observed that as Vol % concentration (ϕ) increases, the heat transfer enhancement is also increases and its value ranges from 1.2 to 3.2 and it was found that as for R134 a with cu nanoparticle have highest enhancement factor (EF) approx 3.2 at 5 vol %.

6. Effect of nanoparticle volume concentration (ϕ) on the 1st law efficiency in terms of C.O.P. of vapour compression refrigeration system(VCRS)

Fig. 3.6(a): Variation of C.O.P vs (ϕ) of R134a with different nanoparticle

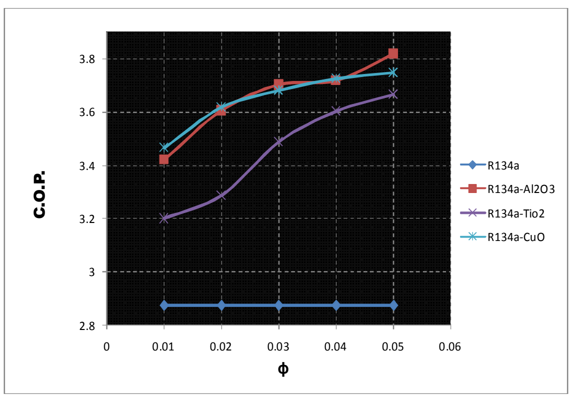


Fig. 3.6(b): Variation of C.O.P vs (ϕ) of R407c with different nanoparticle

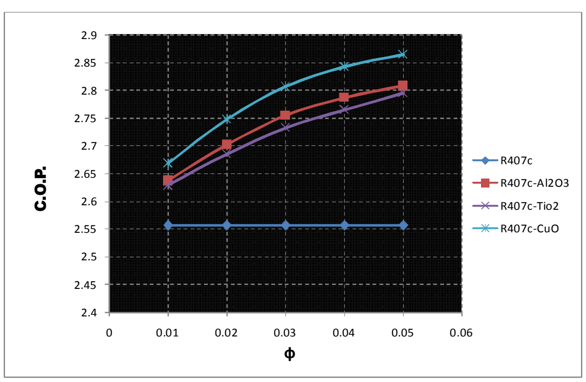


Fig. 3.6(c): Variation of C.O.P vs (ϕ) of R404A with different nanoparticle

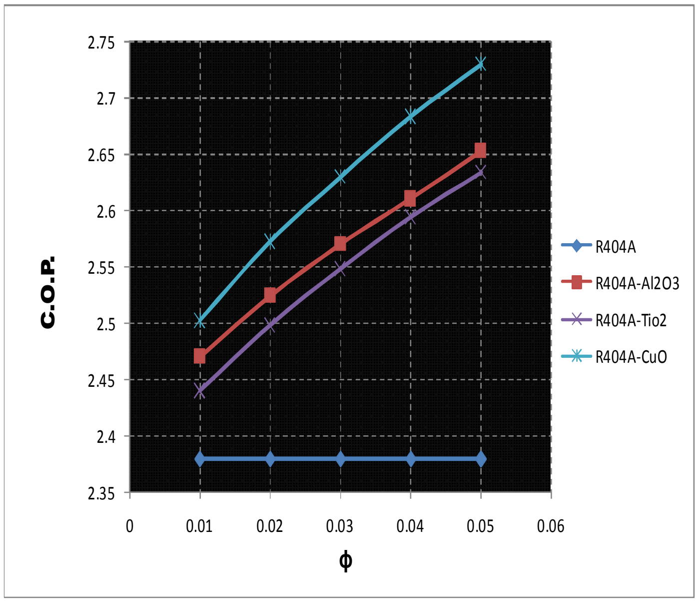


Fig 3.6(a) -3.6(c) showed that 1st law of efficiency in terms of COP with Vol % concentration (ϕ) and it was observed that as concentration (ϕ) increases , the COP is also increases and COP enhancement of VCRS can be achieved by using nanorefrigerant as a working fluid in VCRS. It was observed that the maximum enhancement theoretically achieved about 35 % with combination of R134a with Al_2O_3 nanoparticle at 5 vol% based nanorefrigerant .C.O.P enhancement theoretically achieved by using R134a/ Al_2O_3 approx 19,25,28,29 and 32 % at 1,2,3,4and 5 vol % respectively.

7. Effect of nanoparticle volume concentration (ϕ) on the Exergy destruction ratio of of VCRS

Fig. 3.7(a): Variation of Exergy Destruction. Ratio (EDR) vs variation of (ϕ) of R134a with different nanoparticle

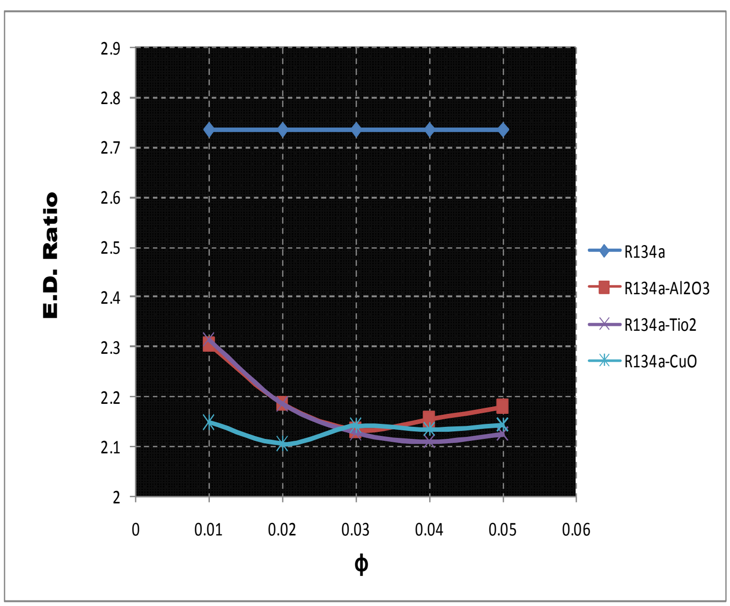


Fig. 3.7(b): variation of Exergy Destruction. Ratio (EDR) vs variation of (ϕ) of R407c with different nanoparticle

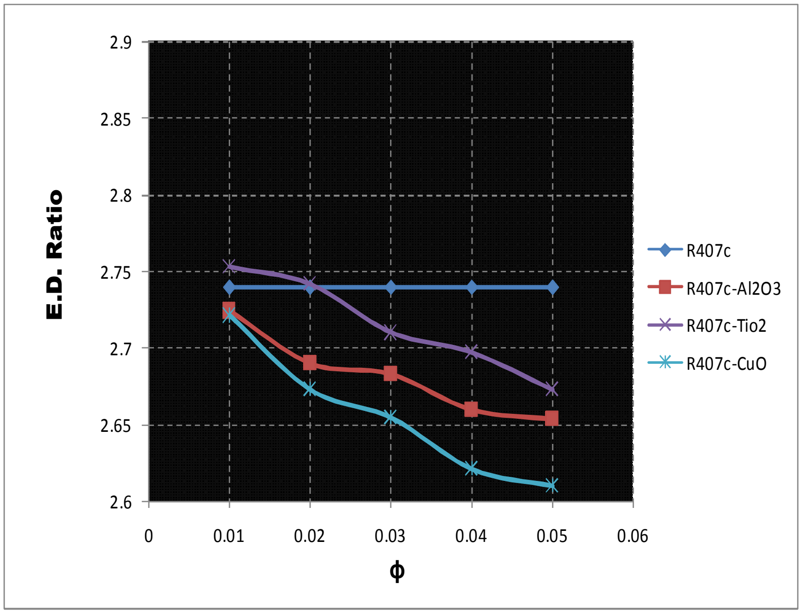


Fig. 3.7(c): Variation of Exergy Destruction. Ratio (EDR) vs variation of (ϕ) of R404A with different nanoparticle

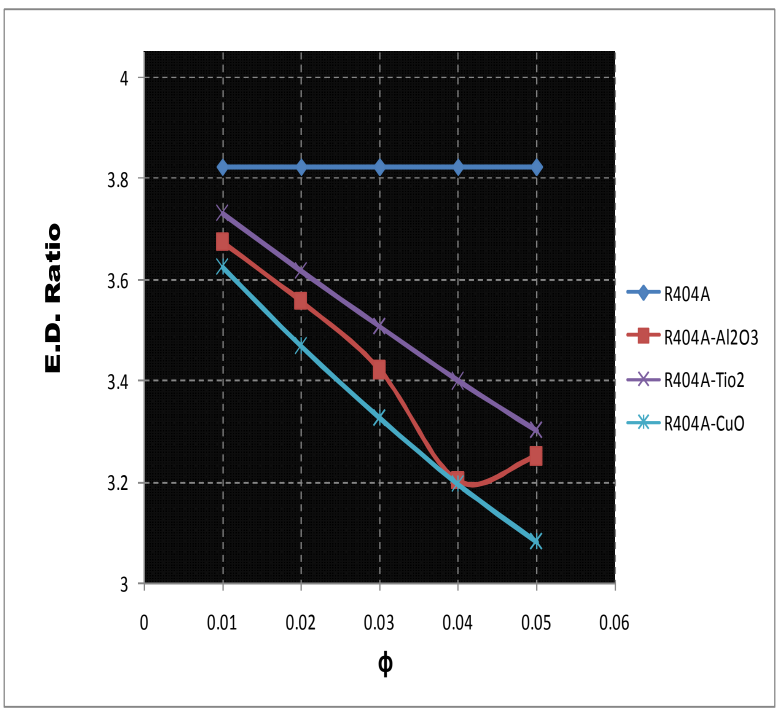


Fig 3.7(a)-3.7(c) shows the variation with of Exergy Destruction. Ratio (EDR) with variation of (ϕ) of ecofriendly refrigerants in the vapour compression refrigeration system (VCRS) and it was observed that exergy destruction ratio (EDR) is decreases as (ϕ) increases and will reduce by using nanofluid (nanoparticle based nanorefrigerant)

8. Effect of nanoparticle volume concentration (ϕ) on the 2nd law efficiency of VCRS

Fig. 3.8(a): 2nd Law efficiency vs (ϕ) of R134a with different nanoparticle

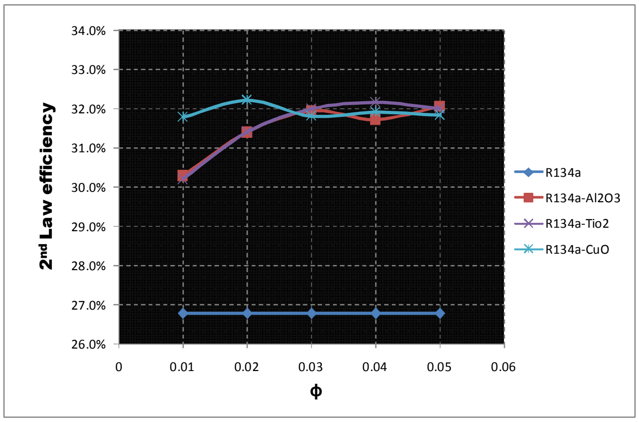


Fig. 3.8(b): 2nd Law efficiency vs (ϕ) of R407c with different nanoparticle

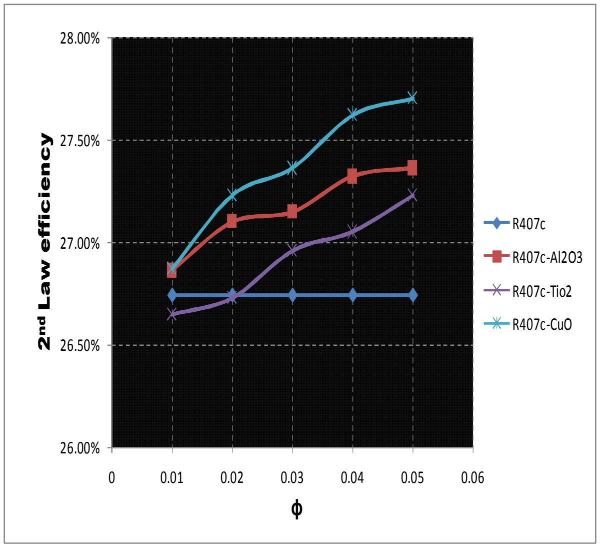


Fig. 3.8(c): 2nd Law efficiency vs (ϕ) of R404A with different nanoparticle

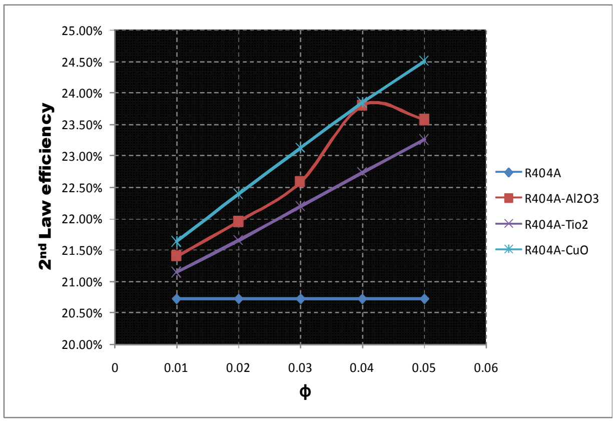


Fig 3.8(a)-3.8(c) showed the variation of exergetic efficiency (i.e.2nd Law efficiency) with variation of (ϕ) and it was observed that as (ϕ) increases the exergetic efficiency is also increases and also it will increases by using nanorefrigerant.

CONCLUSIONS

An experimental test rig of a variable-speed vapor compression chiller has been fabricated and model was developed by using LMTD approaches for environment friendly refrigerants. This model is based on steady state equations. The Input conditions are based on the experimental data collected from an existing experimental facility.

The graphical presentation between the input and output variables have been done and data from computational and experimentally well matches under accuracy of 10% for R134a without nano refrigerants. The performance characteristics of different ecofriendly refrigerants in terms of output parameters have been computed using model developed using experimental input parameters for the same design for different nano particles with different combination of nanoparticle suspension into the base refrigerant at 1 to 5 vol % concentration and following conclusions were drawn:-

1. The C.O.P. enhancement (1st law efficiency enhancement) is 19, 25, 28.8, 29 and 32 % by using R134a/Al_2O_3 nanorefrigerant at 1, 2, 3, 4 and 5 vol % of nanoparticle in VCRS also when we use R134a/TiO_2 nanorefrigerant 14, 21, 25, 28, and 29 % respectively at same Vol % and for R134a/CuO nanorefrigerant it was calculated 21, 26, 28, 30, 31 respectively and vol % R407c/ Al_2O_3 gives 3.1, 5.7, 7.9, 9 and 9.86% and R407c/CuO gives 4, 8, 10, 11 and 12 % and R407c/TiO2 gives 3 , 5, 7, 8, and 9% respectively .
2. Maximum Heat transfer enhancement factor with combination of R134a and Cu nanoparticle is 3.14 for R407c and 2.83 with Cu nanoparticle.
3. Second law efficiency also increases by using nanorefrigerant in VCRS about 5 to 18 % enhancement observed.
4. Thermal conductivity of nanorefrigerant increase about 15 to 200 % by suspension of nanoparticle into the base refrigerant.
5. C.O.P. enhancement also calculated by suspension of nanoparticle into the secondary fluid (brine) and found 8 to 19 %
6. C.O.P. enhancement occurs with different concentration of nanoparticle into the base fluid.

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1. Choi S.U.S. (1995). Enhancing thermal conductivity of fluids with nanoparticles, in *Developments and Applications of Non-Newtonian Flows* D.A. Singer and H.P Wang, Eds., American Society of Mechanical Engineers, New York, FED–31/MD-66:99–105.