Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

PERFORMANCE ANALYSIS OF A DOMESTIC REFRIGERATOR USING CUO –R600A NANO – REFRIGERANT AS WORKING FLUID

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ABSTRACT

The application of nano refrigerants in refrigeration system is considered to be a potential way to improve the energy efficiency and to make the use of environment-friendly refrigerants. In this paper we report a method that uses natural gas to enhance the energy efficiency of refrigeration retorting method employing CuO - R600a as alternate refrigerants. Thus reliability and performance of nano refrigerant in the working fluid have been investigated experimentally. A new nano refrigerant is employed in the domestic refrigerator. The performances of the nano refrigerant, such as the cooling capacity, energy efficiency ratio were determined. The results indicate that the mixture of R600a with nano particles (CuO) works normally in the domestic refrigerator. The cooling capacity of the domestic refrigerator is increased by 10 - 20% by using nano – refrigerant. The performance calculation of suction pressure, discharge pressure at no-load, part-load, fully-loaded condition, and running time, COP.

INTRODUCTION

Nano-refrigerant was proposed on the basis of the concept of the nanofluids, which was prepared by mixing the nanoparticles and traditional refrigerant. There were three main advantages followed for the nanoparticle used in the refrigerator.

Firstly, nanoparticles can enhance the solubility between the lubricant and the refrigerant. For example, Wang and Xie found that TiO2 nanoparticles could be used as additives to enhance the solubility between mineral oil and hydro fluorocarbon (HFC) refrigerant. The refrigeration systems using the mixture of R134a and mineral oil appended with nanoparticles TiO2, appeared to give better performance by returning more lubricant oil back to the compressor, and had the similar performance compared to the systems using polyol-ester (POE) and R134a.

Secondly, the thermal conductivity and heat transfer characteristics of the refrigerants should be increased, which have been approved by a lot of investigations. For instance, Jiang et al measured the thermal conductivities of CNT-R113 nano-refrigerants and found that the measured thermal conductivities of four kinds of 1.0 vol.% CNT-R113 nano-refrigerants increase 82%, 104%, 43% and 50%, respectively. Wang et al. carried out an experimental study of boiling heat transfer characteristics of Al2O3 nanoparticles dispersed in R22 refrigerant, and found that nanoparticles can enhance the heat transfer characteristic of the refrigerant, and the bubble size diminish and move quickly near the heat transfer surface.

Wu et al. investigated the pool boiling heat transfer of the R11 refrigerant mixed with nanoparticles TiO2, and the results indicated that the heat transfer enhancement reached 20% at a particle loading of 0.01 g/L. Park and Jung investigated the effect of carbon nanotubes (CNTs) on nucleate boiling heat transfer of halocarbon refrigerants of R123 and R134a. Test results showed that CNTs increase nucleate boiling heat transfer coefficients for these refrigerants. Especially, large enhancement up to 36.6% was observed at low heat fluxes of less than 30 kW/m2. Peng et al. found that the heat transfer coefficient of CuO-R113 was larger than that of pure refrigerant R113, and the maximum enhancement of heat transfer coefficient was 29.7%. Ding et al. investigated the migrated mass of nanoparticles in the pool boiling process of both nano-refrigerant and nanorefrigerant–oil mixture, and found that the migrated mass of nanoparticles and migration ratio in the nano-refrigerant were larger than those in the nano-refrigerant–oil mixture. Finally, nanoparticles dispersed in lubricant should decrease the friction coefficient and wear rate.

Lee et al. investigated the friction coefficient of the mineral oil mixed with 0.1 vol.% fullerene nanoparticles, and the results indicated that the friction coefficient decreased by 90% in comparison with raw lubricant, which lead us to the conclusion that nanoparticles can improve the efficiency and reliability of the compressor.

Jwo et al. carried out the performance experiment of a domestic refrigerator using hydrocarbon refrigerant and 0.1 wt. % Al2O3-mineral oil as working fluid, the results indicated that the power consumption was reduced by about 2.4%, and the coefficient of performance was increased by 4.4%. In the previous work, the author has investigated the basic characteristics of the TiO2-R134a nano-refrigerants, including the dispersion behavior, thermal conductivity and flow boiling heat transfer. The performance of a domestic refrigerator with nanoparticles added was also investigated. In the former experiment, the nanoparticles were added into the refrigeration system in two different ways. In one way the nanoparticles were added to the refrigeration system by first adding them into the lubricant to make a nanoparticle–lubricant mixture. Then, the mixtures were put into the compressor as the lubricant. In the other way nanoparticles and traditional refrigerant were mixed directly to make nano-refrigerant. The results of both of the ways had showed the better performance of the refrigerator with nanoparticles added.Isobutane (R600a) is more widely adopted in domestic refrigerator because of its better environmental and energy performances. A domestic R600a refrigerator was selected. CuO-R600a nano-refrigerant was prepared and used as working fluid. The energy consumption test and freeze capacity test were conducted to compare the performance of the refrigerator with nano-refrigerant and pure refrigerant so as to provide the basic data for the application of the nanoparticles in the refrigeration system.

EXPERIMENTS

The experimental apparatus was built according to the testing environment, domestic refrigerator and data collection processing system is shown. The refrigerator was placed on a platform in a constant temperature room. The room temperature was controlled by three adjusting heaters. The fluctuation of the ambient temperature was ± 0.7 degree Celsius. The experimental domestic refrigerator was a BCD-231GS/MS type manufactured by electric co.ltd, which was a multi-controlled refrigerator. The specification of the refrigerator was shown in table.

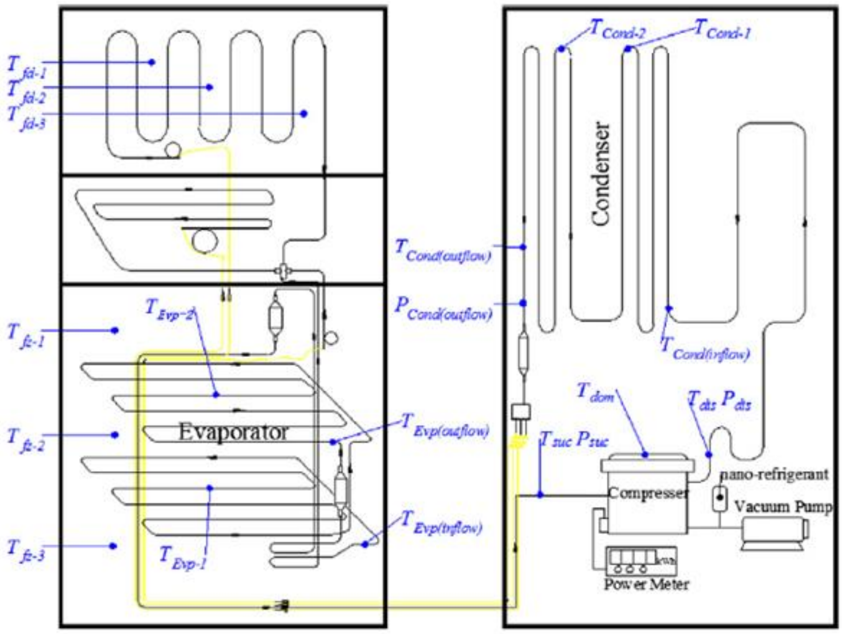

Fig 1. Schematic diagram of experimental apparatus.

T_{suc} –compressor suction temperature, $T_{cond\ (inflow)}$ – condenser inlet temperature, T_{dis} – discharge temperature, $T_{cond\ (outflow)}$ – condenser outlet temperature, T_{dom} – compressor dome temperature, $T_{evp(inflow)}$-evaporator inlet temperature, $T_{cond1,2}$- condensation temperature1,2. $T_{evp(outflow)}$-evaporator outlet temperature, $T_{evp1,2}$-evaporation temperature1,2. $T_{fz1,2,3}$- frozen food storage compartment evaporator temperature 1,2,3. P_{suc}-compressor suction pressure, $T_{fd1,2,3}$-fresh food storage compartment evaporator inlet temperature 1,2,3. P_{dis}-compressor discharge pressure, $P_{cond(outflow)}$-condenser outlet pressure

19 resistance thermometers and three pressure transducer were placed on the chill compartment, fresh food storage compartment and refrigeration system pipeline and detail arrangement was illustrated. The power consumption of the domestic refrigerator was measured by a digital watt-H meter with a precision of 1%.

REFRIGERATOR SPECIFICATION

- Gross capacity 165 liters
- Refrigerant CuO – R600a
- Charged mass 38g
- Compressor type – Reciprocating

EXPERIMENTAL PROCEDURE

The experimental procedure is as followed.

1. A performance test is made for the pure R600a system firstly. The experimental results are established to be a foundation for comparison.
2. CuO - R600a with different concentrations of nano particles were put into the refrigeration systems, and the tests were conducted again under the same condition.

PERFORMANCE TEST

In this study, the performance test of the domestic refrigerator comprise of energy consumption test and freezing capacity test. According to that, the energy consumption of the domestic refrigerator operates continuously 24hr under a steady operating condition that the average temperature of the fresh food storage compartment is less than 5degree Celsius and the temperature of the chill compartment is less than -18 degree Celsius. The freezing capacity is evaluated by the time that measured package temperature drops from 25± 1°c to -18°c within 24 hr under the specified test conditions. During the performance tests, the operating parameter was recorded including compressor, suction, and discharge pressure, evaporator temperature and so on.

PREPARATION OF THE TIO2-R600A NANO-REFRIGERANT

Nano-refrigerant was prepared in a recommended method for nanofluids, the nanoparticles were mixed into the refrigerant and then the mixture was kept vibrated with an ultrasonic oscillator to fully separate nanoparticles. The average particle diameters were about 50 nm and the mass purity was about 99.5%.The stability of the nano-refrigerant was an important and basic problem. On the basis of the former study on the dispersion of nanoparticles in the refrigerant, 0.1 and 0.5 g/L concentration were selected for the further investigations. The refrigerant masses added to the refrigerator had to be strictly controlled to be less than ±1 g in accuracy.

RESULTS AND DISCUSSIONS:

Figures 2 & 3 compared the compressor discharge and suction pressures of the refrigeration system over one on-off cycle, showing that both pressures were reduced for the CuO - R600a relative to the R600a system, in which the largest reduction one was 0.5g/L.

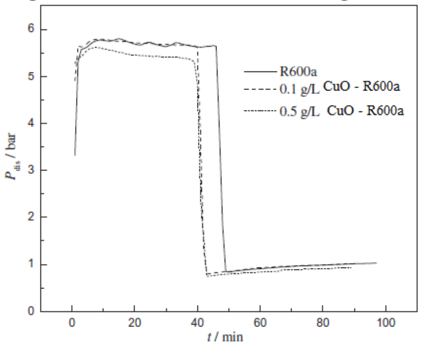

Fig.2. Compressor Discharge Pressure

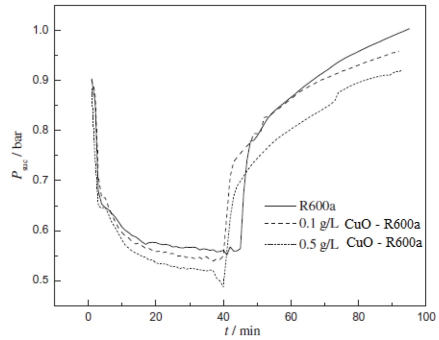

Fig.3. Compressor Suction Pressure

The results were similar with the former investigation about R600a as working fluids.

Fig. 4 & 5 showed the evaporation temperature, fresh food storage compartment temperature. The results showed that the evaporation temperature was reduced with the CuO - R600a, which lead to the lower food storage and frozen food storage compartment temperatures

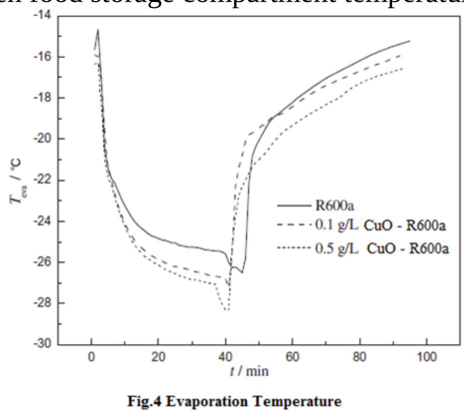

Fig.4 Evaporation Temperature

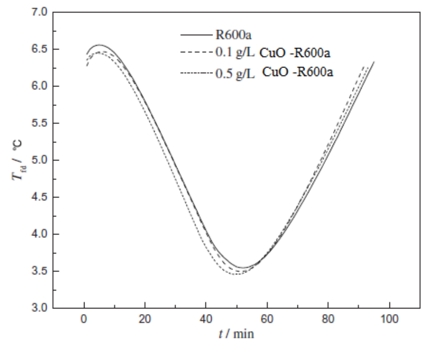

Fig.5 Fresh Food Storage Compartment Temperature

Table.1.Energy Consumption test Results

Proportion(g/L)	Tfd(◦c)	Tfz(◦c)	Psuc(bar)	Pdis(bar)	Tdom(◦c)	Tevp(◦c)	Tcond(◦c)	TRoom(◦c)
0	5.33	-18.13	0.595	5.611	42.14	-24.30	33.87	25.91
0.1	5.40	-18.80	0.583	5.700	45.09	-24.96	34.91	24.99
0.5	5.36	-19.06	0.574	5.463	47.18	-25.14	34.18	25.27

Table.2.Energy Consumption Results

Concentration(g/L)	0	0.1	0.5
Energy Consumption(kWh)	0.9567	0.8435	0.7856
Energy Savings(%)	-	11.83	17.88

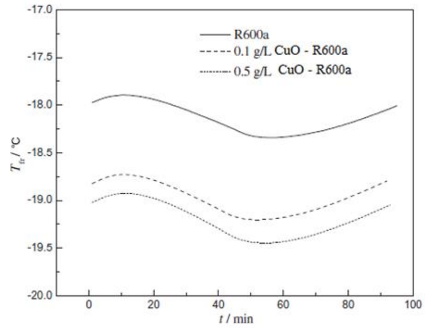

Fig.6 Frozen Food Storage Compartment Temperature

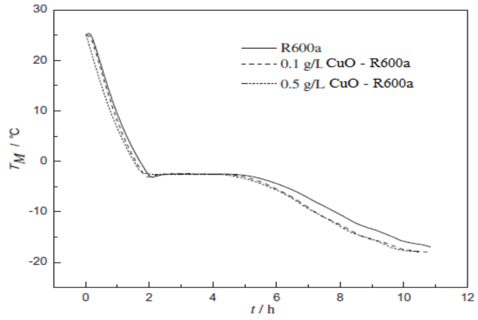

Fig.7 Freezing Capacity

Table 1 summarized the system parameter from the energy consumption tests. The energy consumption results were listed in table 2. Every test was run at least 4-5 times under the same condition to ensure the repeatability. All the results presented here had less than 1% difference in the energy consumption for parallel tests. Form table 2, energy consumption of CuO - R600a HC290 + R600a was less than that of pure R600a. The energy consumption of 0.885 KW h/day was least at a concentration of 0.5 g/L, which is 15% less than the pure R600a system.

Fig.7 described the freezing capacity of the refrigerator with different working fluids. It was obviously that the freezing velocity of CuO - R600a was more quickly than the pure R600a system.

These results confirm that the refrigerator performance with CuO - R600a is better than with the pure R600a. The reason may be that the CuO - R600a enhance the heat transfer characteristics of the refrigerant and also improve the friction characteristics of the lubricant.

CONCLUSIONS

In this paper, CuO - R600a were used as a working fluid of domestic refrigerators. The results indicated that CuO - R600a can work normally and efficiently in refrigerator. Combined with refrigerator using pure R600a as working fluids. 0.1 & 0.5g/L concentrations of CuO - R600a can save 11.83% and 17.88% energy consumption respectively 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.

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