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ScienceDirect
Applied Thermal Engineering 28 (2008) 1834–1843
Applied Thermal Engineering
www.elsevier.com/locate/apthermeng

Application of nanoparticles in domestic refrigerators

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Received 19 May 2007; accepted 13 November 2007
Available online 21 February 2008

Abstract

The reliability and performance of a domestic refrigerator with nanoparticles in the working fluid was investigated experimentally. Mineral oil with TiO_2 nanoparticles mixtures were used as the lubricant instead of Polyol-ester (POE) oil in the 1,1,1,2-tetrafluoroethane (HFC134a) refrigerator. The compatibility of nonmetallic materials in the system with the HFC134a and mineral oil–nanoparticles mixtures was studied before the refrigerator performance tests. The refrigerator performance with the nanoparticles was then investigated using energy consumption tests and freeze capacity tests. The results indicate that HFC134a and mineral oil with TiO_2 nanoparticles works normally and safely in the refrigerator. The refrigerator performance was better than the HFC134a and POE oil system, with 26.1% less energy consumption used with 0.1% mass fraction TiO_2 nanoparticles compared to the HFC134a and POE oil system. The same tests with Al_2O_3 nanoparticles showed that the different nanoparticles properties have little effect on the refrigerator performance. Thus, nanoparticles can be used in domestic refrigerators to considerably reduce energy consumption.

Keywords: Domestic refrigerator; Nanoparticles; Mineral oil; Performance

1. Introduction

1,1,1,2-Tetrafluoroethane (HFC134a) is the most widely used alternative refrigerant in refrigeration equipment such as domestic refrigerators and automobile air-conditioners. Though the greenhouse warming potential (GWP) of HFC134a is relatively high, HFC134a has been accepted as a long-term alternative refrigerant in many countries. Due to the strong chemical polarity of HFC134a, traditional mineral oil can not be used in refrigeration systems with HFC134a as the working fluid, thus Polyol-ester (POE) oil is used as the lubricant. However, POE oil is known to be hydroscopic and hydrolytic, so there are many problems in refrigeration systems using POE oil such as wadding deposition, bulging equipment that chokes the flow and severe friction in the compressor.

Nanoparticles can be used to improve the working fluid properties due to their special properties which have attracted attention worldwide. Choi et al. [1] first proposed creating "nanofluids" by suspending high thermal conductivity nanoscale metallic or nonmetallic particles in base fluids. These nanofluids have been shown to have superior heat transfer capabilities and have become a popular research topic in heat transfer research. Many efforts have been made to investigate the effective thermal conductivity, the convective heat transfer and the phase change heat transfer of nanofluids. However, contradictory results have shown that the nanoparticles can both enhance and reduce the phase change heat transfer. For example, Das et al. [2] investigated nucleate pool boiling heat transfer of Al_2O_3–H_2O nanofluids on the surface of a cylindrical cartridge heater. The presence of the nanoparticles was found to reduce the boiling performance and the degradation increased with increasing nanoparticles concentrations. The authors attributed the deterioration to changes in the surface characteristics of the heaters. They argued that

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1359-4311/$ - see front matter
doi:10.1016/j.applthermaleng.2007.11.018

the surface became smoother during boiling with nanofluids due to sedimentation of the nanoparticles on the nucleate sites. Higher concentrations resulted in smoother surfaces and, hence, considerable deterioration of the heat transfer coefficient. However, Wen et al. [3] also studied the pool boiling heat transfer characteristics of Al_2O_3–H_2O nanofluids and showed that alumina nanofluids can significantly enhance boiling heat transfer. The enhancement increased with increasing particle concentration and reached 40% at a particle loading of 1.25% by weight.

More recently, some investigations have used nanoparticles in refrigeration systems to use advantageous properties of nanoparticles to enhance the efficiency and reliability of refrigerators. For example, Wang et al. [4] found that TiO_2 nanoparticles can be used as additives to enhance the solubility of the mineral oil in the hydrofluorocarbon (HFC) refrigerant. In addition, refrigeration systems using a mixture of HFC134a and mineral oil with TiO_2 nanoparticles appear to give better performance by returning more lubricant oil back to the compressor with similar performance to systems using HFC134a and POE oil. Wang et al. [5] carried out an experimental study of the boiling heat transfer characteristics of R22 refrigerant with Al_2O_3 nanoparticles and found that the nanoparticles enhanced the refrigerant heat transfer characteristics with reduced bubble sizes that moved quickly near the heat transfer surface. Li et al. [6] investigated the pool boiling heat transfer characteristics of R11 refrigerant with TiO_2 nanoparticles and showed that the heat transfer enhancement reached 20% at a particle loading of 0.01 g/L. Park [7] investigate the effects of carbon nanotubes (CNTs) on the nucleate boiling heat transfer of R123 and HFC134a refrigerants. Their test results showed that CNTs increase the nucleate boiling heat transfer coefficients for these refrigerants. Large enhancements of up to 36.6% were observed at low heat fluxes of less than 30 kW/m^2.

Thus, the use of nanoparticles in refrigeration systems is a new, innovative way to enhance the efficiency and reliability of refrigerators. This study analyzes the use of nanoparticles in domestic refrigerators by measuring the refrigeration performance of a domestic refrigerator charged with HFC134a and mineral oil mixed with nanoparticles.

2. Preparation and stability of the mineral oil and nanoparticles mixture

The nanoparticles are added to the refrigeration system by first adding them into the lubricant to make a nanoparticle–lubricant mixture. Then, the mixtures are put into the compressor as the lubricant. The preparation and stability of these lubricant and nanoparticles mixtures are very important.

Using a recommended method for nanofluids [8], the nanoparticles were mixed into the mineral oil and then the mixture was kept heated and vibrated with an ultrasonic oscillator to fully separate nanoparticles. Surface activators and/or dispersants are often used to make the suspension stable for long periods, but to reduce the complexity of the experiment and the analysis, no activator or dispersant was used and the concentration of nanoparticles added to the fluid was very small.

The mixture stability was evaluated by observing the sedimentation pictures and light transmission ratio index method. The sedimentation was observed by comparing the appearance of mixtures at various sedimentation time using digital pictures. The light transmission index was measured with a 722 s visible light spectrophotometer manufactured by Shanghai Precision and Scientific Instrument Co. Ltd. Smaller changes in the light transmission index indicate that the mixture is more stable.

The TiO_2 nanoparticles were provided by Zhejiang Hongsheng Nanotech Co. Ltd. The average particle diameters were about 50 nm and the mass purity was about 99.5%. The mineral oil, a type commonly used in refrigeration and air-conditioning systems, was SUNISO 3GS refrigeration oil selected because of its premium quality.

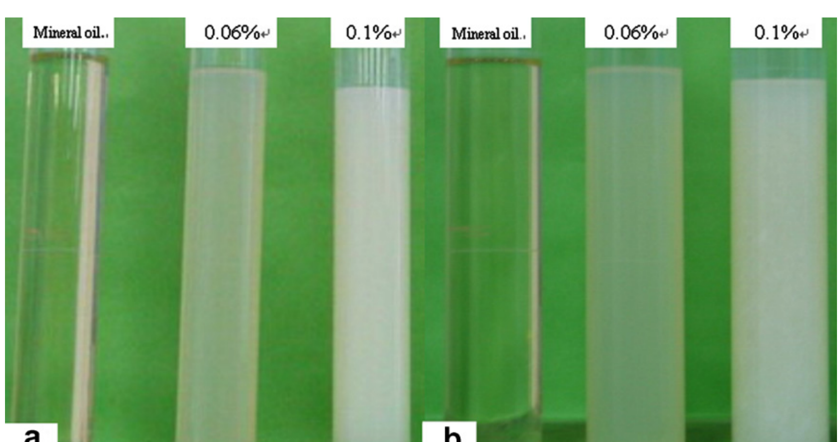

Fig. 1. Sedimentation of mineral oil and TiO_2 nanoparticle mixtures at the beginning (a) and after three days (b).