Effect of nanolubricant on Evaporator and Condenser Pressure of Automotive Air Conditioning System

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Abstract—Automotive Air Conditioning system efficiency can be improved by dispersing nanolubricant in the refrigeration system. The condenser and evaporator pressure was closely related to the performance of the system. In this paper, the nanolubricant and conventional lubricant performance in the AAC system was compared. The condenser and evaporator pressure was reduced by an average of 8.47 % and 3.84 % respectively when being replaced with nanolubricant compared to conventional lubricant. The nanolubricant also improve the compressor work reduction up to 17.1 %. As conclusion, it is recommended to use the nanolubricant as replacement to improve the energy efficiencies in AAC system. .

Keywords—nanolubricants, evaporator pressure, condenser pressure, compressor work; refrigeration system

1. INTRODUCTION

At present, the automotive air conditioning (AAC) is a matter of necessity rather than just an accessory. Cooling is necessary to provide thermal comfort in the passenger cabin, particularly in countries such as Malaysia, which experienced a warm and humid climate throughout the year Statistics show that the an average car trip normally takes about 249 hours every year [1]. AAC system in a vehicle consumes about 43-49% of the total energy produced by the engine or 107-121 hours yearly [2]. The AAC system was different with the residential air conditioning in two ways [3]. Firstly, AAC system are limited in term of space and weight, which is related in fuel efficiency directly. Secondly, the variation of the thermal load in car cabin changes drastically. So, AAC system design must be able to operate in all the variety of different conditions. Many improvements in efficiency AAC energy system has been introduced to the automotive industry to reduce the environmental impact and to obtain better fuel economy. In refrigeration system, the effort to improve the efficiency of the system by introduces nanoparticles in refrigerant (nanorefrigerant) and in lubricant oil (nanolubricant). Nanotechnology has been used as an additive to improve performance in many applications, for example in motor and transmission oil cooling, refrigeration (domestic and conditioning), fumes evaporator heating and cooling of buildings; cooling of electronic components, oil, biomedical applications and nanofluids in transformer oil which has been studied by different researchers [4-6]. Nanofluids show great potential to enhance the thermodynamic and mechanical performance of refrigeration systems. In a review by Alawi et al. [7], there are several benefit of using nanoparticles dispersed in a lubricant for application in refrigeration system. Firstly, it improves the solubility of lubricant-refrigerant mixture, and secondly, it also enhances the lubricant in term of thermo-physical properties. Third, the friction coefficient and wear rate also improves. Adding nanoparticles to the base fluid can improve the transport properties and efficiency of the system, but the effect on pressure should be studied thoroughly before it can be used in the system. Nanolubricant effect on condenser and evaporator pressure is a major concern in the cooling system. This is because the pressure and the evaporator is closely linked to the performance of the system. For example, the condenser pressure and temperature are directly correlated with subcooling, and this factor has affected the saturated refrigerant liquid, refrigerant vaporisation and mass flow rate of the system [8]. Both these parameters have a great impact on the work of the compressor, heat absorption, and also performance. By changing the original compressor oil PAG with nanolubricant, will definitely give a different effect on the evaporator-condenser pressure and compressor work. Therefore, the aim of this study was to investigate the effect of using SiO_2 nanoparticles dispersed in Polyalklene Glycol (PAG) lubricant on the basis pressure evaporator and condenser in relation of compressor work of the Automotive Air Conditioning System.

2. MATERIALS

SiO2 nanoparticles used in this experiment was obtained from Beijing DK Nanotechnology Co. Ltd .. Fig. 1 shows the average size of SiO2 nanoparticles are viewed with Field Emission Scanning Electron Microscope (FESEM). Table 1 shows the basic properties of these nanoparticles.

The base fluid used to be mixed with nanoparticles lubricant is polyalkylene glycol (PAG), which is also commonly used lubricants in AAC compressors. Table 2 shows the properties of the lubricant.

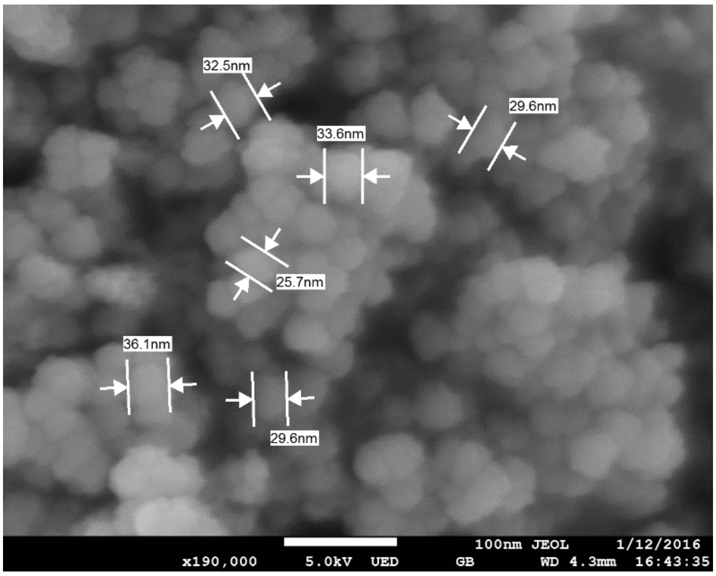

Figure 1: SiO_2 nanoparticles with average size of 30 nm.

Table 1**:** Properties of SiO_2 nanoparticles used in this experiment [9, 10]

Property	**SiO_2**
Molecular mass, g mol^{-1}	60.08
Average Particle diameter, nm	30
Density, kg m^{-3}	2220
Thermal Conductivity, W m^{-1} k^{-1}	1.4
Specific heat, J kg^{-1} K^{-1}	745

Table 2: Properties of PAG lubricant [11-13]

Specifications	Value
Kinematic viscosity, cSt @ 40 °C	41.4-50
Kinematic viscosity, cSt @ 100 °C	11
Pour point, °C	-51
Viscosity index	184
Density, kg/cm3@ 15 °C	0.9954

3. METHODOLOGY

A. Preparation of Nanolubricant

SiO_2/PAG nanolubricant were prepared using two methods ledge as described in [13, 14]. In this study, magnetic stirrer used to mix the nanoparticles SiO_2 into PAG compressor lubricant for an hour. Then SiO_2/PAG which have been mixed earlier, will be put into an ultrasonic bath for two hours. Ultrasonic bath model Fisherbrand: FB15051 will be used as stabilizers techniques to help improve dispersion stability. Ultrasonfication process will ensure nanoparticle dispersed well with a liquid base and helps to break down the agglomeration. The nanolubricant with a volume concentrations of 0.05 % was prepared in this experiment. The volume concentration of nanolubricant was calculated using the formula in Eq. (1).

$$\phi = \frac{\frac{m_p}{\rho_p}}{\frac{m_p}{\rho_p} + \frac{m_L}{\rho_L}} \times 100 \tag{1}$$

B. Stability Evaluation of the Nanolubricant.

The experiments will be conducted using AAC test rig system for measuring the performance capabilities and also effects of nanolubricant on condenser-evaporator pressure, which was developed in the laboratory NanoLab FKM. AAC specification test rig systems are summarized in Table 3.

Table 3: Specification of experimental test set-up

Equipment	Specification
Compressor	1.2 kW (Rotary vane type)
Refrigerant	R134a
Charge	115 g
Evaporator calorimeter cabin capacity	60L

Fig. 2 shows a schematic diagram of AAC system test setup. This system consists of rotary vane type compressor normally used in compact car, a fan cooled condenser, an expansion valve and an evaporator that was put in an insulated calorimetric cabin containing water to cool the water (capacity 60 L). The purpose of this evaporator calorimetric cabin was to obtain the refrigerant mass flow rate in accordance to the standard of Standard 41.9-2000 (Calorimeter Test Methods for Mass Flow Measurements of Volatile Refrigerants). This can be achieved by assuming the heat rate absorb by the evaporator was equal with the cooling absorbed by water, so the mass flow rate was obtain using these Eq (2). The thermocouples used to measure the temperature and performance at various point of refrigeration cycle was T type thermocouple, with an accuracy of ± 0.1°C. The temperature reading data were obtain using ADAMView data acquisition system. Two pressure gauges were used to obtain the gauge pressures of the high side and low side of the system.

$$m_r = \frac{\dot{Q}_{water}}{Q_{in}} \qquad \text{where } Q_{in} = h_1 - h_5 \tag{2}$$

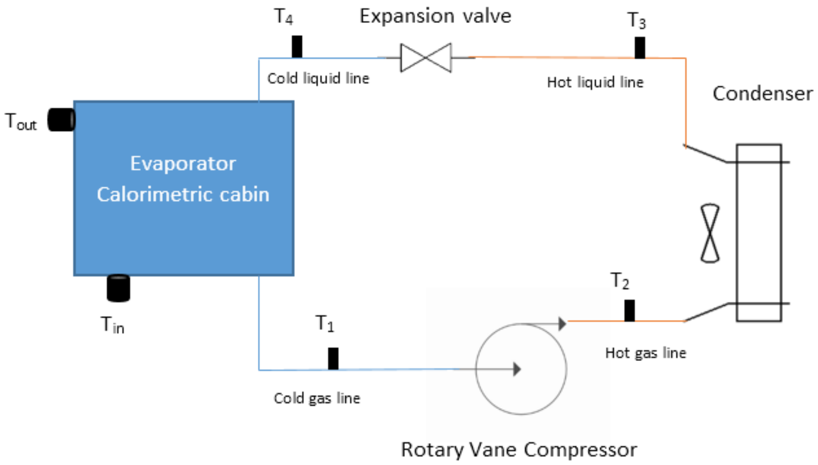

Figure 2: Schematic diagram of Automotive Air Conditioning experimental set-up.

The experimental test set-up was vacuum first by using vacuum pump to remove the moisture and to check if there are leak in the system. Refrigerant R134a with amount of 115g was charged to the system using refrigerant charging machine. Then, the experiment will begin by turn on the AAC system. The system will keep running for 20 minutes to obtain a steady state condition. After 20 minutes passed, then the average data readings were taken for 10 minutes. The experimental set-up was placed in a special room with constant ambient temperature which is 25 °C with increment of ± 0.1 °C and constant humidity. The compressor work was calculated using Eq (3):

$$W_{in} = h_2 - h_1 \quad (3)$$

4. RESULTS AND DISCUSSION

A. Effect of nanolubricant on Condenser Pressure effect

According to the experiment testing data, the effect of condenser pressure with different compressor speed for the conventional lubricant (PAG) and nanolubricant which SiO_2 was shown in Fig. 3. The graph shows the condenser pressure increases with increasing speed compressor. In addition, the graph also shows that the condenser pressure showed a slight decrease when adding SiO2 nanoparticles into the lubricant compared with conventional PAG lubricants. This shows that the nature of the lubricant-refrigerant has changed when using nanolubricant. The results of this experiment can be summarized nanoparticle give little effect on condenser pressure. Table 4 show the summary of the condenser pressure data on different compressor speed.

B. Effect of nanolubricant on Evaporator Pressure effect

The experimental test data for the evaporator pressure of the different speed of the compressor for PAG lubricants and nanolubricant SiO2 were compared in Fig. 5. In the graph, it has been shown that the evaporator pressure generated when using nanolubricant in AAC system decrease compared with conventional PAG lubricants. In addition, the results above show that the evaporator pressure for both lubricant is decreased when increasing the speed of the compressor.

C. Effect of nanolubricant on Compressor work

Pressure on condenser and evaporator also is a factor that is closely related to the mass flow rate of the coolant. According to experimental test data shown in Figure 6. The mass flow rate of the coolant is lower after adding the nanoparticles into the lubricant PAG. After comparing the results in Figure 4 and Figure 5, it can be shown that the decrement in the mass flow rate of refrigerant from nanolubricant have an effect on the pressure drop in air conditioning systems.

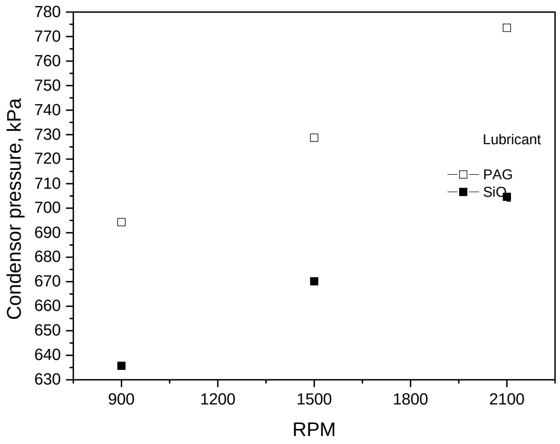

Figure 3: Experimental testing data effect on the condenser pressure with different compressor speed

Table 4: Experimental data condenser pressure

Compressor speed (rpm)	Pressure (kPa)		Percentage of reduction (%)
	PAG	**SiO_2/PAG**	
900	694.274	635.6689	8.44120621
1500	728.748	670.1427	8.041915724
2100	773.5638	704.6165	8.912942927

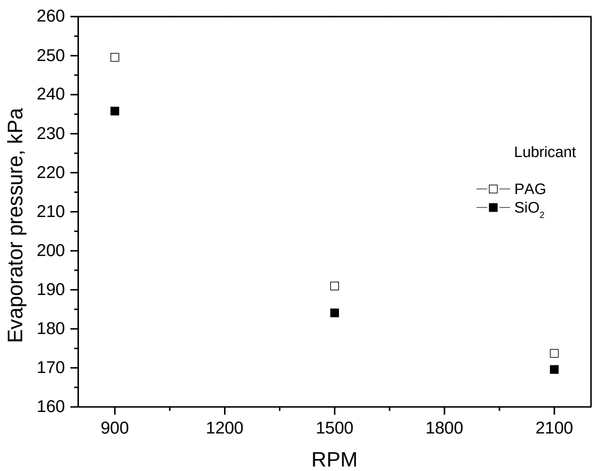

Figure 5. Experimental data evaporator pressure compare with different compressor speed

Table 5: Experimental data evaporator pressure

Compressor speed (rpm)	Pressure (kPa)		Compressor speed (rpm)
	PAG	**SiO_2/PAG**	
900	249.5623	235.77282	5.525465986
1500	190.9568	184.06212	3.610596742
2100	173.71995	169.583124	2.381318899

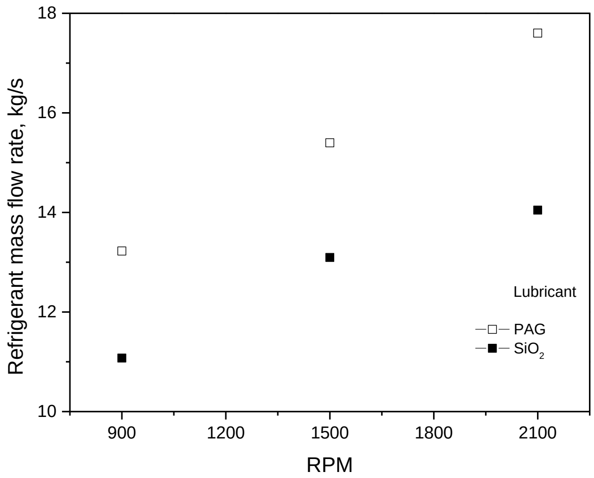

Figure 6: Experimental data the refrigerant mass flow rate with different compressor speed

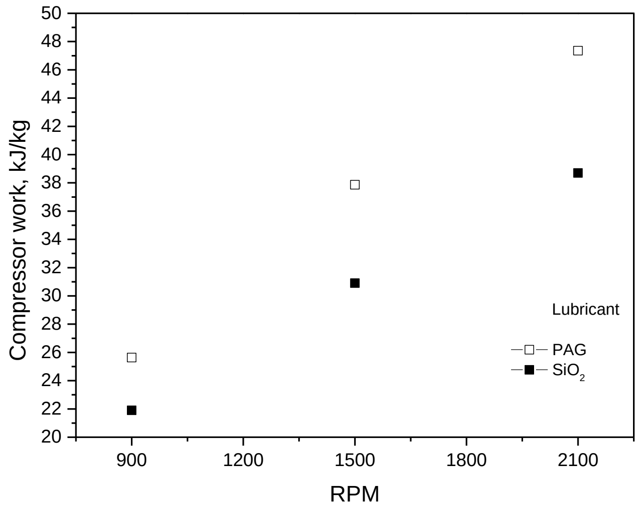

Figure 7: Experimental data the compressor work with different compressor speed

One of the biggest effects of the evaporator-condenser pressure reduction while using nanolubricant, is the impact on the compressor work in AAC system. Figure 7 shows a graph of the speed of the compressor work. Work on the compressor was significantly reduced when using SiO_2/PAG as a lubricant compressor compared to its base lubricant. This is because when the pressure in the condenser and evaporator decreases, the compression ratio also decreased. So, the work required to drive the compressor is also decreased. Work by the compressor also increases linearly with the increasing speed of the compressor. This is because the speed of the compressor increases, the work required to drive the compressor by also increasing.

5. CONCLUSIONS

SiO_2 was dispersed into the PAG lubricant which normally utilize in the refrigeration system using two-steps method without any surface stabilizer or surfactants. The nanolubricant and conventional lubricant performance in the AAC system was compared. The condenser and evaporator pressure was reduced by an average of 8.47 % and 3.84 % respectively when being replaced with nanolubricant compared to conventional lubricant. The nanolubricant also improve the compressor work reduction up to 17.1 %. As conclusion, it is recommended to use the nanolubricant as replacement to improve the energy efficiencies in AAC system.

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