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Study on Comparative Air Conditioning Performance Using SiO_2 and Al_2O_3 Nanolubricants Operating with R123yf Refrigerant

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A B S T R A C T

The use of nanofluids in the refrigeration system and the substitution of nanolubricant for traditional lubricant are two of the best approaches to increase the efficiency of AAC (automotive air conditioning). Even if the effect on pressure needs to be carefully considered, adding nanoparticles to the base liquids can improve all of their transport qualities and the system's effectiveness. Additionally, nanolubricants can improve their tribological characteristics (lubricity, resistance to wear, high pressure situation), which has obvious benefits for compressors. The use of automotive air conditioning systems that use hydrofluoroolefin-1234yf or R1234yf refrigerant has now lowered the risk of global warming. This study aims to investigate the compatibility of SiO_2 and Al_2O_3 nanolubricants with R1234yf in the vehicle air conditioning mechanism.

Nanolubricants are lubricants that have nanoparticles added to them to improve their thermo-physical characteristics. Numerous recent research have noted improvements in the thermo-physical characteristics of nanolubricants, such as thermal conductivity and viscosity. One of the primary strategies for improving the performance of the VCRS for flow boiling heat transfer in the evaporator and condensation heat transfer in the condenser is the adjustment of thermo-physical characteristics. The tribology and rheology properties of the nanolubricants were likewise superior to those of the original lubricants

KEYWORDS: *R123yf, Nanolubricants, Cooling capacity, Compressor work, Coefficient of performance.*

1. Introduction

Nowadays, majority of automakers are now concentrating on creating cars with lower energy use. The effectiveness of nanolubricant in enhancing the performance of the automotive air conditioning (AAC) system has been demonstrated in several studies by eminent specialists. The development of hybrid and completely electric cars with both internal combustion engines and electric motors has prompted additional advancements in the automotive air conditioning (AAC) system. The current fashion is to create AAC systems that consume less energy and have less of an impact on the environment. The AAC system uses some of the engine's output as a parasitic load. The usage of AAC in a car was found to reduce mileage by 20% and increase nitrogen oxides (NOx) by as much as 80%. AAC is currently being used more frequently because of the rise in car production. Many factors contributed to the rise in the average world temperature. The usage of refrigerants with a high potential for global warming (GWP) is, however, the fundamental problem. If a leak or uncontrolled discharge occurs, the refrigerant will leave the AAC system. In addition to being discharged into the atmosphere and becoming trapped there, the refrigerant also creates an atmospheric layer that traps heat and reflects it back to the earth's surface. This phenomenon is known as greenhouse effect. As a result, the main goal of the current study is to concentrate on replacing the existing, high GWP R134a refrigerant in the AAC system.

A better replacement for the current refrigerant R134a is R1234yf. R1234yf's thermodynamic qualities are almost identical to those of R134a. As a result, it doesn't require any significant changes to the original AAC system and may be used immediately. Although it works better than the currently used refrigerant R134a, the AAC system with R1234yf (AAC-R1234yf) has a lower coefficient of performance (COP). As a result, a few recent studies have shown that many auto manufacturers still do not use R1234yf in their AAC systems

1.1 Experimental Description

AAC experimental test setup's fundamental schematic diagram is shown in Figure 1. The fundamental elements of an automotive air conditioning system served as the foundation for the AAC test setup. The typical application compact car's AAC system served as the refrigeration system. Similar cooling capacity trends have been noted by other researchers. Four significant components may be identified in the experimental setting. The refrigeration system came first. Compressor, condenser, evaporator, expansion valve, and the piping system comprise the majority of an average AAC system. The driver and control system, which makes use of an electrical motor and an inverter frequency controller, is the next component. The water bath system and pipe systems make up the third component. The instrumentation and data logger of the AAC system served as the final component of the experimental setup. The AAC system is properly instrumented with temperature indicators, pressure gauges, and digital power analysers.

The performance of the test rig was investigated through experiments to ascertain the impact of the initial refrigerant charge (90 to 120 g) on AAC performance; (ii) the impact of compressor speed (900 to 2100 rpm) on AAC performance; and (iii) the comparison of AAC performance with various types of lubricants, including PAG lubricant, SiO2/PAG, and Al2O3/PAG nanolubricants at different volume concentrations.

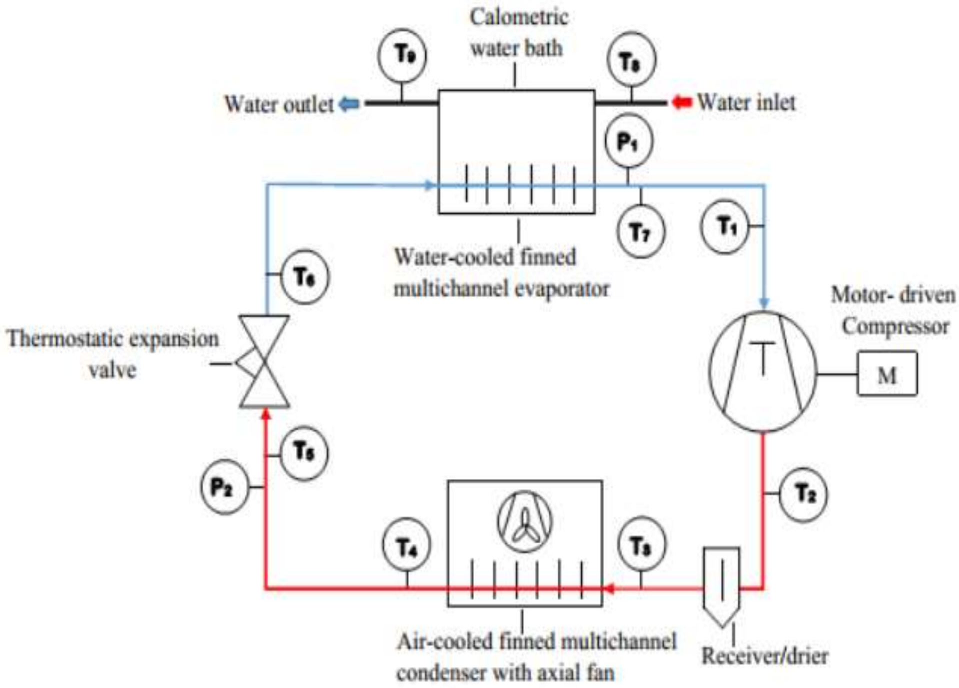


Fig.1. The schematic diagram of automotive air conditioning (AAC) system.

Beijing DK Nanotechnology produced the SiO_2 nanoparticles, and Sigma-Aldrich provided the Al_2O_3 nanoparticles. The SiO_2 and Al_2O_3 nanoparticles were produced with 99.9% purity and average particle sizes of 30 and 13 nm, respectively. In the current work, to prevent any excessive moisture, the nanoparticles were stored in a dry cabinet with controlled temperature and humidity. Therefore, the nanoparticles can be dried without the use of heat. Table 1 displays the properties of nanoparticles.

Table 1- Properties of Al_2O_3 & SiO_2 at room temperature.

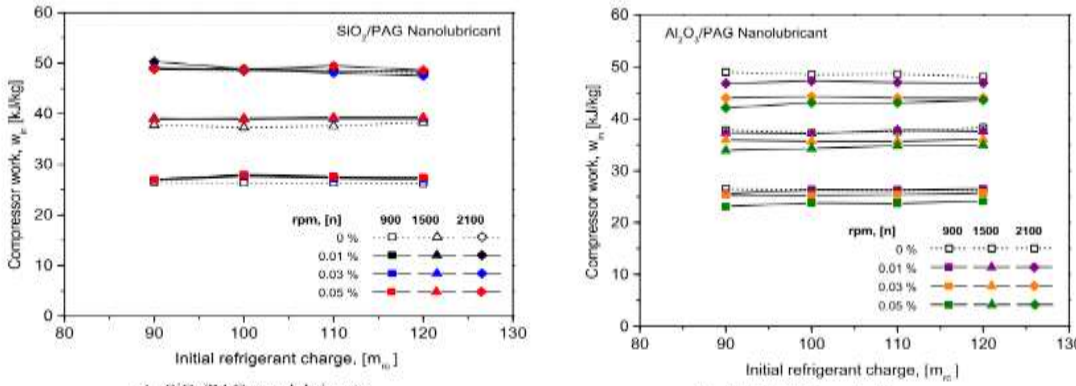
Sl No.	Property	Al_2O_3	SiO_2
1	Average particle diameter (mm)	13	30
2	Thermal conductivity (W/m K)	36	1.4
3	Purity (%)	99.9	99.9
4	Specific heat (J/Kg K)	773	745
5	Molecular Mass(g/mol)	101.96	60.08
6	Density (Kg/m^3)	4000	2220
7	CAS Number	a. 1344–28-1	14808–60-7

The characteristics of R123yf refrigerant and the PAG lubricants are represented in the table 2. In order to assess the suitability of the new type of polyalkylene glycol (PAG ND12) nanolubricants with R1234yf in the AAC-R1234yf system, a systematic experimental performance investigation at various volume concentrations as well as various types of materials for SiO_2 and Al_2O_3 nanolubricants is performed in this study.

Table 2- Characteristics of refrigerant R123yf and PAG ND12 lubricant.

R123yf		PAG ND12	
Critical pressure (bar)	34	ISO Viscosity grade (cP)	46
Critical temperature (°C)	95	Density (g cm^{-3})	1.021 @ 40°C
Boiling point (@1 atm (°C)	-29	Kinematic viscosity (mPa s)	39.3 @ 40°C
ODP	0	Viscosity Index	216.157
GWP	1	Flash Point (°C)	-36

1.2 Compressor Performance



a) SiO_2/PAG nanolubricants

b) Al_2O_3/PAG nanolubricants

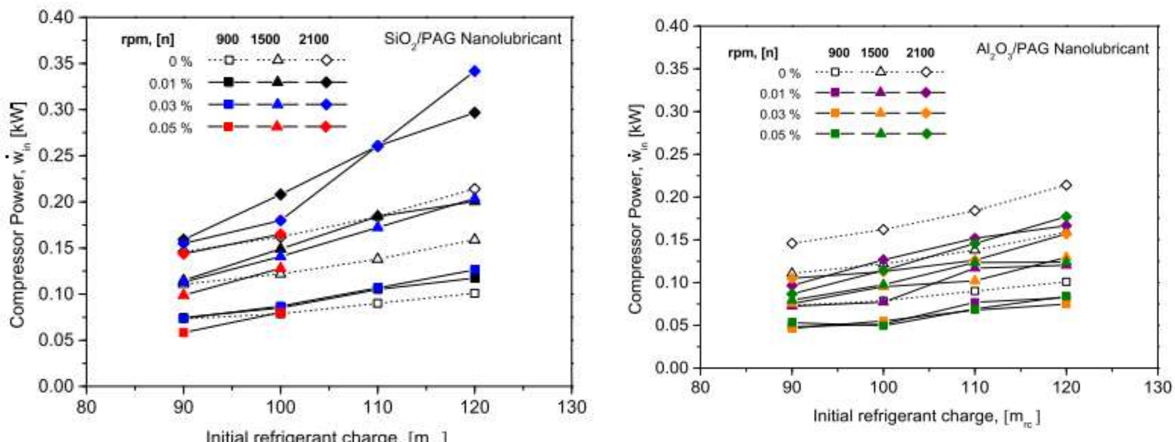
Fig 2 :Compressor work for different charges of nanolubricant.

The above figure illustrates the work performed by the AAC compressor employing SiO_2/PAG and Al_2O_3/PAG nanolubricants with compressor speeds ranging from 900 to 2100 rpm. The initial refrigerant charge and compressor speed both increased the compressor work linearly. As can be seen in Fig. (a), the compressor work performed for the AAC-SiO_2/PAG system was marginally up to 2% more than that of the AAC-PAG system, although this difference was negligible. The work performed by the compressor was somewhat higher in the AAC-SiO_2/PAG system than in the AAC-PAG system due to its lower superheating rate and higher refrigerant mass flow rate. It was important to note that, as indicated in Fig., the Al_2O_3/PAG nanolubricant promoted 7.2% less compressor work than the original PAG lubricant (b).

Overall, at the same operating condition, the AAC system with Al_2O_3/PAG nanolubricant required less power input than SiO_2/PAG nanolubricant. Al_2O_3/PAG nanolubricant's superior tribology properties and higher heat conductivity than SiO_2/PAG nanolubricant

were to blame for this.

The following Fig.3(a) and 3(b) illustrate the AAC power input by an AAC compressor using SiO_2/PAG and Al_2O_3/PAG nanolubricants with various initial refrigerant charges for compressor speeds ranging from 900 to 2100 rpm. According to Fig.3 (a), the AAC-SiO_2/PAG system had a higher compressor power input than the AAC-PAG system and the AAC-Al_2O_3 system. There was a significant amount of compressor work done on the AAC-SiO_2/PAG system. As a result, compared to the other systems, the compressor power input was also marginally higher. Lower power input was caused by the AAC system's use of an Al_2O_3/PAG nanolubricant, which is further highlighted in Fig.3(b).



a) SiO_2/PAG nanolubricants

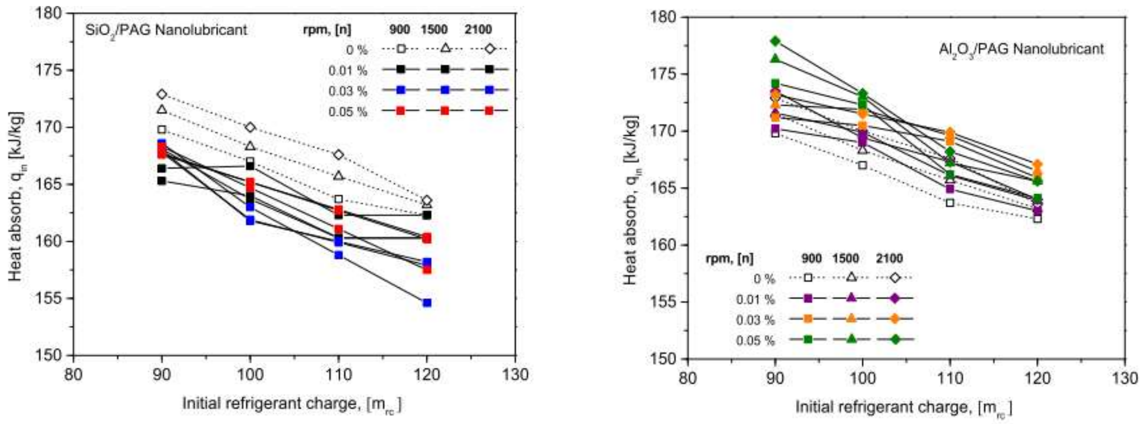
b) Al_2O_3/PAG nanolubricants

Fig 3: Comparison of compressor power at the different refrigerant charges of nanolubricant.

1.3 Cooling Performance

Evaluation of the AAC-R1234yf cooling system must take into account both the cooling capacity and the AAC evaporator's capacity to absorb heat. Fig. 4(a) and (b) represent the experimental results for Al_2O_3/PAG and SiO_2/PAG, for heat absorb by AAC evaporator at different refrigerant charges.

The AAC evaporator uses nanolubricants to absorb heat at various refrigerants charges. The relationship between the two graphs is inverse, at various compressors, heat absorption and initial refrigerant charges both nanolubricants work at similar speeds. For the AAC-SiO_2/PAG Fig. 4(a) system exhibits less evaporator heat absorption compared to In Fig. 4(b) the AAC-PAG and AAC-Al_2O_3/PAG systems. Nonetheless, this was as a result of the decrease being only 2.6%, it was deemed negligible. more than PAG lubricants High refrigerant mass in the AAC system reduced flow rates may result in a lower heat absorption value, and vice versa.

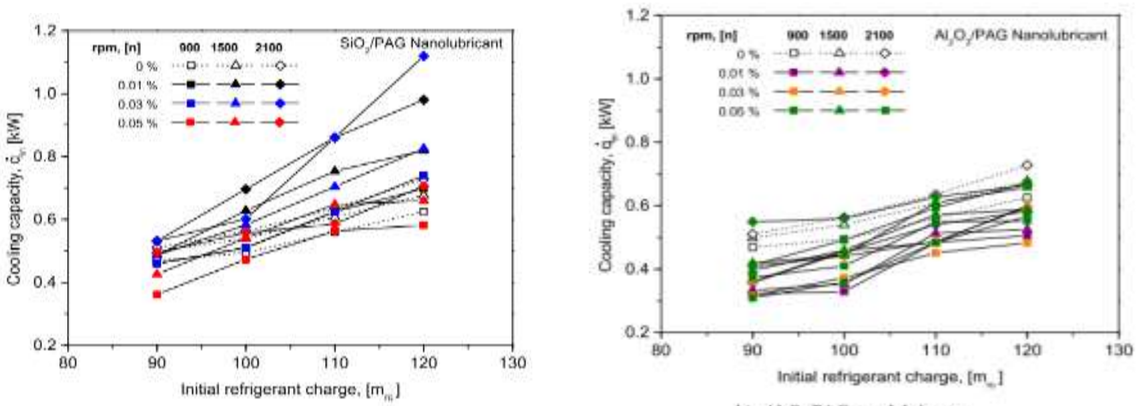


a) SiO_2/PAG nanolubricants b) Al_2O_3/PAG nanolubricants

Fig. 4: comparison of heat absorption for different refrigerant charge of nanolubricants.

The relationship between cooling capacity and initial refrigerant charge at various compressor speeds is shown in Figs. 5(a) and (b). It is evident from the graph that when the initial refrigerant charges and speeds increase, cooling capacity also increases. In fig 5(a) First off, compared to base PAG lubricants, the SiO_2/PAG nanolubricants with volume concentrations of 0.01 and 0.03% performed better with higher capacity heating in the AAC system for up to 15.7 and 15.1%, respectively. Second, the cooling performance of the AAC-SiO_2/PAG system with 0.05% volume concentration was up to 6% lower than that of the PAG lubricants.

Fig. 5(b), on the other hand, illustrates the AAC system's cooling capacity when using Al_2O_3/PAG nanolubricants. In comparison to the AAC-PAG system, the average cooling capacity for Al_2O_3/PAG nanolubricants was 19.9% lower. Despite having an excellent heat absorption performance, the AAC-Al_2O_3/PAG system's low mass flow rate results may compromise its total cooling capacity. Therefore, SiO_2 nanoparticles in a vapour compression system outperformed Al_2O_3 nanoparticles in terms of cooling capacity, and the AAC-Al_2O_3/PAG system had a higher heat absorption rate than the AAC-SiO_2/PAG system.



a) SiO_2/PAG nanolubricants b) Al_2O_3/PAG nanolubricants

Fig. 5: Comparison of cooling capacity of nanolubricants at different refrigerant charges.

1.4 Overall System Performance

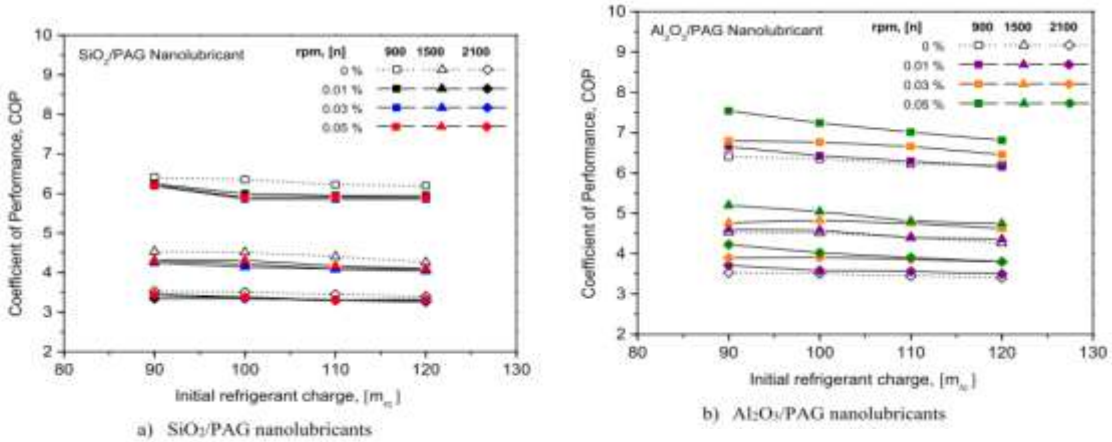


Fig. 6: Comparison of COP for nanolubricant at different refrigerant charges.

Fig. 6 shows how the coefficient of performance (COP), which measures the ratio of the evaporator to the power compressor, varies at various beginning refrigerant charges and compressor speeds. The graph shows that the COP increased with initial refrigerant charge while remaining essentially constant. As seen in Figures 6(a) and 6(b), the COP also fell as compressor speed increased.

When compared to the AAC-PAG system, the COP for the AAC-SiO_2/PAG system decreased on average by 4.4%. However, an average increase in cooling capacity of 12.2% was enough to balance out these reductions. AAC-Al_2O_3/PAG should be noticed, it generated COP that was higher than the AAC-PAG system, on average by 9.8%. Additionally, it was observed that nanolubricants performed better at larger volume concentrations.

For the AAC-SiO_2/PAG system, the negative value in the COP enhancement analysis was seen in Fig.7 The AAC-SiO_2/PAG system's significant power consumption was the source of the COP drop. Nevertheless, the disadvantage of COP reduction for the AAC SiO_2/PAG system was deemed unimportant due to a slight loss of less than 5% in comparison to the large increase in cooling capacity.

Compared to the AAC-PAG and AAC-SiO_2/PAG systems shown, the COP enhancement for the AAC-Al_2O_3/PAG system increased with volume concentration. The decrease in compressor work was what caused the COP to increase with volume concentration.

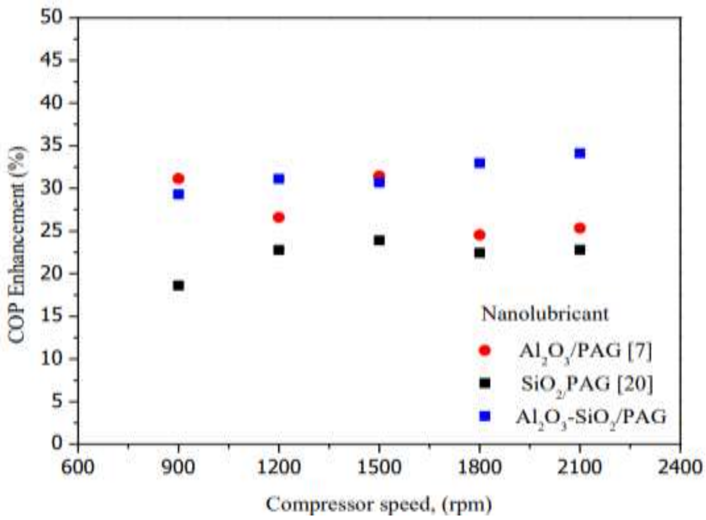


Fig.7: AAC COP against various compressor speed for different nanaolubricnats

1.5 Conclusion

The purpose of the experimental effort was to highlight the overall effectiveness and impact of various nanolubricant types in the AAC system using R1234yf as an alternative refrigerant. According to the stability studies, the nanolubricant demonstrated good stability and a low rate of agglomeration. Although the AAC-SiO_2/PAG system had a lower COP and more energy consumption, it had better cooling capability. At 0.01% volume concentration, the AAC-SiO_2/PAG stem's average cooling capacity increased by 15.7%. The AAC-Al_2O_3/PAG system, in contrast, fared better in terms of power usage and COP increase. At 0.05% volume concentration, the AAC-SiO_2/PAG system's average COP and power consumption improved by up to 9.8% and decreased by up to 27.1%, respectively. In addition, it is feasible to use nanolubricants in the AAC system because of the small amount of Al_2O_3 nanoparticles, approximately 0.2 g per 100 ml of lubricants for a 0.05% volume concentration.

Performance of the automotive air-conditioning (AAC) system needs to be increased to cut down on energy use and encourage energy efficiency. Applying the proper lubricants will boost the efficiency of the AAC system. Composite nanolubricants, which combine various metal oxide components and composition ratios, are anticipated to perform better than single-component nanolubricants in terms of enhancing AAC system performance. In the current study, Al_2O_3-SiO_2/PAG composite nanolubricants were used to examine how well the AAC system performed. Al_2O_3-SiO_2/PAG composite nanolubricant is therefore recommended instead of single component nanolubricants for the compressor's lubrication to improve AAC performance system.

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