PERFORMANCE ANALYSIS OF SiO_2/PAG NANOLUBRICANT IN AUTOMOTIVE AIR CONDITIONING SYSTEM

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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LIST OF SYMBOLS

$\overline{A}_r$	Absorbance ratio
$\overline{A}_o$	Initial absorbance
$\overline{A}$	Final absorbance
Bf	Based fluid
cSt	Centistoke
Eff	Effective
Eq	Equation
Exp	Experiment
h	Enthalphy
k	Thermal conductivity, W/m.K
k_r	Thermal conductivity ratio, k_{NL}/k_L
L	Lubricant
m_{RC}	Initial refrigerant charge, g
μ_r	Viscosity ratio, μ_{NL}/μ_L
μ	Dynamic viscosity, mPa.s
NL	Nanolubricant
P	Nanoparticle
ϕ	Volume concentration, %
φ	Volume concentration in fraction
Q_L	Heat absorb
r	Ratio
ρ	Density, kg/m^3
T	Temperature, ^oC

ν	Kinematic viscosity, cSt
W_{in}	Compressor work

LIST OF ABBREVIATIONS

AAC	Automotive air conditioning
AD	Average deviation
ANSI	American National Standard Institute
ASHRAE	American Society of Heating, Refrigerating and air conditioning engineers
CFD	Computational Fluid Dynamic
COP	Coefficient of performance
EC	Electrical Conductivity
EER	Energy Efficiency Ratio
FESEM	Field emission scanning electron microscopy
IEP	Isoelectric Point
LPM	Liter per minute
OD	Outer Diameter
rpm	Revolution per Minute
SAE	Society of Automotive Engineers
SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscopy
UMP	Universiti Malaysia Pahang

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ABSTRAK

Pada masa kini, kebarangkalian untuk meningkatkan kecekapan bahan api dengan teknologi terkini telah mula dijalankan dengan teliti oleh ramai penyelidik. Salah satu cara terbaik untuk meningkatkan kecekapan bahan api adalah dengan meningkatkan prestasi sistem pendingin hawa automotif (AAC). Sistem AAC kini adalah satu keperluan dan bukan lagi hanya kehendak semata-mata, dan penyejukan adalah diperlukan untuk mewujudkan suasana yang selesa di dalam kabin penumpang terutamanya pengguna di negara seperti Malaysia, yang mengalami cuaca panas dan lembap sepanjang tahun. Dengan iklim panas dan juga kesan El-Nino yang berlaku dengan lebih kerap kebelakangan ini, penggunaan AAC dalam kenderaan automatik akan meningkat secara drastik. Ini akan memberi kesan kepada penggunaan bahan api dan seterusnya mengurangkan jarak perjalanan sesebuah kenderaan dalam tempoh setahun. Oleh itu, prestasi AAC perlu dipertingkatkan untuk meminimumkan kesan buruk ke atas alam sekitar dan mengurangkan penggunaan bahan api dunia. Objektif kajian ini adalah untuk menghasilkan SiO_2/PAG nano pelincir dan mengukur sifat kekonduksian haba dan kelikatan untuk nano pelincir ini. Selanjutnya, sistem ujikaji AAC direkabentuk dan dibangunkan untuk menganalisis prestasi SiO_2/PAG nano pelincir di dalam sistem tersebut. SiO_2/PAG nano pelincir dihasilkan melalui kaedah dua langkah dan kestabilan nano partikel di dalam PAG disahkan. Kemudian, kekonduksian haba dan kelikatan untuk SiO_2/PAG nano pelincir telah diukur bagi kepekatan 0% sehingga 1.5% dan pada suhu 30 hingga 80 °C. Ujikaji AAC telah dijalankan dengan menggunakan gas penyejuk bermula dari 95 sehingga 125 gram dan kelajuan pemampat bermula dari 900 sehingga 2100 rpm. Prestasi sistem AAC itu dinilai dengan mengukur tahap penyerapan haba, kerja pemampat dan pekali prestasi (COP). Keputusan pengukuran sifat kelikatan dan kekonduksian haba SiO_2/PAG nano pelincir menunjukkan peningkatan sifat tersebut dengan kepekatannya tetapi menurun dengan suhu. Persamaan bagi menganggar kekonduksian haba dan kelikatan untuk SiO_2/PAG nano pelincir telah dicadangkan dalam tesis ini. Hasil dari penilaian sifat termo-fizikal, penggunaan SiO_2/PAG nano pelincir untuk aplikasi pada sistem AAC hanya boleh digunakan untuk kepekatan sehingga 0.7% sahaja. Prestasi keseluruhan sistem AAC telah bertambah baik dan kerja pemampat yang berkaitan dengan penggunaan bahan api berjaya dikurangkan. Penggunaan gas penyejuk untuk sistem AAC beroperasi dengan pelincir PAG adalah optimum dengan sukatan 115 g. Keputusan eksperimen untuk sistem AAC beroperasi menggunakan SiO_2/PAG nano pelincir menunjukkan peningkatan maksimum COP sebanyak 24% dan pertambahan purata COP sebanyak 10.5%. Sistem AAC mencapai kerja pemampat minimum dan maksimum COP pada kepekatan 0.05%. Oleh itu, COP menunjukkan prestasi paling tinggi pada kepekatan 0.05% untuk semua keadaan kelajuan pemampat. Kepekatan pada tahap 0.05% juga didapati kepekatan yang terbaik bagi SiO_2/PAG nano pelincir dan hasil SiO_2 nano partikel di campurkan dengan PAG telah terbukti berkesan bagi meningkatkan prestasi COP untuk semua kepekatan yang diuji. Oleh itu, boleh disimpulkan bahawa 0.05% adalah kepekatan yang paling optimum bagi SiO_2/PAG nano pelincir untuk aplikasi dalam sistem AAC. Maka, adalah disyorkan untuk menggunakan SiO_2/PAG nano pelincir dengan kepekatan sebanyak 0.05% dalam sistem penyaman udara kenderaan untuk mendapatkan prestasi yang terbaik. Cadangan ini telah disokong oleh ujikaji secara visual dalam saluran mini bagi komponen penyejat sistem AAC yang dipastikan tiada hakisan dan tidak tersumbat setelah penggunaan SiO_2/PAG nano pelincir.

ABSTRACT

Currently, the possibility to enhance fuel efficiency with cutting edge advancements is thoroughly investigated by researchers. One of the best ways to increase the fuel efficiency is by improving the performance of the automotive air conditioning (AAC) system. The AAC is currently a thing of necessity instead of just an accesory, and cooling is needed to give thermal comfort in the passenger's cabin especially for countries like Malaysia, that experience hot weather throughout a year. With the hot weather climate and also because of the El-Nino impacts that occur frequently, the use of AAC in auto vehicles will increase drastically. This will affect the fuel consumption and consequently reduce the automobile travelling distance yearly. Therefore, the AAC performance needs to be enhanced in order to minimize its environmental impact and reduce global fuel consumption. The objectives of the present work are to formulate the SiO_2/PAG nanolubricants and evaluate the thermal conductivity and viscosity of the nanolubricants. Furthermore, the AAC system test rig is designed and developed for performance analysis of SiO_2/PAG nanolubricants in the system. The SiO_2/PAG nanolubricant is formulated by the two-step method and had established the colloidal stability of the suspended nanoparticles. Then, the viscosity and thermal conductivity of the SiO_2 nanoparticles dispersed in Polyalkylene glycol (PAG) lubricants for 0 to 1.5% volume concentrations and 30 to 80 °C working temperatures were investigated. The AAC experiment was conducted with initial refrigerant charge ranging from 95 to 125 gram and compressor speeds of 900 to 2100 rpm. The performance of the AAC system was evaluated by determining the heat absorb, compressor work and coefficient of performance (COP). The viscosity and thermal conductivity of the SiO_2 nanolubricants increased with volume concentration but decreased with temperature. The thesis proposed correlations for viscosity and thermal conductivity of SiO_2 nanolubricants at various concentrations and temperatures. From the thermo-physical properties evaluation, the use of SiO_2/PAG nanolubricants for application in AAC compressor is applicable for volume concentrations up to 0.7% only. The overall AAC performance of the system improved and the compressor work related to the fuel consumption can be greatly reduced. The optimum refrigerant charge of the present AAC system run with PAG lubricant is attained with 115 g. The results found that the maximum increase and the average COP enhancement for SiO_2/PAG nanolubricants are 24% and 10.5%, respectively. At 0.05% concentration, the system attained minimum compressor work with maximum COP. Consequently, it was observed that the COP was highest at 0.05% volume concentration for all compressor speeds. A volume concentration of 0.05% is found to be the best volume concentration for SiO_2/PAG nanolubricants and dispersing SiO_2 nanoparticle in PAG lubricant has proven to enhance the performance of the COP for all volume concentrations. Finally, it can be concluded that 0.05% is the optimum volume concentration of SiO_2/PAG nanolubricants for applications in AAC systems. Therefore, it is recommended to use SiO_2/PAG nanolubricants with a volume concentration of 0.05% for the best performance in the automotive air conditioning systems. This recommendation is supported by the visual investigation inside the mini channel of AAC evaporators which observed zero erosion and no clogging by the use of SiO_2/PAG nanolubricants.

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