TRIBOLOGICAL PERFORMANCE ANALYSIS OF NANOCELLULOSE-AL_2O_3-ENGINE OIL

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DOCTOR OF PHILOSOPHY

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

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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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ABSTRAK

Dalam kajian semasa, pelincir nano memainkan peranan penting dalam semua komponen mesin untuk menghindari kehausan dan kakisan akibat gerakan relatif antara permukaan yang bersentuhan seperti alas bebola, aci sesondol, omboh, kotak gear, skru, kerja logam, cecair, gear, dan dalam penghawa dingin automotif. Memandangkan undang-undang alam sekitar sentiasa mengalami peningkatan pembaharuan, industri pelincir telah berusaha keras untuk menghasilkan pelincir alternatif yang mesra alam sekitar untuk enjin pembakaran dalaman. Dalam menangani cabaran ini, kegunaan pelincir mestilah mematuhi piawaian alam sekitar dan dalam pada masa yang sama mengekalkan prestasi pelincir yang baik. Tesis ini mengkaji keupayaan tribologi bagi pelincir hibrid dalam meningkatkan prestasi pelincir nano dengan melakukan penyelidikan dengan menggunakan Nano Selulosa (CNC) dan Aluminium Oksida (Al_2O_3) yang merupakan pelincir nano hibrid, sebagai penyelesaian alternatif yang memastikan pengurangan kelakuan tribologi terhadap pelincir pepejal dan cecair serta meningkatkan jangka hayat komponen mekanikal yang mana CNC adalah konduktor haba yang baik berdasarkan susunan strukturnya yang membolehkan konduksi haba. Pelincir nano berhibrid dengan nisbah yang berbeza adalah sebagai aditif di dalam minyak enjin, yang digunakan untuk mengawalselia sifat-sifat fizikal-termo seperti mengurangkan kesan COF dan WR yang menggunakan bahan omboh yang sama. Pelincir nano disediakan dengan beberapa nisbah kepekatan seperti 0.3 %, 0.5 % dan 0.7 % yang dibandingkan dengan minyak asas 10W-40 dan diukur nilai termo fizikalnya pada beberapa nilai suhu iaitu 30 ºC, 50 ºC dan 70 ºC. Konduksi haba dan kelikatan dinamik menunjukkan tindak balas yang positif kepada perbandingan dengan minyak asas di mana kekonduksian terma meningkat apabila suhu meningkat manakala kelikatan dinamik pula berkurangan apabila suhu meningkat. Pelincir nano berhibrid mempunyai peningkatan 18.09 % pengkonduksian termal yang tertinggi berbanding dengan 10W-40 minyak asas. Sementara pelincir nano pula memberikan peningkatan 21.8 % kelikatan dinamik yang paling rendah berbanding dengan 10W-40 minyak asas. Berdasarkan kepada semua ujian sifat asas termal, pelincir nano berhibrid dengan kepekatan 0.5 % memberikan keputusan yang terbaik. Pemerhatian secara visual memaparkan terdapat sedikit mendapan tetapi ianya tidak signifikan dan sampel-sampel dianggap stabil setelah melalui ujian kestabilan selama dua bulan. Hasil pengiraan nilai optimum mendapati bahawa pelincir nano hibrid (CNC+Al_2O_3) menghasilkan geseran yang minimum, kurang kesan lusuh dan ia boleh bertahan pada beban yang tinggi. Berdasarkan hasil penyelidikan, kesimpulannya semua objektif penyelidikan telah tercapai. Campuran hibrid Nano partikel Al_2O_3 + CNC boleh digunakan sebagai pelincir tambahan dalam mengurangkan COF (16 %) dan WR (71 %). Selain itu, kajian ini juga menunjukkan bahawa penggunaan partikel Al_2O_3 turut berpotensi untuk menambah baik minyak pelincir pada ketahanan tinggi melalui mereplikasi setiap pengukuran ujikaji terhadap enjin pembakaran dalaman pada kereta sebenar.

ABSTRACT

In the current studies, the nano-lubricants have been the vital role in all machine components in preventing wear and tear due to relative motion between the contact surfaces such as bearings, camshaft, piston, gearbox, lead screw, metal working, fluids, gears, and in automotive air-conditioning. Given continuous environmental legislation, the lubrication industry has been striving to produce environmentally suitable lubrication alternatives for internal combustion engines. Addressing this challenge requires the use of lubricants that conforms to environmental standards while maintaining excellent lubrication performance. This thesis investigates the tribological viability of hybrid lubricants in improving the performance of the nano-lubricants, research is done by using Nano cellulose (CNC) and Aluminium Oxide (Al_2O_3) as the hybrid nano-lubricant, being as the promising alternative and solution for tribological behaviour of both solid and liquid lubrication and extends the life of the mechanical components which CNC is well known as a good heat conductor due to its structural arrangement that allow to conduct heat. The hybrid of nano-lubricant with different ratios as additives in engine oil is then used to conduct thermo-physical properties as to reduce the COF and WR of similar piston material. The nano-lubricant is prepared with multiple ratios 0.3 %, 0.5 % and 0.7 % concentration which were compared to base oil 10W-40 and tested for properties at 30 ºC, 50 ºC and 70 ºC. Thermal conductivity and dynamic viscosity showed a positive response to the comparison with base oil as for thermal conductivity, it increases as temperature increases while dynamic viscosity reduces as the temperature increases. Nano-hybrid lubricant has the highest thermal conductivity enhancement compared with 10W-40 base oil at 18.09 %. Meanwhile, nano-lubricant exhibit lowest enhancement of dynamic viscosity compared with 10W-40 base oil at 21.8 %. As per over all property test, 0.5 % nano-hybrid lubricant concentration has the best result. The visual observation displayed a very small sedimentation which is insignificant and samples are considered stable throughout the stability test done for two months. Optimisation finding that hybrid ($CNC+Al_2O_3$) nano-lubricant produced less friction, less wear effect and it can stand high load. Based on the research finding, it can be concluded that the research objectives are achieved. The hybrid Al_2O_3 nanoparticles + CNC can be used as additive in lubricant in reducing the COF (16 %) and WR (71 %). Moreover, this study has shown that the used of the Al_2O_3 nanoparticles have the potential to improvise the lubricant for better durability to apply in the system replicating an internal combustion engine of an actual car.

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LIST OF ABBREVIATIONS

Ag	Silver
Al	Aluminum
Al/Sn	Aluminum-Tin
Al_2O_3	Aluminum Oxide
Al_2O_3/SiO_2	Aluminum Oxide-Silicone Oxide
AW	Anti-wear
APS	Average particle size
C	Carbon
C_D	Drag Coefficient
C_f	Coefficient Friction Factor
Co	Cobalt
CO_2	Carbon Dioxide
CNC	Nano cellulose
Cr	Chromium
Cu	Copper
COF	Coefficient of Friction
CuO	Copper (II) Oxide
Dh	Hydraulic diameter
DV	Dynamic Viscosity
EDX	Energy-dispersive X-ray Spectroscopy
Ep	Extreme pressure
Fe	Iron
FESEM	Field Emission Scanning Electron Microscopy
g	Gravity
h	Height
H_2	Hydrogen
He	Helium
IC	Internal combustion
IR	Infrared
L	Length
LOF	Lack of Fit

Mg	Magnesium
MoDTC	Molybdenum Dialkylthiocarbamate
MOO	Multi-Objective Optimization
MoS_2	Molybdenum Disulfide
MoS_2/TiO_2	Molybdenum Disulphide-Titanium Dioxide
Ni	Nickel
O_2	Oxygen
OM	Optical Microscopy
P	Phosphorus
p	Hydrostatic pressure
Δp	Pressure drop
Pb	Lead
PAGs	Polyalkylene Glycols
r	Radius of nanoparticle
Ra	Average roughness
Re	Reynold Number
Rq	Mean root mean square roughness
RSM	Response Surface Methodology
S	Sulfur
Si	Silicon
SEM	Scanning Electron Microscope
SiO_2	Silicon Dioxide, Silica
Ti	Titanium
TAG	Triacylglycerol
TAN	Total acid number
TEM	Transmission Electron Microscopy
TiO_2	Titanium Dioxide
TiO_2/SiO_2	Titanium Silicon Oxide, Titanium Silicate, Silicon Titanate
UV-vis	Ultraviolet–visible
vz	settling velocity
VI	Viscosity Index
W	Wide

WS_2	Tungsten Disulfide
WR	Wear Rate
XPS	X-ray Photoelectron Spectroscopy
ZnO	Zinc Oxide
ZrO_2	Zirconium Dioxide
$ZnAl_2O_4$	Zinc Aluminate
ZrO_2/SiO_2	Zirconia Oxide-Silica Oxide
ρNP	Density of nanoparticles
ρF	Density of fluid
τ	Fluid viscosity
ι_w	Shear stress
μ	Viscosity of the fluid

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