STUDY OIL THERMAL-PHYSICAL PROPERTIES FOR NANOCELLULOSE NANOPARTICLES FOR SAE40 ENGINE OIL FOR TRIBOLOGICAL BEHAVIOUR

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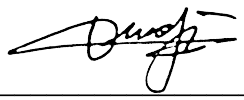

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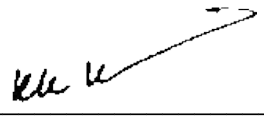

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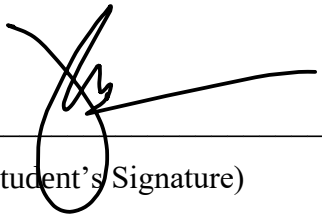

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Doctor of Philosophy

College of Engineering

UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2021

DEDICATED TO

In memories:

My beloved

Walid and Achik;

My baby; Yusra Amanda binti Yusril Akhyar.

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ABSTRAK

Haus dan geseran tidak dapat dielakkan dalam aplikasi kejuruteraan pada masa kini. Salah satu penyelesaian untuk masalah ini adalah dengan menggunakan pelincir yang dapat mengurangkan geseran dan keausan minimum, sehingga meningkatkan efisiensi. Pembangunan bahan tambahan pelincir yang cekap telah mendapat perhatian industri dan akademik untuk meningkatkan ketahanan dan prestasi pelincir sambil memenuhi kriteria pembangunan yang mampan untuk penggunaan bahan bakar dan pengurangan pencemaran. Secara umum, partikel bersaiz nano yang tersebar di pelincir, yang dikenali sebagai pelincir nano, digunakan dalam sistem mekanikal untuk mengurangkan haba dan geseran dengan berkesan. Tambahan pula, peraturan alam sekitar baru akan mendorong pengembangan pelincir dengan teknologi pelinciran yang lebih hijau. Untuk menangani masalah ini, ia memerlukan penggunaan pelincir yang mematuhi piawaian persekitaran sambil mengekalkan prestasi pelinciran yang sangat baik. Oleh itu, nanopartikel Nano Selulosa (CNCs) dicadangkan sebagai bahan tambahan hijau baru dalam minyak enjin. CNCs dipilih kerana ciri khasnya seperti konduktor haba yang baik kerana susunan strukturnya yang memungkinkan untuk melakukan haba. Tujuan kajian ini adalah untuk mengkaji kesan minyak enjin SAE 10 W 40 (SAE 40) berasaskan CNCs pada sifat fizikal-termal dan tingkah laku tribologi. Reka bentuk optimum ditentukan dan ditunjukkan parameter mana yang signifikan secara statistik untuk memperoleh pekali geseran (COF) rendah dan kadar keausan tertentu (WR) dengan minyak enjin SAE 40 berasaskan CNCs. Nanopartikel CNCs tersebar dalam minyak enjin SAE 40 menggunakan kaedah penyediaan dua langkah. Minyak enjin SAE 40 berasaskan CNCs dihasilkan dengan kepekatan isipadu yang berbeza iaitu 0.1 % hingga 0.9 %. Sifat termal-fizikal seperti kekonduksian terma, kelikatan kinematik, indeks kelikatan (VI), ketumpatan dan haba spesifik diukur untuk semua kepekatan isipadu. Sementara itu, sifat tribologi minyak enjin SAE 40 berdasarkan CNCs dinilai untuk kelajuan gelongsor, beban dan suhu yang dikenakan. Ujian kehausan geseran melibatkan pergerakan timbal balik linear seperti pasangan cincin omboh silinder yang beroperasi dalam keadaan sebenar. Kemudian, Metodologi Permukaan Respons (RSM) berdasarkan reka bentuk Box-Behnken digunakan untuk mengoptimumkan parameter prestasi tribologi. Penilaian kestabilan menunjukkan minyak enjin SAE 40 berasaskan CNCs dianggap stabil sepanjang tempoh kajian dan pemendapan yang sangat kecil diperhatikan setelah 60 hari. Kekonduksian terma dan pemanasan khusus minyak enjin SAE 40 berasaskan CNCs meningkat dengan kepekatan isipadu. Pemerhatian sifat tribologi dengan keadaan pekali geseran (COF) dan kadar keausan tertentu (WR), didapati pada kepekatan isipadu 0.1% berkesan dalam meningkatkan ketahanan anti-haus dan membuktikan bahawa lapisan tribo atau lapisan perlindungan yang berlaku semasa eksperimen. Struktur permukaan spesimen menunjukkan bahawa minyak enjin SAE 40 berasaskan CNCs menghasilkan permukaan yang lebih halus. Hasil pengoptimuman menunjukkan bahawa untuk COF dan WR, penyelesaian terbaik yang diperoleh pada 500 rpm, 78.71 N dan kepekatan isipadu 0.1 % dengan kehendak tertinggi 75.4%. Kehadiran nanopartikel CNCs sebagai bahan tambahan dalam sampel minyak enjin SAE 40 meningkatkan prestasi tribologi sepenuhnya. Minyak asas yang mengandungi 0.1% CNC mempunyai sifat tribologi yang sangat baik, termasuk nilai COF terendah dan rintangan haus tertinggi berbanding semua kepekatan isipadu pelinciran. Berdasarkan dapatan kajian ini, dapat disimpulkan bahawa selulosa nanocrystal adalah aditif pelumas yang menjanjikan, terutama untuk aplikasi hijau.

ABSTRACT

Wear and friction are inevitable problems in engineering applications which causes reduced efficiency in mechanical systems. One solution to this problem is to use a lubricant that can reduce friction and wear to a minimum, resulting in increased efficiency. The development of efficient lubricant additives has received significant industrial and academic attention for tribological properties enhancement and increased thermal conductivity. In general, nano-sized particles dispersed in the lubricants, known as nano lubricants, are used in mechanical systems to reduce heat and friction effectively. Furthermore, new environmental regulations will encourage the usage of lubricants with greener lubrication technologies. Addressing this issue requires the use of lubricants that conforms to environmental standards while maintaining excellent lubrication performance. Therefore, as a new green additive, this study intends to investigate the dispersion of Cellulose Nanocrystals (CNCs) nanoparticles in engine oils. The purpose of this study is to investigate the effect of CNCs added SAE 10 W 40 (SAE 40) engine oil on the thermal-physical properties and tribological behaviour. The optimum design was analysed to indicate which parameters are statistically significant for obtaining a low coefficient of friction (COF) and low wear with CNCs added on SAE 40 engine oil. CNCs nanoparticles were dispersed in the baseline engine oil using the two-step method preparation. The two-step method preparation with a low volume concentration in the range of 0.1 % to 0.9 %., was used in the preparation of CNC's based engine oil. Thermal-physical properties such as thermal conductivity, kinematic viscosity, viscosity index (VI), density, and specific heat were measured for all volume concentrations. Meanwhile, tribological properties of CNCs added on SAE 40 engine oil were evaluated for different sliding speeds, applied load, and temperatures. The friction-wear test involves making linear reciprocating movements like a cylinder-piston ring pair operating under actual conditions. To optimize the tribology performance parameters, the Response Surface Methodology (RSM) based on the Box-Behnken design was adopted. Stability evaluation showed CNCs added SAE 40 engine oil was stable throughout the study, and after 60 days, very little sedimentation was observed. Thermal conductivity and specific heats of CNCs added SAE 40 engine oil had increased with the volume concentration. The tribology properties observation with optimal conditions of coefficient of friction (COF) and wear rates were found at 0.1% volume concentration, effective in improving the anti-wear and scuffing resistance via the formation of self-laminating protective films. The surface morphology of the specimens revealed that the CNCs added SAE 40 engine oil produced a smoother surface. The optimization results yielded an optimum COF and surface wear rate from 500 rpm, 78.71 N, and 0.1 % volume concentrations with the highest desirability of 75.4 %. The presence of CNCs nanoparticles as an additive in SAE 40 engine oils samples ultimately improved the tribological performances. Base oil containing 0.1% CNC has excellent tribological properties, including the lowest COF and the highest wear resistance under all lubrication conditions. Based on the findings of this study, it can be concluded that cellulose nanocrystal is a promising lubricant additive, especially for green applications.

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