# TRIBOLOGICAL BEHVIOUR OF COPPER (II) OXIDE NANOPARTICLES BASED LUBRICANT TO IMPROVE DURABILITY OF CONTACT SURFACE

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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 Master of Science in Mechanical

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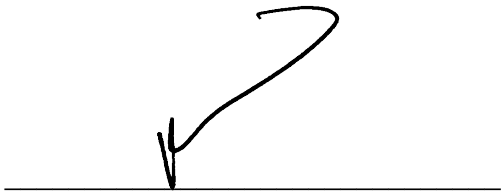

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## STUDENT'S DECLARATION

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

| | |
|---|---|
| $\rho$ | Density |
| $\mu$ | Coefficient of friction |
| N | Normal Load |
| V | Velocity |
| F | Force |
| $\Delta V$ | Volume loss |
| $\Delta W$ | Weight Loss |
| % | Percentage |
| $S_s$ | Sliding distance |
| W | Load |
| $W_1$ | Weight before test |
| $W_2$ | Weight after test |
| $W_p$ | Weight of Particles |
| $W_{bf}$ | Weight base fluid |

## LIST OF ABBREVIATIONS

| | |
|---|---|
| CuO | Copper (II) Oxide |
| Cu | Copper |
| TiO | Titanium Oxide |
| $Al_2O_3$ | Aluminium Oxide |
| ZnO | Zinc Oxide |
| Fe | Iron |
| Co | Cobalt |
| Zn$O_2$ | Zirconium dioxide |
| VI | Viscosity Index |
| RSM | Response Surface Methodology |
| ASTM | American Society for Testing and Material |
| FESEM | Field Emission Scanning Electron Microscope |
| EDX | Energy dispersive X-ray |
| OM | Optical machine |
| COF | Coefficient of Friction |
| TDC | Top Dead Centre |
| ICE | Internal Combustion Engine |
| EHL | Elastohydynamic |
| SWR | Specific Wear Rate |
| ANOVA | Analysis of Variance |
| BBD | Box-Behnken design |
| DOE | Design of Experiment |

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# ABSTRAK

Pada masa kini, minyak mineral adalah pelincir yang paling banyak digunakan di pasaran, seperti sintetik, semi sintetik dan minyak mineral sepenuhnya. Memandangkan sebahagian besar pelincir sedia ada telah mencapai had prestasi mereka, salah satu tugas saintifik adalah dengan membangunkan rumusan minyak pelincir baru yang dapat mencapai kecekapan tenaga dan mengurangkan tingkah laku tribologi di pelbagai bidang. Pelinciran adalah salah satu cara yang paling berkesan untuk mengurangkan geseran dan haus bahan haba tambahan yang lebih rendah. Oleh itu, prestasi pelincir yang lebih baik perlu dibangunkan untuk mengelakkan tingkah laku tribologi dan nanopartikel tambahan membantu meningkatkannya. Pelincir baru juga mesti berkualiti dan mesra alam sekitar. Nanopartikel telah dipilih dalam penyelidikan ini kerana dalam beberapa tahun kebelakangan ini, nanoteknologi mendapat perhatian penyelidik kerana sifat fizikal dan kimia mereka yang memberi perbezaan dalam industri terutama yang berkaitan dengan pelincir. Pelincir baru telah dibangunkan untuk mencabar masalah yang berlaku terutamanya dalam sistem mekanikal yang berkaitan dengan komponen perindustrian, industri automotif, peralatan dan lain-lain yang akan terjejas oleh geseran dan haus. Dalam kajian ini, nanopartikel membantu meningkatkan sifat pelincir dan tembaga (II) oksida telah dipilih kerana pengaruh mereka pada kawalan kepekatan yang lebih tinggi dan lebih rendah dengan parameter yang digunakan. Dalam kajian semasa, percubaan dibuat untuk mengkaji batasan nanopartikel CuO dalam SAE 30 dalam kepekatan yang berbeza, menyiasat pekali geseran (COF), kadar haus tertentu (WR) dan mekanisme haus serta mengoptimumkan parameter operasi untuk meningkatkan ciri-ciri tribologi. Penyelidikan ini akan dijalankan secara eksperimen dengan memakai penguji tribo yang berkaitan dengan dikawal oleh perisian Arduino dan langkah penguji dalam pergerakan gelongsor bergulung. Pelincir nano, adalah pencampuran minyak asas dengan 0.005% wt dan 0.01% wt CuO nanopartikel dengan menggunakan ultrasonik dan kaedah Kaedah Surface Response (KSR) digunakan untuk merancang percubaan dengan tiga jenis parameter yang telah dipilih. Keputusan menunjukkan geseran menurun pada 0.06125 dan geseran tertinggi terjadi pada 0.4848 di mana kedua-duanya menggunakan 0.005% wt kepekatan nanopartikel CuO. Walau bagaimanapun, ia digunakan dengan kombinasi parameter yang berbeza. Ditambah nanopartikel CuO di dalam minyak asas, ia juga boleh meninggal dengan 0.2482 ketika kepekatan 0.005% wt digunakan. Kebanyakan percubaan yang dijalankan telah memberikan pengurangan yang signifikan dalam geseran dan hausi apabila nanopartikel CuO ditambah. Walau bagaimanapun, nanopartikel CuO memberikan pengurangan geseran yang efektif dan haus dalam kepekatan yang berbeza yang digunakan tetapi, ia masih mempunyai batasan mengikut keadaan parameter. Struktur, terbentuk, sifat-sifat unsur diperhatikan dengan menggunakan kaedah Pengimbasan Pelepasan Emisi Lapangan Eletron Microscope (PPELEM) dan Energy Dispersive X-Ray (EDX), analisis membuktikan bahawa pembentukan lapisan tribo atau lapisan perlindungan yang berlaku semasa eksperimen. Penggunaan nanopartikel CuO telah meningkatkan geseran dan haus kerana mempengaruhi kelakuan tribologi pelincir tersebut. Nilai optimum bagi koefisien geseran (COF) adalah 0.0613μ dan0.6941 untuk kadar haus (WR) dengan parameter yang berkaitan seperti kelajuan, beban dan kepekatan adalah 291.33 rev / mim, 7.52kg dan 0.0086% kepekatan wt. Dari hasilnya, ia menunjukkan bahawa nanopartikel CuO pada kepekatan 0,005wt% menghampiri pelincir (SAE 30)

## ABSTRACT

Nowadays, a mineral oil was the most used lubricant in the market, divided into three types of fully synthetic, semi-synthetic and mineral oil. Since most of the existing lubricants have reached their performance limit, one of the significant scientific task is to develop new lubricant formulation that can achieved energy efficiency and reduce the tribological behaviour across various fields. Lubrication is one of the most effective ways to reduce friction, wear and lower the heat addition. Therefore, better performance of lubricant must be developed to prevent the tribological behaviour and nanoparticles additive help to improve it. The new lubricants also must be good quality and environmental friendly. Nanoparticles were selected in this research because in last few years, nanotechnology was gained researchers attention due to their physical and chemical properties that gives positive effect especially related to lubrication industries. New lubricant was developed to challenge the problem that occurred especially in the mechanical system that related to movement parts, industrial components, automotive industries, tools and others that will affected by friction and wear. In this research, nanoparticles help to improve the properties of lubricants and copper (II) oxide (CuO) have been selected due to their influence at higher and lower concentration control by the parameter used. In the current study, an attempt was made to study the limitation of CuO nanoparticles in SAE 30 in different concentration, investigate the coefficient of friction (COF), specific wear rate (WR) and wear mechanism and to optimize the operation parameter to enhancement the tribology characteristics. The research will be experimentally conducted using wear tribo-tester controlled by Arduino software and the tester move in reciprocating sliding motion. The nanolubricants, are the mixing of the base oil with 0.005%wt and 0.01%wt CuO nanoparticles by using ultrasonic water bath and Response Surface Methodology (RSM) method was used to design the experiment with three type of parameters that have been selected. Result showed the lowers friction was 0.06125 and highest friction occurred at 0.4848 where both were using 0.005%wt concentration of CuO nanoparticles. However, it applied with the combination of different parameters. Added CuO nanoparticles in the base oil, it also may be deceased the wear by 0.2482 when 0.005%wt concentration was used. Most of the experiment conducted has giving the significant reduction of the friction and wear when CuO nanoparticles were added. However, CuO nanoparticles provide an effective reduction of friction and wear in different concentration used but, it still have limitation according to the condition of the parameter. The structure, formed, element properties were observed using Field Emission Scanning Electron Microscope (FESEM) and Energy Dispersive X-Ray (EDX) method therefore, the analysis proved that the present of formation of the tribo-layer or protection layer that occurred during the experiment. The used of CuO nanoparticles were improved the friction and wear due to the affects the tribological behaviour of the lubricant. The optimum value for coefficient of friction (COF) is 0.0613μ and 0.6941 for wear rate (WR) with relevant parameter such as speed, load and concentration are 291.33 rev/min, 7.52kg and 0.0086%wt concentration. From the result, it shows that the CuO nanoparticles at 0.005wt% concentration approached with the lubricant (SAE 30).

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