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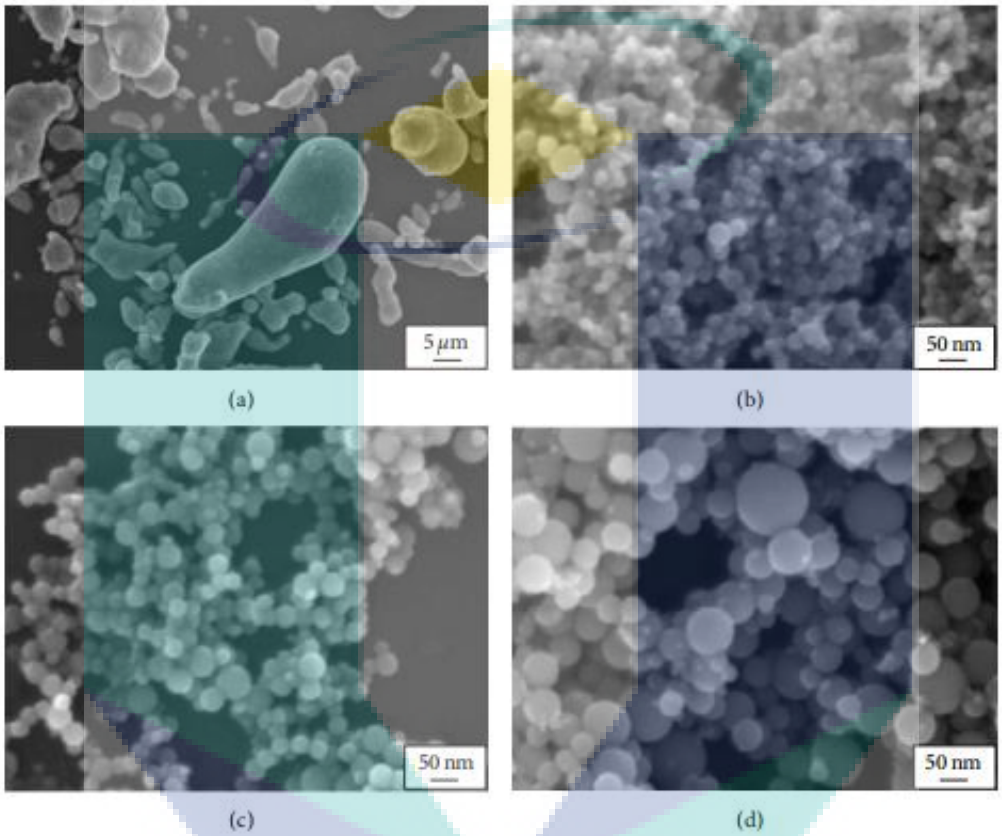

INVESTIGATION OF DISPERSION, STABILITY, AND TRIBOLOGICAL PERFORMANCE OF OIL-BASED GRAPHENE AND COPPER NANOFLUIDS

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ABSTRACT (120 words)

In the current decade, the development of recyclable, renewable, and sustainable products to replace fossil products is an essential and important matter for industrial and environmental purposes. In the present study copper (II) oxide nanoparticles were dispersed in SAE10W-30 to reduce wear and friction on piston skirt. Moisture content and viscosity values were analysed to study the physical properties of the dispersed lubricant. The wear and friction performance was evaluated using a piston skirt-liner contact tester, and the material used was aluminium 6061, which is the standard material for piston skirt. The design of experiment (DOE) was constructed using the response surface methodology (RSM) technique. The influence of different operating parameters such as rotational speed (200 rpm, 250 rpm, 300 rpm), volume concentration (0.005% and 0.01% of dispersed nanomaterial), and load (2 N, 5.5 N, and 9 N) were determined and optimal lubricant concentration was obtained. FESEM was used to identify the type of wear occurring during the experimental process. The results showed that CuO nano-particles dispersed in the base oil exhibited good friction-reduction and anti-wear properties. The coefficient of friction obtained was 0.06125 and the wear rate was 0.2482 mm3/Nm when a concentration of 0.005% was used. SEM results showed that the constituent element of the nano-particles precipitated at the contact area. A protection layer was observed during the EDAX analysis. The optimal parameters obtained were 0.008% concentration; 291 rpm speed and 75.152 N load.

1. INTRODUCTION

Worldwide concerned on an environmental issue keep increasing from time to time especially on the transportation and energy sectors. Demand for the higher productivity and lower emission for both sectors have been an issue for many governments. There has been growing concern about the use of mineral oils as lubricants because of productivity and environmental issues. The development of new lubricants can benefit many people because it may lower the cost of energy (cost saving), reduce waste and give positive environmental impact. According to Abdullah et al., and other researchers in recent years, many automotive studies have to use the nano-particles as an oil additive to improve the anti-wear property and also friction. In addition, there are other nano-particles that contribute to reducing tribological behaviour such as metal, metal oxide, metal sulphides, carbonate, borate organic material and more. Nano-particles that are effective as nano-lubricants not only depend on the type of nano-particle used, but also on the characteristics.Therefore, according to researchers, the size range, shape and concentration of Cu nano-particles influence its friction reduction and anti-wear behaviour mostly in the range of 2–120 nm.

2. RESEARCH METHODOLOGY

The main properties of the nano-particles, lubricant and specimen used in the experiment are listed in Table 1. The concentrations of nano-particle were selected to be between 0.005% to 0.03%, that was stated as the optimum concentration for nano-particles in previous studies. In the present research, CuO nano-particles(0.005% and 0.01%) on weight basis were selected as the tribological behaviour modifier. CuO nano-particles were weighed using a precision electronic weighing balance Syntium oil and sonicated for 1 h 30 min using a sonicator water bath. It functions mostly like a piston-ring contact in the engine. The tribological test was carried out under the lubricant ofSyntium800SL10W-30 base oil, base oil containing 0.005% and 0.01% (additive concentration) CuO nano-particles. Low engine speed interval (200,250 and 300) rpm was selected during the test because at that point, it generates the greatest friction in engine, especially during the first movement and at TDC. Normal load (20, 55, and 90) N were applied to the tester by hanging the weight on the bar where the piston ring sample was attached as shown in Figure 1. The distance travelled by the piston ring during the tribology test was set to 20 mm. The experiment was carried out under different loads from (2.2–5.5) N, speeds (250–300) rpm and concentrations of the lubricant (0–0.01). The loads were chosen based on highest point for friction that can occur in the engine. This especially occurs during engine start up at low engine revolutions.

Table 1 : Properties of material

Material	Properties					
Nanoparticle: Copper (II) oxide [49]	Morphology: Nearly Spherical	Size: 40 nm	Purity: 99%	Melting point: 1326	Density (g/mol): 79.55	Hardness (Mohs): 3.5
Base oil Syntium 800SL 10W-30 [50]	Physical Properties Density at 15 °C 0.864 kg/l Kinematic viscosity at (40 °C) 74.1cSt Kinematic viscosity at (100 °C) 11.2 cSt Viscosity index 141 Flash Point 228 °C Pour Point −33 °C CCS viscosity at (−35 °C) 4900cP Sulfated ash 0.82 wt% Neutralization No.(TBN-E) 6 Colour 3					

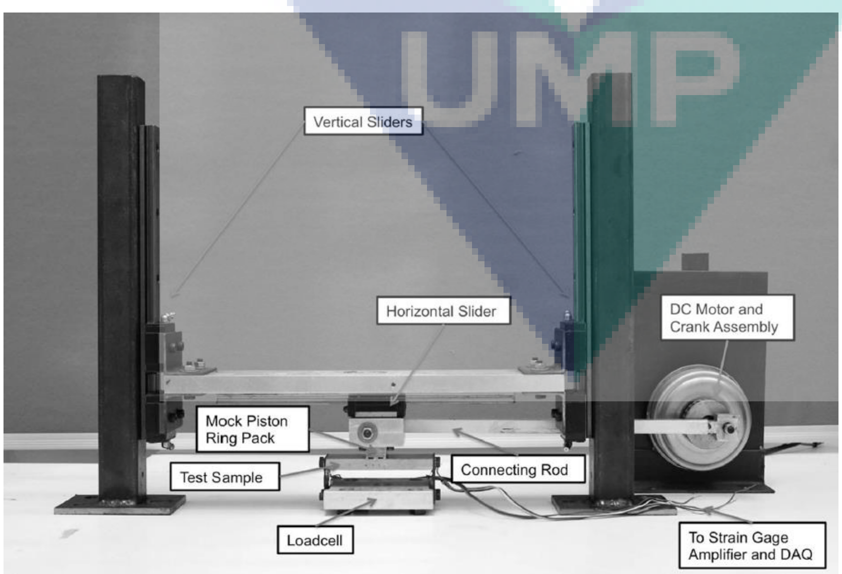


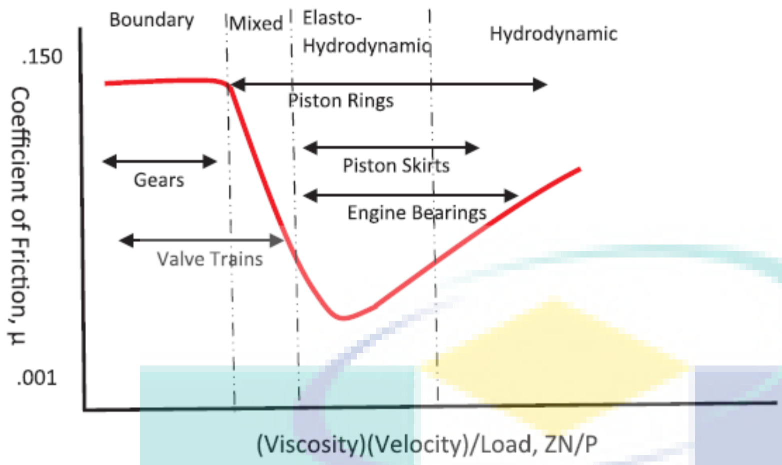
Figure 1: Tribology tester

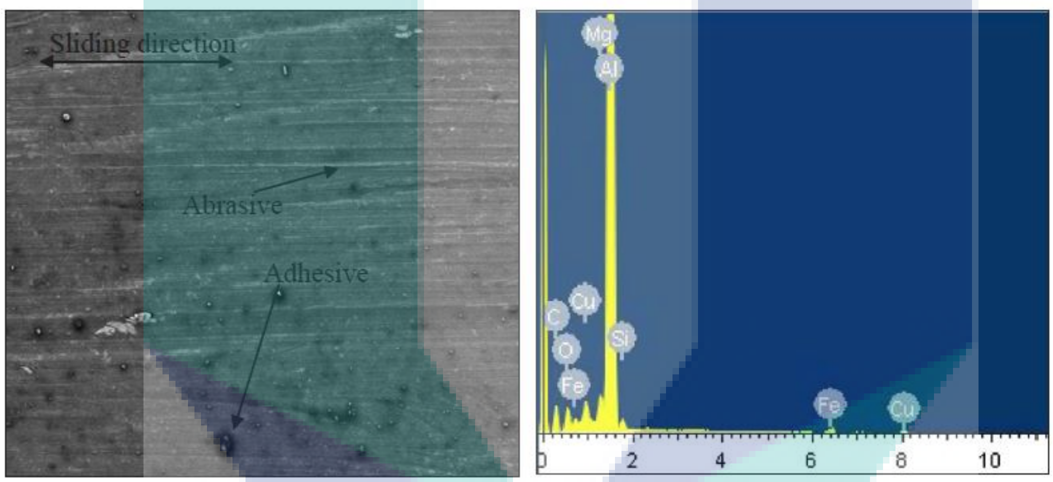
3. LITERATURE REVIEW

The nano-particle itself is good as it has self-repair function for the worn surface [33], in another word, it creates a protection layer, which is deposited at the contact area to improve tribological properties [26]. According to Zhang et al. [34], the interposed layer between two surfaces will improve the smoothness of the relative movement and prevent damage in a variety of materials in many forms such as gas, liquid and solid. The new variant of lubricant developed when the combination of any type of the nano-particle was mixed with the lubricating oil [35,36].The study from Padgurskas et al.[36] shows that the combination of different nano-particles will result different additive effect as the lubricant. Most researchers stated that the size, concentration, shape, hardness influence tribological behaviour and play important roles in a lubricating oil as an additive [16,25,28,35,37]. In addition, nano-lubricant also can fill in and repair the worn surface with good environmentally friendly characteristics, but not all combinations improve friction and wear characteristics. The tribological effect of different combinations of nano-particles is better than base oil for reducing friction coefficient. However, according to Padgurskas et al. [36], copper nano-particles are more effective in mixed lubrication than full film lubrication and are the most active in combination or alone. Generally, friction and wear of material are considered as important properties in engineering practice. Recently, researchers reported on a comparison of various nano-particles such as Al2O3 [38], CuO [28,33,39], Zr O2 [40], Fe, and Co [36], but copper is the most effective nano-particles in lubricating oil as it provides good friction reduction and anti-wear behaviour.

4. FINDINGS

The coefficient of friction presents an energy loss caused by friction. Therefore, it is found that syntium oil with CuO nano-particles can reduce energy loss in mechanical lubricant. When used at highload, the friction coefficient decreased, which showed the load is the important parameter in the experiment, However, the speed of sliding and the concentration of the nano-particles also influence friction. According to Padgurskas et al., nano-particles are most efficient at boundary and lubricant regimes where two basic mechanisms should be considered for additive efficiency. Lubrication helps to decrease the friction and wear of mating surfaces. Lubrication between two surfaces have different regimes namely, boundary, mixed and hydrodynamic lubrications. Figs. 9–11 shows that, when the base oil was used, the lubricant regime was the mixed lubrication regime, whereas base oil containing copper (II) oxide nanoparticles resulted in full-film lubrication regime as shown in Fig. 13 in the Stribeck curve. CuO nano-particles were more effective in the mixed lubrication regime rather than in full-film lubrication regime. Besides that, CuO nano-particles had a positive effect when the coefficient of friction was lower and this phenomenon has been observed in full-film and mixed lubricant regimes. Filling the micro-asperities on the friction surface with nano-particles from the lubrication oil is the first mechanism. The first mechanism will increase the contact area of the friction surface, decrease the contact pressure and replace the rolling effect in the contact area. The second mechanism is related to the formation of ultrathin protection film of oil-copper when the temperature and real pressure contact is high enough to produce an electrochemical reaction and electrostatic adhesion of nano-particles





5. CONCLUSION

In the present study, copper (II) oxide nano-particle was dispersed in SAE10W-30 to reduce wear and friction on a piston skirt. It can be concluded that:

i. The coefficient of friction and wear rate were affected significantly by the linear load and quadratic load for both models. The optimized andpredictedvalues oftheparametersareallowing thelower response of COF and wear rate to occur. For improving the lubricant, theoptimalvalueswere75.152Nload, 291.3360rpmspeed and at 0.0086wt% concentration as calculated by statistical software using RSM method.

ii. ii. CuO nano particles that were used as an additive in Syntium oil helped to reduce friction and anti-wear in the lubricating oil effectively. The formation of Cu film separated the two friction surfaces and avoided direct contact. Moreover, the film layer was present when using higher load and middle value of concentration.

iii. It was shown that the parameters used had a limitation, especially the effect of CuO nano-particles influenced the lubricant. This is because the concentration of CuO nano-particles worked at lower and higher concentrations, however, it also depended on the surface roughness and the friction contact during the operation. This experiment showed the limitation of the additive used and gave the besttribologicalbehaviour.TherangeofthelimitationofCuOnanoparticles used was around 0.005wt% to 0.0086wt%. On the other hand, FESEM images showed that higher concentration (0.001wt%) also gave better wear, however, nan-oparticles had deleterious effects in some cases, causing increased either wear rate or COF.

ACHIEVEMENT

i) Name of articles/ manuscripts/ books published

- Copper (II) oxide nanoparticles as additve in engine oil to increase the durability of piston-liner contact, Fuel, 212,656 - 667.Q1
- Waste cooking oil blended with the engine oil for reduction of friction and wear on piston skirt, Fuel, 205, 247-261.Q1

ii) Human Capital Development

- Sakinah Hisham – Graduation in 2017

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