Harnessing the Synergistic Potential of SiO_2 and Cu Nanoparticles as Lubricant Additives for Enhanced Tribological Efficiency

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ABSTRACT
Zinc dialkyldithiophosphate (ZDDP) is widely utilized in the lubricant industry due to its exceptional anti-wear and antioxidant properties. However, its detrimental impact on exhaust emissions containing phosphorus (P) and sulphur (S) calls for alternative solutions. This study delves into the exploration of diverse nanoparticles as additives in oils to mitigate reliance on ZDDP. Nanoparticles offer promising advantages to lubricants, such as reduced friction, enhanced wear resistance, and improved thermal stability. As industries strive to optimize machinery performance and prolong equipment lifespan, the incorporation of nanoparticles as additives in base oils emerges as a critical pursuit [1]. This research endeavours to assess the effectiveness of nanoparticles in diminishing or obviating the necessity for ZDDP while simultaneously upholding or enhancing lubricant performance.
Initially, we investigated a hybrid additive formulation comprising reduced ZDDP concentrations and green silica (SiO_2) nanoparticles. Macro-scale reciprocating sliding wear tests were conducted to evaluate the tribological performance of the oil formulations. Our findings reveal that this hybrid formulation, in conjunction with oleic acid, showcases superior performance compared to individual additives, both at ambient and elevated temperatures. Specifically, the combination of 0.75 wt.% ZDDP, 0.5 wt.% SiO_2 nanoparticles, and 0.5 wt.% oleic acid markedly reduced friction and wear by ~80% and ~96%, respectively, at elevated temperatures, and by ~60% and ~70% at ambient temperature compared to the neat base oil. Insights into the wear mechanisms further elucidated the enhanced tribological properties conferred by the hybrid additives.
The incorporation of metallic and ceramic nanoparticles as hybrid additives into base oils presents a promising avenue for augmenting the performance and durability of lubricants [1]. Hence, we examined a combination of SiO_2 and copper (Cu) nanoparticles to eliminate ZDDP from the formulation. The optimization of nanoparticle concentrations was systematically explored to ascertain the most efficacious combination for enhancing lubricant performance. Furthermore, the study extended beyond performance evaluations to investigate the mechanisms of wear on surfaces lubricated with the hybrid nanoparticle additives. Advanced analytical techniques, including scanning electron microscopy (SEM) and time of flight-secondary ion mass spectroscopy (TOF-SIMS), were employed to analyze worn surfaces. By correlating wear characteristics with nanoparticle concentrations insights into the lubricating mechanisms and the role of hybrid additives in mitigating wear were garnered. Overall, this research yields invaluable insights into the synergistic effects of combining various nanoparticles as hybrid additives in base oils and highlights the feasibility of utilizing nanoparticle-based additives to alleviate the environmental impact associated with conventional lubricant formulations containing ZDDP, while simultaneously enhancing performance and sustainability across diverse operating conditions.

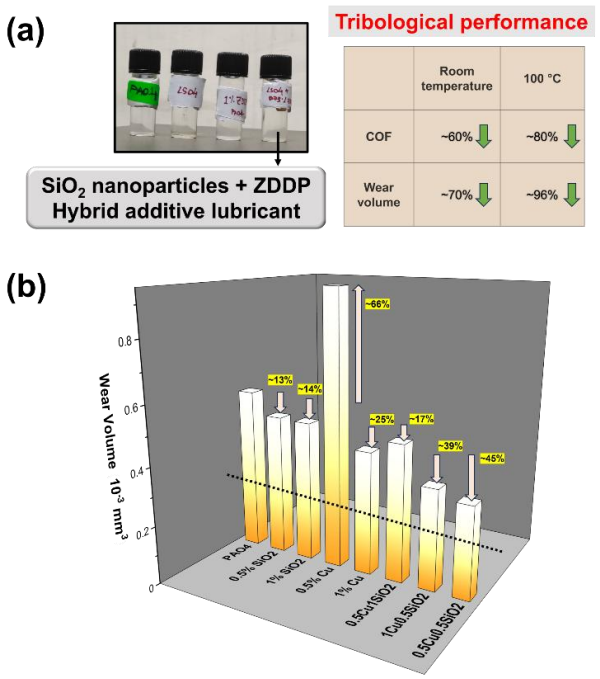

Figure : (a) Tribological performance of silica-ZDDP hybrid additive oil, (b) Wear resistance comparison of the neat base oil with the Cu-SiO_2 hybrid formulations.

REFERENCES
[1] Shahnazar Sheida, et al. "Enhancing lubricant properties by nanoparticle additives." *International Journal of Hydrogen Energy* 41. 4 (2016): 3153-3170.