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# Experimental Study on the Effect of Speed and Time Parameters on the Synthesis of Nanoparticles Produced from Sugarcane Bagasse (Nano-Biochar) Using Mechanical Milling and Their Impact on the Physical and Thermal Properties of Nano-Lubricants

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## Extended Abstract

### Introduction

The increasing cost of fuel and the depletion of fossil energy resources have highlighted the importance of identifying effective approaches to reduce fuel consumption in vehicles. Factors influencing fuel consumption can generally be classified into two main categories: engine design and manufacturing, and optimization of engine operating conditions. Although design-related modifications can significantly reduce fuel consumption, they are often costly and impractical for existing vehicles. In contrast, optimizing engine operating conditions through parameters such as fuel quality, engine oil, and filtration systems represents a more feasible and cost-effective approach. Engine oil plays a critical role in reducing frictional losses and improving engine performance, thereby contributing to lower fuel consumption. The use of low-viscosity oils with a high viscosity index is particularly effective during cold starts, as improved oil flow reduces energy losses. At the same time, maintaining sufficient viscosity at elevated temperatures is essential to ensure the formation of an effective lubricating film. In addition, surface-enhancing additives can reduce microscopic surface asperities, decrease friction between contacting surfaces, and improve lubrication efficiency, ultimately leading to reduced fuel consumption. In recent years, the incorporation of nanoparticles as lubricant additives has attracted considerable attention due to their ability to enhance tribological properties, improve heat transfer, increase engine efficiency, and reduce maintenance costs. Nanoparticles can penetrate the contact interface between frictional surfaces, fill surface irregularities, and significantly reduce friction and wear. Furthermore, the use of bio-based nanoparticles offers additional environmental benefits by reducing pollutant emissions and promoting the utilization of agricultural waste materials.

Considering the abundance of sugarcane waste in Khuzestan Province, the production of biochar nanoparticles from sugarcane bagasse as a bio-based additive for engine oil presents a promising approach to improving the physical and tribological properties of lubricants. This strategy not only contributes to friction reduction and enhanced lubricant performance but also supports environmental sustainability, waste valorization, and local economic development. Despite extensive research on various nanoparticle additives, studies focusing on the application of biochar nanoparticles in engine oils remain limited, highlighting the need for further systematic investigation.

### Materials and Methods

In this study, biochar nanoparticles were produced from sugarcane bagasse char using a planetary mechanical milling process. The initial char, obtained through pyrolysis under controlled temperature and time conditions, was first dried to eliminate residual moisture. Mechanical milling was carried out using stainless steel balls with a predefined mass ratio, and samples were collected at different milling durations. The particle size and morphology were examined using scanning electron microscopy to confirm the formation of nanoparticles. The base oil was selected based on economic considerations and practical applicability. The lubricant performance was evaluated for a commonly used urban motorcycle, and a widely used single-grade mineral oil was chosen as the base lubricant. Due to its extensive application, this oil requires improvement in lubrication performance and service life. To prepare the nanolubricant, biochar nanoparticles were dispersed in the base oil using a biodegradable nonionic surfactant and an ultrasonic dispersion technique. The ultrasonication duration was optimized to achieve stable and uniform dispersion. Biochar nanoparticles were added to the base oil at different weight concentrations, and the static stability of the prepared nanolubricants was evaluated visually over an extended period. The observations confirmed excellent stability, with no sedimentation or phase separation detected. The physical properties of the nanolubricants, including density, kinematic viscosity, pour point, and flash point, were systematically measured. Kinematic viscosity was determined at different temperatures for various nanoparticle concentrations. In addition, the operational temperature range of the lubricants was assessed through pour point and flash point measurements. Finally, the thermal conductivity of the nanolubricants was measured using a transient line heat source method to evaluate the effect of biochar nanoparticle addition on heat transfer performance.

## Results and Discussion

This study aimed to synthesize biochar nanoparticles from sugarcane bagasse and evaluate their effects at concentrations of 0.5, 1, and 2 wt.% on the physical, tribological, and thermal properties of a base lubricating oil. All experiments were conducted following standard procedures, and the performance of the nanolubricants was compared with that of the base oil to assess the effectiveness of biochar nanoparticles as lubricant additives.

### 3.1 Biochar Nanoparticle Synthesis

Elemental analysis confirmed the presence of carbon, oxygen, silicon, and calcium in the synthesized nanoparticles, with carbon and silicon as the dominant elements. The detected oxygen is mainly attributed to surface oxidation caused by the increased specific surface area of the particles during mechanical milling and subsequent exposure to air. Microstructural observations indicated that extending the milling time reduced particle size and agglomeration. Prolonged milling induced severe plastic deformation and enhanced particle refinement, leading to improved homogeneity. Phase analysis confirmed the formation of silicon dioxide and calcium carbonate with crystalline structures consistent with reference patterns. Nanoparticles produced after longer milling exhibited smaller size and lower agglomeration and were therefore selected for lubricant preparation.

### 3.2 Physical Properties of Nanolubricants

The results showed that increasing biochar nanoparticle concentration led to a moderate increase in density and kinematic viscosity at both 40 and 100 °C compared to the base oil. These changes remained relatively small at lower concentrations and became more noticeable with higher nanoparticle loading. Variations in viscosity are influenced by particle type, concentration, dispersion quality, and interaction with the base fluid. The addition of biochar nanoparticles resulted in a reduction in flash point, while the pour point increased with nanoparticle concentration. These changes indicate that nanoparticles alter the thermal and low-temperature flow behavior of the lubricant by modifying intermolecular interactions and transport properties within the fluid.

### 3.3 Thermal Conductivity Enhancement

Thermal conductivity measurements demonstrated a clear enhancement with increasing nanoparticle concentration. This improvement is attributed to the high specific surface area of the nanoparticles and the formation of effective heat transfer pathways within the lubricant. Enhanced thermal conductivity improves heat dissipation and contributes to better thermal stability during operation. Overall, all nanolubricants exhibited superior thermal conductivity compared to the base oil, confirming the positive role of biochar nanoparticles in improving lubricant performance.

## Conclusion

- Increasing the mechanical milling time effectively reduced nanoparticle agglomeration and produced finer biochar nanoparticles due to severe plastic deformation and enhanced mass transfer during milling.
- Incorporation of biochar nanoparticles into the base oil resulted in an increase in lubricant density, while viscosity exhibited only a slight rise, particularly at low nanoparticle concentrations.
- The addition of nanoparticles led to a reduction in flash point and an increase in pour point, indicating modified thermal and low-temperature flow characteristics of the lubricant.
- Viscosity variations were governed by nanoparticle concentration, base oil properties, dispersion quality, and the dispersion technique; however, these changes remained negligible at lower loadings.

- Biochar nanoparticles improved low-temperature lubricant performance by preventing paraffin crystallization and oil solidification through stable particle suspension.
- Thermal conductivity of the lubricant increased significantly with rising nanoparticle concentration, attributed to the high specific surface area and reduced interparticle spacing.
- Formation of nanoparticle clusters enhanced heat transfer capability, demonstrating the potential of biochar-based nanolubricants for advanced thermal management and lubrication applications.

**Keywords:**Bio-nanoparticles, Physical properties, Thermal properties, Lubricant.

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