

# Investigation of Wear and Friction Properties of AL–SI Alloy Piston with and Without Lubrication

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## Abstract

Aluminium–Silicon (Al–Si) alloys are extensively used in automotive piston applications due to their excellent castability, low density, and favorable tribological properties. However, friction and wear remain critical factors influencing engine efficiency and component life. In the present study, the frictional sliding behavior of a cast Al–Si piston alloy was experimentally investigated under dry and lubricated conditions using DOT 4 hydraulic brake fluid as a lubricant. Wear rate and coefficient of friction were analyzed under varying operating conditions. The results demonstrate that lubrication significantly reduces friction and wear, thereby enhancing the tribological performance of the Al–Si alloy. The findings provide useful insights for selecting lubricants and improving piston durability in internal combustion engines.

**Keywords:** Al–Si alloy, piston material, wear, coefficient of friction, DOT 4 brake fluid, lubrication

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## I. Introduction

The automotive and transportation industries have played a crucial role in societal development; however, they have also contributed significantly to environmental challenges such as global warming. This has imposed increasing pressure on engine designers to improve overall efficiency through mass reduction of key components while operating at higher service temperatures. Among engine components, the piston is subjected to severe mechanical and thermal loading conditions, making material selection and tribological performance critically important.

Al–Si piston alloys offer an excellent balance of low density, high thermal conductivity, and good wear resistance. Nevertheless, friction between the piston and cylinder liner leads to power losses, noise, and reduced service life. Lubrication plays a key role in mitigating these effects. This study focuses on evaluating the wear and friction characteristics of cast Al–Si alloy pistons under dry and lubricated conditions, with special emphasis on DOT 4 hydraulic brake fluid as a lubricant.

## II. Requirements for Piston Alloys

Piston materials must satisfy stringent functional requirements:

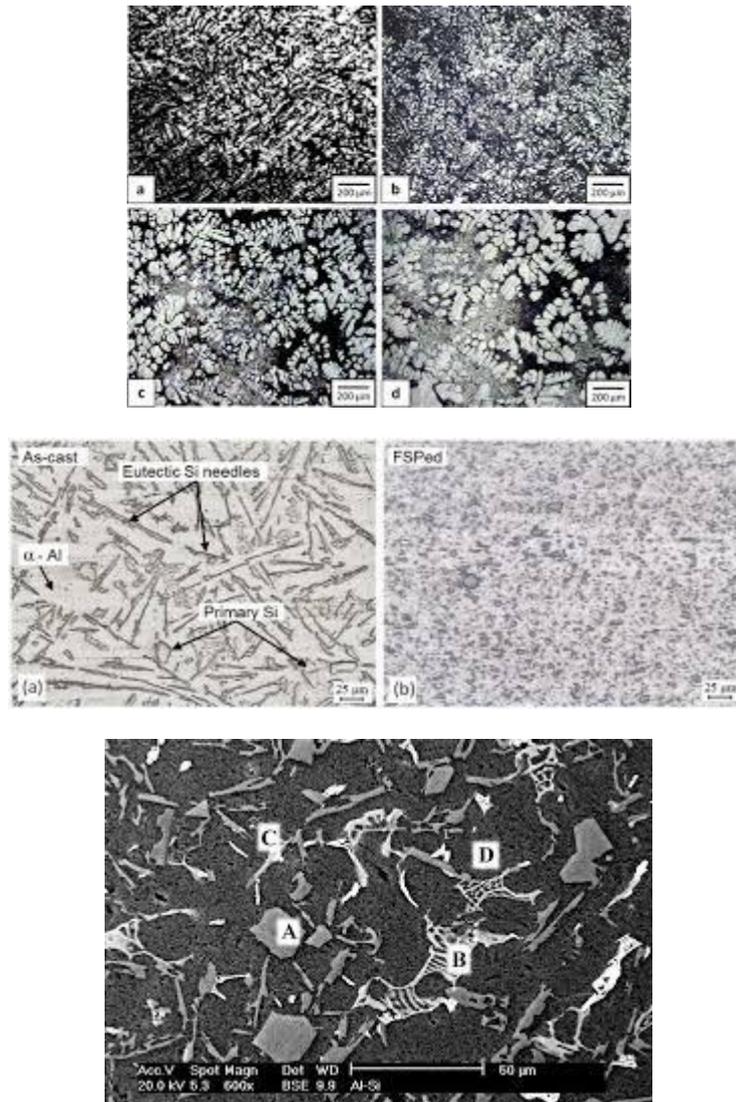
- High strength-to-weight ratio
- High thermal conductivity
- Thermal stability at elevated temperatures
- Resistance to wear and corrosion
- Low coefficient of thermal expansion

Al–Si alloys fulfill these requirements effectively, making them the most widely used materials for automotive pistons.

## III. Aluminium–Silicon (Al–Si) Alloys for Pistons

Al–Si alloys are classified into hypoeutectic, eutectic, and hypereutectic compositions based on silicon content. Near-eutectic Al–Si alloys ( $\approx 12$  wt.% Si) are commonly referred to as *piston alloys* due to their superior wear resistance, low thermal expansion, and good high-temperature strength.

Wear in piston alloys arises mainly from adhesive and abrasive mechanisms, influenced by microstructure, operating load, sliding speed, and lubrication conditions.



**Figure 1.** Typical microstructure and worn surface features of Al–Si piston alloys.

#### **IV. Lubrication System for Engine Pistons**

##### **4.1 Wet Sump Lubrication System**

The wet sump lubrication system is commonly used in piston engines. Oil is stored in a sump and circulated to moving components through an oil pump, reducing friction, dissipating heat, and preventing corrosion.

##### **4.2 Types of Lubricants**

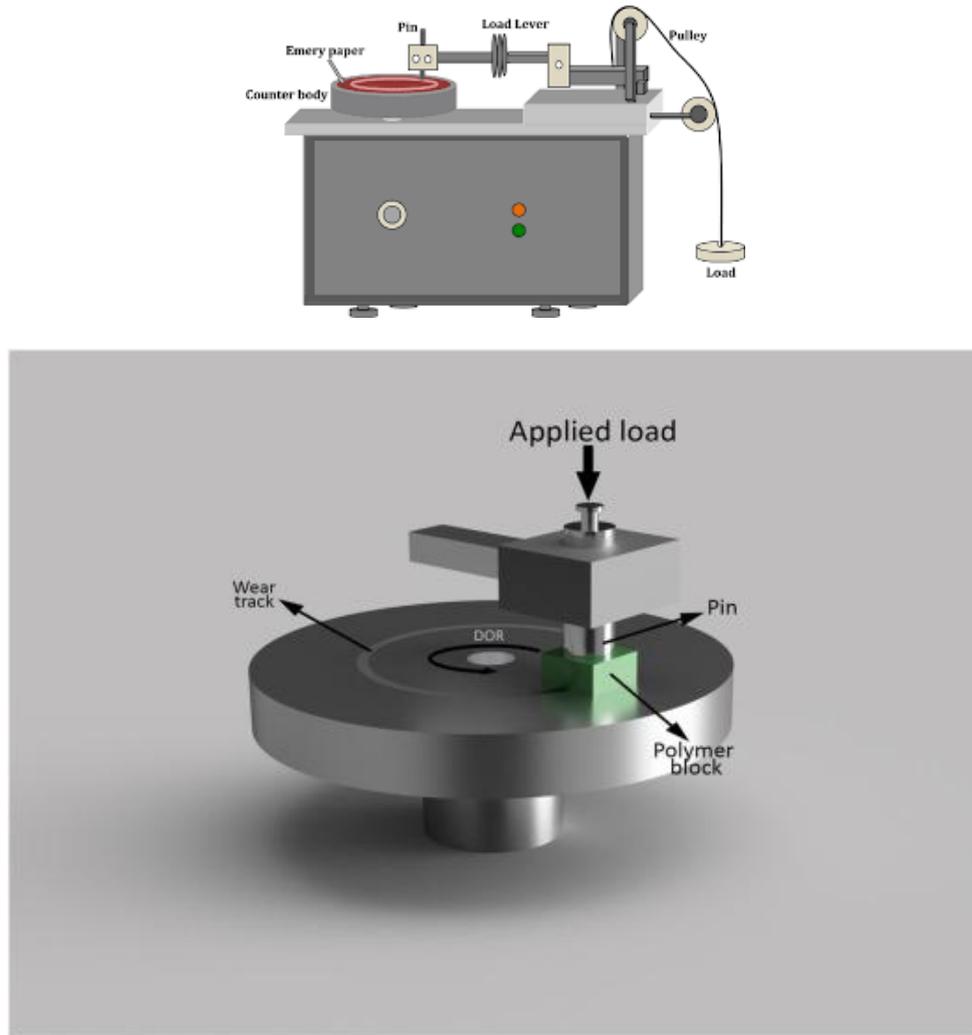
Lubricants used in engine applications include oils, greases, and dry lubricants. Oils are most suitable for piston–cylinder interfaces due to their low resistance to motion and effective heat dissipation.

#### **V. DOT 4 Brake Fluid as Lubricant**

DOT 4 brake fluid is a glycol-ether-based synthetic fluid characterized by:

- High boiling point
- Excellent thermal and chemical stability
- Good corrosion resistance
- Compatibility with sealing materials

In the present work, DOT 4 brake fluid was employed as a lubricant to study its influence on friction and wear behavior of Al–Si alloy under sliding conditions.



**Figure 2.** Schematic representation of pin-on-disc tribometer used for wear testing.

## **VI. Literature Review**

Previous studies indicate that aluminium alloy pistons significantly outperform cast iron pistons due to superior thermal conductivity and reduced mass. Al–12Si alloys, in particular, exhibit excellent abrasion resistance and dimensional stability. Researchers have shown that microstructural refinement, alloying additions, and lubrication conditions strongly influence tribological performance. However, limited studies are available on the use of hydraulic brake fluids as lubricants in piston alloy wear analysis, motivating the present investigation.

## **VII. Experimental Methodology**

### **7.1 Material**

Cast Al–Si alloy piston material (Al–12Si) was used for the study.

### **7.2 Wear Testing**

Wear tests were conducted using a pin-on-disc tribometer under:

- Dry condition
- Lubricated condition (DOT 4 brake fluid)

Parameters such as normal load, sliding speed, wear rate, and coefficient of friction were recorded.

## **VIII. Results and Discussion**

### **8.1 Coefficient of Friction**

Lubricated tests showed a significant reduction in coefficient of friction compared to dry sliding, attributed to the formation of a lubricating film that reduces metal-to-metal contact.

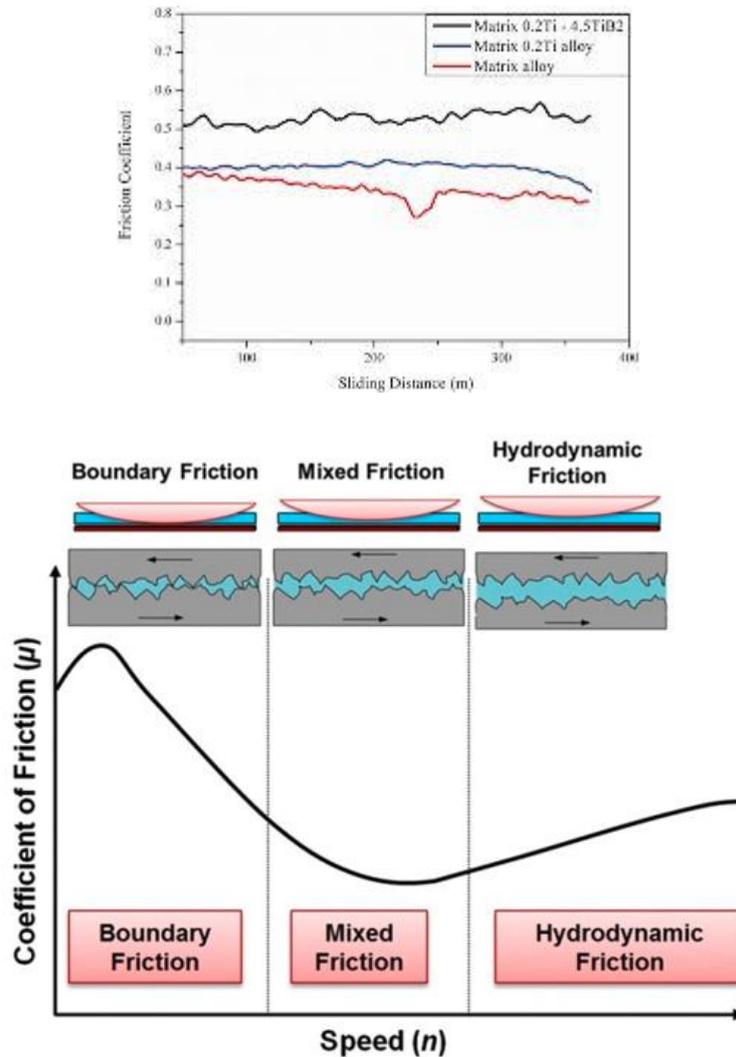


Figure 3. Variation of coefficient of friction under dry and lubricated conditions.

## 8.2 Wear Rate

The wear rate of Al–Si alloy was substantially lower under lubrication due to reduced adhesive wear and surface temperature.

## IX. Expected Outcomes

- Improved understanding of wear mechanisms in Al–Si piston alloys
- Quantification of friction and wear reduction due to DOT 4 lubrication
- Identification of lubrication benefits for piston durability
- Comparison of tribological behavior with conventional materials

## X. Conclusions

The experimental investigation confirms that lubrication using DOT 4 brake fluid significantly enhances the tribological performance of cast Al–Si piston alloys. Reduced coefficient of friction and wear rate under lubricated conditions indicate the potential of alternative lubricants for improving piston life and engine efficiency.

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