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Investigation of the Effects of 0W20 and 10W40 Lubricating Oils on Cylinder Liner Wear

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***Abstract* –** Proper lubrication regime in engines significantly impacts engine performance, fuel efficiency, durability, and environment. Lubrication regimes reduce friction between engine components, control wear, and ensure long-lasting parts. This study conducted experiments on a wear-testing device to determine the amount of wear between the piston ring and cylinder pair. The experimental work was performed at different loads and speeds. The tribological properties of 0W20 and 10W40 lubricating oils were examined in the study. As a result of the experimental work, when using 10W40 lubricating oil in the wear testing device, lower cylinder wear was observed compared to using 0W20 lubricating oil. The study found that the amount of wear increases as the load on the cylinder sample increases. The maximum cylinder wear was obtained under an 80N load. The minimum cylinder wear was determined under a 40N load. SEM images of the cylinder samples were also examined to determine the damage after wear.

Keywords – Cylinder Liner, Wear, Engine Oil, Wear Device

I. Introduction

Engines are indispensable power sources for the industrial and transportation sectors [1]. Proper lubrication and wear control are crucial for engines to operate efficiently and have a long lifespan [2]. Engine oils reduce friction between moving parts inside the engine and prevent wear [3]. Additionally, the lubricating oils used improve the lifespan of components and reduce repair time. Therefore, oils play an essential role in managing and minimizing the wear process of engine parts [4].

Cylinder wear is one of the most common types of wear in engines. The cylinder is the part that covers the inner surface of the cylinder and where the piston moves [5,6]. Engine oils are designed to reduce cylinder wear and keep this process under control through proper lubrication [7]. Oils create a thin film layer on the cylinder surface, reducing friction and preventing wear [8,9]. Different factors, such as the chemical composition of oils, viscosity index, and anti-wear additives, determine their effects on cylinder wear. Oils with high levels of anti-wear additives and an appropriate viscosity range can effectively control cylinder wear [9,10].

The oils used in engines are exposed to different temperatures. The viscosity of oils varies at different temperatures. Therefore, different lubrication regimes occur in engines based on operating conditions [11]. Hydrodynamic, Mixed, and Boundary Lubrication conditions occur in the moving parts of engines. The goal of lubrication systems is to ensure the occurrence of the hydrodynamic lubrication regime under all conditions and the formation of an oil film between the parts instead of metal-to-metal contact. This improves engine efficiency. Therefore, the correct selection of oils used in engines and determining the operating conditions are significant [11,12].

Johansson et al. conducted experimental investigations on friction and wear between the cylinder and piston ring. They used 10W40 oil as the lubricant in their experimental study. The results showed that the differences in friction were related to the conditions of oil film formation, while surface roughness was independent of material properties [13]. Truhan et al. used a wear testing device to examine wear between the cylinder and piston ring pair. They performed experiments using Jet A aviation fuel, mineral oil, and new, using 15W40 engine oils as lubricants. They investigated the friction and wear behavior of the piston ring material under different lubrication regimes, temperatures, and loads. Their experiments with different lubricants under the same conditions found that the friction coefficient was highest for Jet A fuel and lowest for used 15W40 oil. That wear was directly proportional to friction force [14]. Keller et al. researched to examine the effects of material chemical composition and microstructure on cylinder liner wear in heavy-duty diesel engines. They used a commercial synthetic oil with a viscosity of 5W30 specifically designed for diesel engines as the lubricant. After the application of a tribological film, a decrease in wear rates was observed [15].

In this study, the amount of cylinder wear was experimentally investigated under low engine speeds and different loads, which are the conditions where friction and wear occur most prominently in engines. The lubricants used were 10W40 semi-synthetic oil and 0W20 full synthetic oil. Additionally, SEM images were examined to determine the damage that occurred on the cylinder samples after wear.

II. MATERIALS AND METHOD

In the experimental study, a wear testing device was utilized to determine the amount of wear. The wear-testing device moves linearly (Figure 1). A DC motor provides the motion in the wear-testing device. A controller was used to control the DC motor in the wear-testing device to enable testing at different speeds.

A heating system and control unit were employed to control the operating temperature during the experiments and ensure consistent conditions for each test. This allowed for conducting experiments under the same conditions for each test and obtaining reliable results.

Fig. 1 Wear device

The wear experiments were conducted at operating speeds of 50, 75, and 100 rpm with loads of 40N, 60N, and 80N, respectively. Different piston ring-cylinder pairs were used in each experimental stage to examine the wear characteristics occurring between them. The working temperature of the lubricating oil was set at 30°C throughout the experiments.

To determine the amount of wear, the weight difference method was employed. A precision balance with a sensitivity of 0.0001 g was used to measure the wear. Before and after each experiment, the cylinder and piston ring pairs were cleaned with ethyl alcohol. The wear amount was calculated by taking the difference between the measured values.

For lubrication, 0W20 and 10W40 lubricants were used in the experiments. The lubricants were supplied to the system using a drip method at a rate of 0.5 ml per hour. The characteristics of the lubricants used in the experiments are provided in Table 1.

Table 1. Properties of lubricating oils

Properties	0W20 Oil	10W40 Oil
Kinematic Viscosity 40ºC mm^2/s	42.22	84.1
Viscosity Index	168	156
Intensity 15ºC kg/m^3	848.9	866
Pour Point	-42	-42

III. RESULTS

This study uses different lubricants to investigate the segment wear amount between the piston ring-cylinder pair. Figure 2 shows the variations in the cylinder wear amount at different sliding velocities under a 40N load. From the figure, it can be observed that the wear amount decreases with an increase in rotational speed for the 10W40 lubricant. The maximum wear amount occurs at 50 rpm, while the minimum is obtained at 100 rpm. Similar results were obtained for the 0W20 lubricant. The decrease in wear amount with increasing speed is attributed to the reduction in tangential force with increasing velocity. When comparing the wear amounts between the two lubricants, the best result is obtained with the 10W40 lubricant. A lower wear amount is observed with the 10W40 lubricant at all speeds. The lower wear amount with the 10W40 lubricant is attributed to its higher viscosity, which promotes the dominance of hydrodynamic lubrication between the piston ring-cylinder pair under load and prevents the transition to mixed or boundary lubrication regimes.

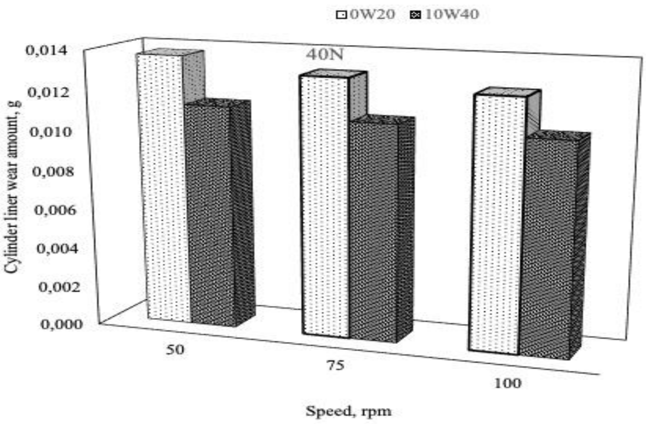


Fig. 2 Change of liner wear amount of 0W20 and 10W40 lubricating oils under 40N load

When comparing the wear amounts, it is observed that the maximum friction coefficient is obtained at 50 rpm, with values of 0.0113 g and 0.0137 g for the 0W20 and 10W40 lubricants, respectively. The minimum wear amount is determined at 100 rpm, with values of 0.0106 g and 0.0112 g for the 0W20 and 10W40 lubricants, respectively.

Figure 3 illustrates the cylinder wear amount under a 60N load. According to Figure 3, it is observed that the wear amount is higher with the use of the 0W20 lubricant compared to the 10W40 lubricant. The experimental results show that the maximum wear amount with the 0W20 lubricant is 0.0159 g at 50 rpm. Under the same conditions, this value is 0.0148 g for the 10W40 lubricant. When investigating the conditions with the lowest wear amount, it is found to be 0.0153 g at 100 rpm for the 10W40 lubricant. Under the same conditions, this value is 0.0103 g for the 0W20 lubricant.

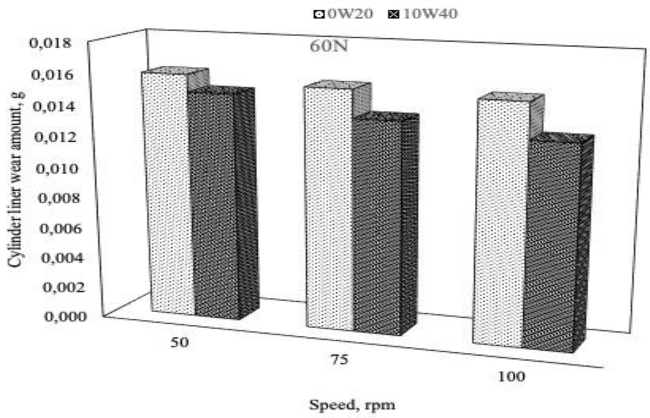


Fig. 3 Change of liner wear amount of 0W20 and 10W40 lubricating oils under 60N load

The variation of cylinder wear amounts under an 80N load in the experimental setup is shown in Figure 4. The values in the figure indicate that the wear amount with the 0W20 lubricant is higher than that with the 10W40 lubricant at all speeds. According to the results obtained from the experiment, the maximum wear amount occurs at 50 rpm when using the 0W20 lubricant, with a value of 0.0211 g. In contrast, the wear amount obtained with the 10W40 lubricant under the same conditions is 0.0153 g. The minimum wear amount is observed at 100 rpm with the 10W40 lubricant, measuring 0.0138 g, while under the same conditions, using the 0W20 lubricant results in a wear amount of 0.0203 g.

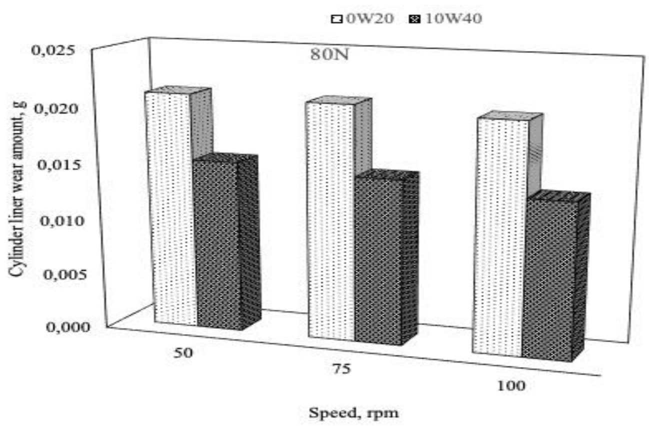
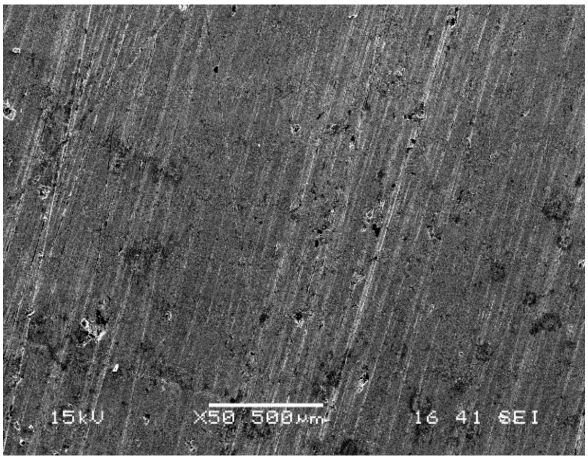
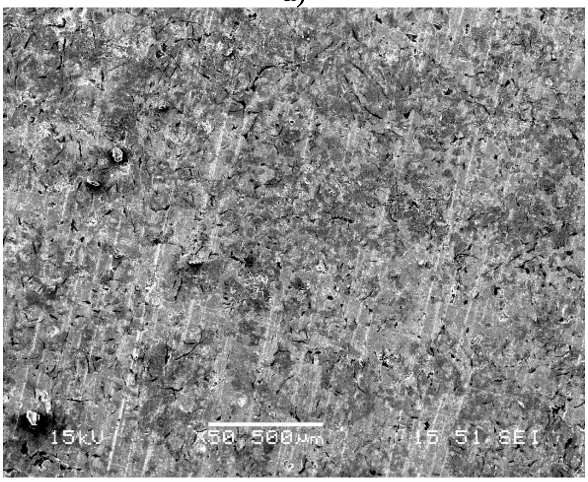


Fig. 4 Change of liner wear amount of 0W20 and 10W40 lubricating oils under 80N load

Figure 5 displays the SEM images illustrating the wear amount on the cylinder sample. Both pre-wear and post-wear SEM images of the cylinder sample are presented. The SEM images were captured for the 0W20 lubricant at 50 rpm and 80N load. Upon examining the wear pattern, it can be observed that the honing marks are nearly disappearing. The wear amount is clearly visible according to the provided data in the graph.



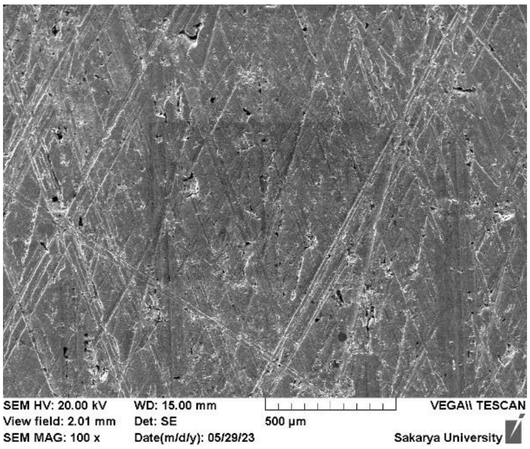
a)



b)

Fig. 5 a) 0W20 cylinder liner before wear b) 0W20 post wear cylinder liner

Figure 6 illustrates the wear marks observed using 10W40 lubricating oil at 80N and 50 rpm. Upon examining the figure, it can be seen that the honing marks are still visible. We can interpret that it undergoes less wear compared to the 0W20 lubricant.



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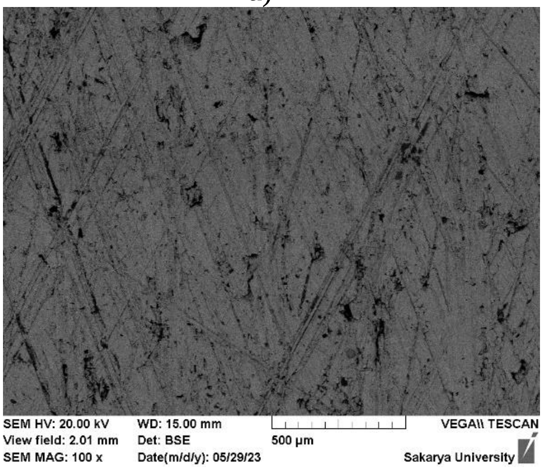

b)

Fig. 6 a) 10W40 cylinder liner before wear b) 10W40 post wear cylinder liner

IV. CONCLUSION

This study investigated the variations in cylinder liner wear between piston rings and cylinder surfaces using different lubricants. The following results were obtained from the experimental study:

- The wear amount varies depending on the speed, with wear decreasing as the rotational speed increases.
- Minimum wear values were observed at 100 rpm, while maximum wear values were recorded at 50 rpm.
- The minimum cylinder liner wear was observed with the use of 10W40 lubricating oil.

Cylinder liner wear is a significant factor that affects engine performance. Rough surfaces and geometric changes resulting from wear hinder gas flow within the cylinder, reduce compression, and decrease combustion efficiency. This leads to decreased engine power, increased fuel consumption, and performance degradation. It is crucial to employ a proper lubrication regime and use oils with suitable viscosity to reduce cylinder liner wear to mitigate these adverse effects. Using appropriate lubricants in engines plays a vital role in controlling cylinder liner wear, enhancing engine performance, and ensuring long-lasting operation.

From an environmental perspective, a proper lubrication regime in engines has positive outcomes, including reduced friction, improved energy efficiency, lower fuel consumption, decreased emissions, minimized oil consumption and waste generation, and reduced environmental impact associated with lubricant production.

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