COMPARATIVE ANALYSIS OF TEMPERATURE VARIATIONS IN ENGINE OIL OF A 5 HP MOTOYAMA GASOLINE ENGINE UNDER LOAD VARIATIONS USING A DRUM BRAKE

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Abstract.*This study experimentally analyzes the performance of engine oil based on the rotational speed (RPM) and temperature response on a Motoyama 5 HP gasoline engine with drum brake loading. Three types of oil, namely Shell Advance, Mesran Super, and Federal Ultratec, were tested at three speed levels (Speed 1–Speed 3) and load variations of 0–800 grams. The test results showed that increasing the load caused a decrease in RPM and an increase in temperature in all oils. Shell Advance consistently produced the highest RPM, namely 2364.5–1881.3 RPM at Speed 1 and 2913.4–2612.9 RPM at Speed 3, compared to Mesran Super and Federal Ultratec. From the thermal side, Shell Advance showed a lower temperature increase (ΔT), namely 10.9 °C at Speed 1 and 37.2 °C at Speed 3, while Mesran Super and Federal Ultratec reached ΔT up to 38.6 °C and 39.7 °C. These results show that Shell Advance has the best lubrication stability and thermal resistance, followed by Federal Ultratec and Mesran Super.*

Keywords: *Drum Brake; Engine Oil Temperature; Gasoline Engine; Load Variation; Thermal Analysis.*

1. INTRODUCTION

Gasoline engines are widely used in various sectors, such as agricultural equipment, workshops, household needs, and simple production systems, due to their compact size, ease of operation, and relatively low maintenance costs (Barman & Deshmukh, 2022). However, engine performance and lifespan are significantly influenced by lubrication conditions, as lubricating oil plays a role in reducing friction and wear while also acting as a heat transfer medium. Therefore, the operating temperature of the oil can be used as an indicator of the thermal load received by the lubrication system and the stability of engine operation (Aguilar et al., 2017).

Under real-world conditions, engines rarely operate at a constant load. Increasing load variations increase engine torque and workload requirements, resulting in higher combustion heat and mechanical losses, ultimately increasing the operating temperature of the oil. Increasing oil temperature is critical because it can accelerate oil degradation, alter flow characteristics, and increase the risk of deposit formation on engine components (Srivyas & Charoo, 2020). Although a wide variety of oils are available on the market, differences in formulation and physical properties can lead to different thermal responses under the same load conditions. However, in practice, oil selection is often based on brand preference or general assumptions rather than empirical data regarding thermal performance, particularly in small-scale gasoline engines with measured load variations (Martins et al., 2019).

To address these issues, this study compares engine speed and oil temperature behavior in gasoline engines using drum brakes as a gradual and measured loading device. The data obtained were analyzed based on operating temperature (final temperature), temperature rise (ΔT), peak temperature at maximum load, and temperature sensitivity to load as quantitative comparison parameters. Thus, the comparison of thermal performance between oils is not based solely on qualitative statements but is supported by measurable trends and magnitudes of change (Pakpahan et al., 2021).

The results of this study are expected to provide an empirical picture of the response to oil temperature increases in various types of oil, measure the extent to which load variations affect the oil's working temperature during testing, and present a comparison of temperatures between oils at certain load conditions as a basis for interpreting thermal performance at various operating levels.

2. LITERATURE REVIEW

2.1 Function of Lubricating Oil and the Relationship between Temperature and Lubrication Performance

Lubricating oil in gasoline engines has the main function of reducing friction and wear by forming a lubricating film between the surfaces of moving components.(Budi et al., 2022). In addition to its tribological function, oil also acts as a heat carrier, helping transfer heat from hot areas (e.g., cylinder walls, pistons, and bearings) to areas where it can more easily dissipate. Oil temperature is an important operational parameter because it affects the oil's physical properties, particularly viscosity. As temperature increases, viscosity tends to decrease, potentially reducing the thickness of the lubricant film. If the temperature is too high, lubrication stability can decrease and the risk of metal-to-metal contact increases. Therefore, the oil temperature profile during operation can be used as an indicator of the thermal condition of the lubrication system and the potential for decreased lubrication performance under certain workloads.(Reza, 2022).

2.2 Effect of Loading on Heat Generation and Oil Temperature in Gasoline Engines

Loading a gasoline engine increases the engine's torque requirements and workload. Thermodynamically, increased load generally increases the rate of chemical energy (fuel) input and increases mechanical losses, resulting in greater heat accumulation that must be managed by the cooling and lubrication systems.(Muchlisinalahuddin., 2018). Under high load conditions, the heat generated from combustion and friction increases, while the heat dissipation capacity does not always increase proportionally; as a result, component temperatures and oil temperatures tend to rise. A common phenomenon is that engine speed may decrease as the load increases (if the power supply setting does not maintain a constant RPM), but the oil temperature remains elevated due to increased effective workload and increased energy losses converted into heat.(Situmorang et al., 2023). Therefore, load variation is a determining factor in the change of oil working temperature and can be used to evaluate the thermal resistance of oil under different operating conditions.

2.3 Variations in Oil Types and Differences in Thermal Response Under the Same Operating Conditions

Different oil types can exhibit different temperature responses in the same engine because their formulation characteristics and physical properties are not identical. Under equivalent operating conditions, differences in the ability to reduce internal friction, maintain viscosity stability over temperature, and heat-carrying capacity can be reflected in measured oil temperature differences. In comparative studies, interpretation of oil thermal performance is generally more robust when based on multiple indicators, such as final/working temperature, temperature rise (ΔT), peak temperature, and temperature sensitivity to load. However, to conclude statistically significant differences, the experimental design typically requires repeating the test at each condition to estimate the variation in the data. Without replication, the most methodologically sound conclusions are descriptive differences based on effect sizes (temperature differences and trends between conditions).(Syarifudin et al., 2020).

3. RESEARCH METHODS

This study uses a quantitative experimental approach with a comparative design, aimed at comparing the oil temperature response in gasoline combustion engines to variations in loading using drum brakes. Testing was conducted on a 5 hp Motoyama gasoline engine with three oil variants, namely Shell Advance, Mesran Super, and Federal Ultratec. The variation of test conditions consisted of three levels of rotational operation (Speed 1 - Speed 3) and five loading levels (0; 200; 400; 600; 800). In each combination of conditions, the parameters recorded included engine speed (RPM), initial oil temperature (Tawal), and final oil temperature (Takhir), with a test duration of 2 minutes per test point.

The object of the study was a 5 hp Motoyama gasoline engine mounted on a static testing system. Loading was applied using a drum brake as a shaft resistance device so that the load could be increased gradually. The measurement instruments used included a rotational speed meter (tachometer/RPM meter) and an oil temperature meter (temperature sensor/thermometer). The test oils used were three oil variants commonly used in gasoline engines, with filling volumes following the engine specifications to ensure lubrication conditions remained within normal operating limits. The stages that will be passed in this research are shown in **Figure 1**.

Figure 1. Flow chart

The research procedure begins with the preparation of tools and materials, including checking the feasibility of the engine, drum brake system, and measuring instruments. At each load level starting from 0 – 800 grams, after the engine condition is stable, the initial Tawal and RPM are recorded, then the engine is run for 2 minutes at that condition. After 2 minutes, the final Tawal and RPM are recorded as verification of the rotation condition. The same procedure is repeated for Speed 2 and Speed 3. After the entire series is completed for one oil variant, the oil is replaced with the next variant and the entire test procedure is repeated with the same sequence of conditions.

Data processing was carried out descriptively and comparatively. The oil temperature increase was calculated using the equation:

$$\Delta T = T_n - T_0$$

Furthermore, the relationship between RPM and load is analyzed through the RPM vs. load graph to see the consistency of the drum brake system's performance. The relationship between temperature and load is analyzed through the T_n vs. load and ΔT vs. load graphs at each speed. To compare the thermal response between oil variants, the peak temperature indicator (T_{nmax}) is used. All results are presented in the form of summary tables and trend graphs to support the interpretation of oil temperature changes due to load variations and differences in characteristics between oils.

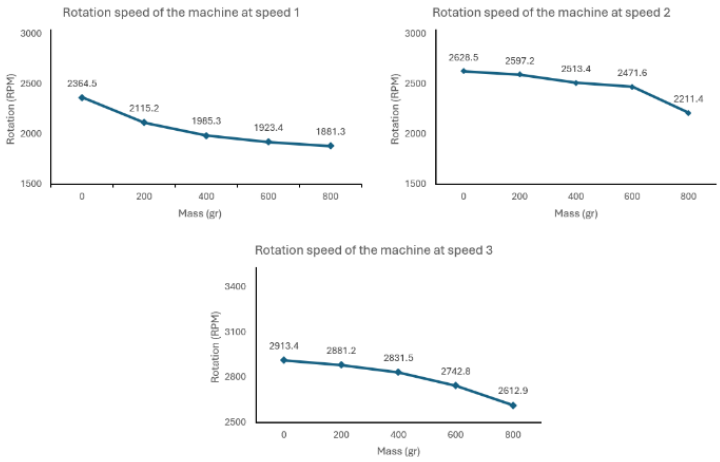
As a limitation of this study, the testing was conducted without replication at each condition point, so the conclusions are focused on descriptive differences based on effect sizes (temperature difference, ΔT, maximum temperature, and load sensitivity). To obtain stronger statistical inferences, further research is recommended to repeat the testing at each condition and add performance parameters such as torque, power, and fuel consumption.

4. RESULTS AND DISCUSSION

A. Shell Advance Oil

1. Engine Rotation Speed at Speed 1, Speed 2, Speed 3 (RPM)

This study measured the engine rotation speed at various mass levels, ranging from 0 grams, 200 grams, 400 grams, 600 grams, and 800 grams. Three transmission types were used in the Motoyama gasoline engine, ranging from Speed 1 to Speed 3. The test was conducted for 2 minutes, resulting in the following results.



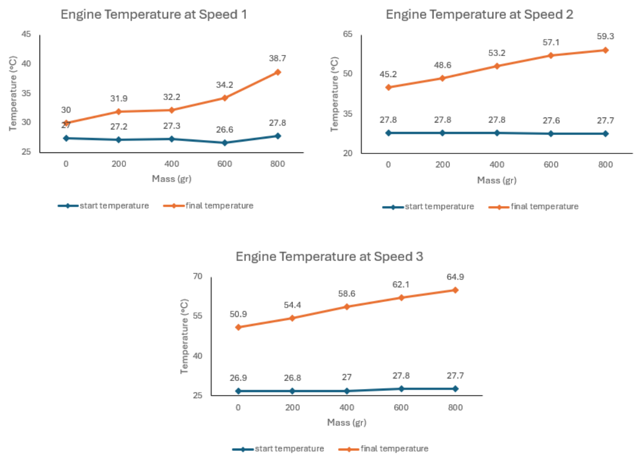
Graph 1. Engine Rotation Speed at Speed 1, Speed 2, Speed 3 Shell Advance Oil

Based on the Speed 1 Engine Rotation Speed graph, increasing the load from 0 to 800 grams causes a decrease in engine rotation from 2364.5 RPM to 1881.3 RPM. In the Speed 2 Engine Rotation Speed graph, the RPM decreases from 2628.5 RPM to 2211.4 RPM when the load increases from 0 to 800 grams. This decrease is gradual and shows an inverse relationship between load and engine rotation speed. Speed 3 Engine Rotation Speed shows an initial RPM of 2913.4 RPM and a final RPM of 2612.9 RPM at a load of 800 grams.

The RPM reduction value shows that at Speed 1, the addition of the load has a significant effect of 20.44% on the reduction in engine speed. At Speed 2, the RPM reduction is smaller than Speed 1 at 15.87%. Meanwhile, at Speed 3, it shows a reduction of 10.31%.

2. Oil Temperature at Speed 1, Speed 2, and Speed 3

Next, the oil temperature was measured by varying the mass of the oil, ranging from 0 grams, 200 grams, 400 grams, 600 grams, and 800 grams. The study used three transmission speeds, from Speed 1 to Speed 3, on a Motoyama gasoline engine. The test was conducted for 2 minutes, resulting in the following results.



Graph 2. Oil Temperature at Speed 1, Speed 2, Speed 3 Shell Advance Oil

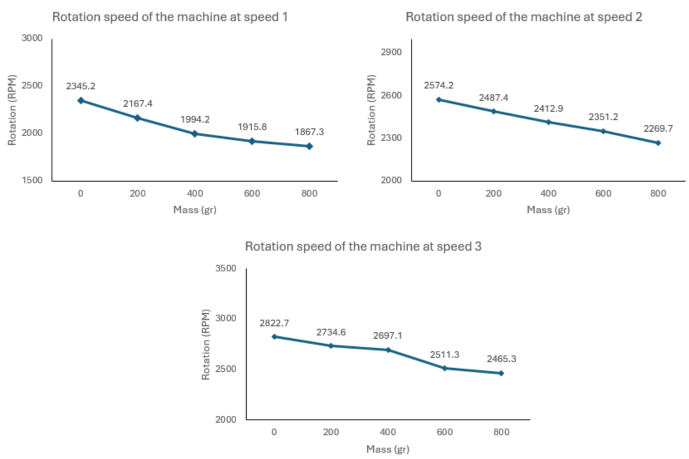
The Engine Temperature Graph at Speed 1 shows an initial temperature ranging from 26.6 – 27.8 °C, while the final temperature increases from 30 °C to 38.7 °C. On the Engine Temperature Graph at Speed 2, the final temperature increases from 45.2 °C to 59.3 °C, while the initial temperature remains stable at around 27.6 – 27.8 °C. The Engine Temperature Graph at Speed 3 shows the highest final temperature, which is 64.9 °C, with an initial temperature of around 27.7 °C.

The relatively small ΔT value at Speed 1 indicates that the heat due to friction is still under control, with a temperature increase of 10.9°C. At Speed 2, the increase in the ΔT value indicates increased friction and heat generation due to an increase in engine speed of 31.6°C. at Speed 3, this indicates the most severe working conditions, but because there is no extreme temperature spike of 37.2°C.

B. Mesran Super Oil

1. Engine Rotation Speed at Speed 1, Speed 2, Speed 3 (RPM)

This study measured the engine rotation speed at various mass levels, ranging from 0 grams, 200 grams, 400 grams, 600 grams, and 800 grams. Three transmission types were used in the Motoyama gasoline engine, ranging from Speed 1 to Speed 3. The test was conducted for 2 minutes, resulting in the following results.



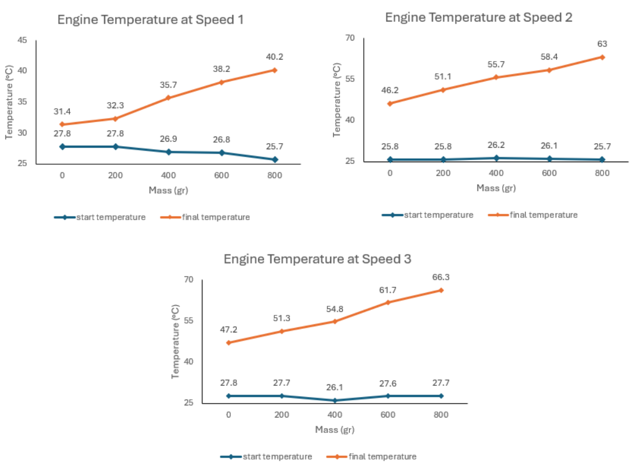
Graph 3. Speed 1 Engine Rotation Speed of Mesran Super Oil

Based on the Speed 1 Engine Rotation Speed graph for Mesran Super oil, it can be seen that increasing the load from 0 to 800 grams causes a decrease in engine rotation from 2345.2 RPM to 1867.3 RPM. At Speed 2, the Speed 2 Engine Rotation Speed, RPM decreases from 2574.2 RPM at a load of 0 grams to 2269.7 RPM at a load of 800 grams. The Speed 3 Engine Rotation Speed shows a decrease in RPM from 2822.7 RPM to 2465.3 RPM when the load increases to 800 grams. This decrease occurs gradually and forms a relatively linear pattern.

The significant decrease in RPM at Speed 1 indicates that Mesran Super oil is not optimal in withstanding increased friction at low revs, with a decrease of 20.38%. At Speed 2, the RPM decrease was smaller, resulting in a relatively more stable engine at 11.83. At Speed 3, the RPM decrease was again significant at 12.66%.

2. Oil Temperature at Speed 1, Speed 2, Speed 3

Next, the oil temperature was measured by varying the mass of the oil, ranging from 0 grams, 200 grams, 400 grams, 600 grams, and 800 grams. The study used three transmission speeds, from Speed 1 to Speed 3, on a Motoyama gasoline engine. The test was conducted for 2 minutes, resulting in the following results.



Graph 4. Oil Temperature at Speed 1, Speed 2, Speed 3 of Mesran Super Oil

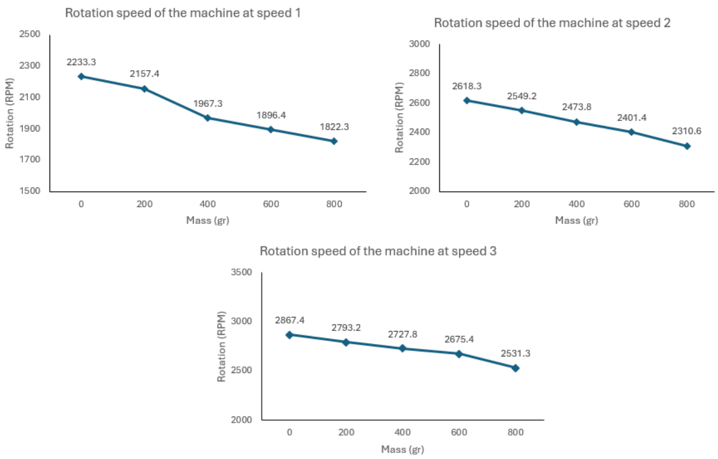
At Speed 1, the engine temperature shows that the initial temperature is in the range of 25.7 – 27.8 °C, while the final temperature increases from 31.4 °C to 40.2 °C as the load increases. At Speed 2, the final temperature increases from 46.2 °C to 63 °C, while the initial temperature is relatively stable at around 25.7 – 26.2 °C. The Speed 3 engine temperature graph shows the most extreme thermal conditions, with the final temperature increasing from 47.2 °C to 66.3 °C at a load of 800 grams, while the initial temperature is in the range of 26.1 – 27.8 °C.

The relatively high ΔT value at Speed 1 indicates that friction remains significant, increasing by 14.5°C. At Speed 2, the consistently high ΔT value indicates an increase in heat generation of 37.3°C. At Speed 3, the very high ΔT value indicates a heavy thermal load of 38.6°C.

C. Federal Ultratec Oil

1. Engine Rotation Speed at Speed 1, Speed 2, Speed 3 (RPM)

This study measured the engine rotation speed at various mass levels, ranging from 0 grams, 200 grams, 400 grams, 600 grams, and 800 grams. Three transmission types were used in the Motoyama gasoline engine, ranging from Speed 1 to Speed 3. The test was conducted for 2 minutes, resulting in the following results.



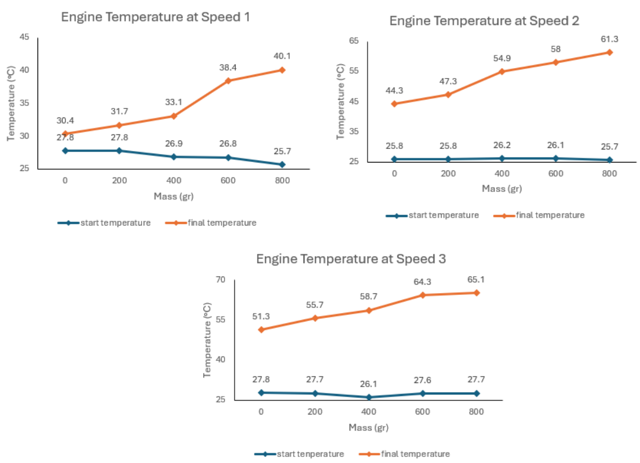
Graph 5. Engine Rotation Speed Speed 1, Speed 2, Speed 3 Federal Ultratec Oil

In the Speed 1 Engine Rotation Speed graph for Federal Ultratec oil, it can be seen that increasing the load from 0 to 800 grams causes the engine rotation speed to decrease from 2233.3 RPM to 1822.3 RPM. This decrease occurs gradually and shows a relatively linear trend. In the Speed 2 Engine Rotation Speed graph, the initial RPM of 2618.3 RPM decreases to 2310.6 RPM at a maximum load of 800 grams. The Speed 3 Engine Rotation Speed shows a decrease in RPM from 2867.4 RPM to 2531.3 RPM when the load increases to 800 grams.

The decrease in RPM at Speed 1 shows that Federal Ultratec oil has quite good load resistance at low speeds of 18.4%. At Speed 2, the decrease in RPM is relatively small at 11.75%. At Speed 3, the decrease in RPM is almost equivalent to Speed 2 at 11.72%.

2. Oil Temperature at Speed 1, Speed 2, Speed 3

Next, the oil temperature was measured by varying the mass of the oil, ranging from 0 grams, 200 grams, 400 grams, 600 grams, and 800 grams. The study used three transmission speeds, from Speed 1 to Speed 3, on a Motoyama gasoline engine. The test was conducted for 2 minutes, resulting in the following results.



Graph 6. Oil Temperature Temperature at Speed 1 Federal Ultratec Oil

The Engine Temperature Graph at Speed 1 shows the initial temperature in the range of 25.8 – 27.6 °C, while the final temperature increases from 30.4 °C to 40.1 °C as the load increases. In the Engine Temperature Graph at Speed 2, the final temperature increases from 44.3 °C to 61.3

°C, while the initial temperature is relatively stable in the range of 25 – 27 °C. The Engine Temperature Graph at Speed 3 shows the highest final temperature reaching 65.1 °C at a load of 800 grams, with the initial temperature being around 25.4 – 27.8 °C.

The ΔT value shows that at low speeds, heat generation due to friction is still relatively controlled at Speed 1 with an increase of 12.5°C. At Speed 2, the increasing ΔT value shows an increase of 34.4°C. At Speed 3, the largest ΔT value indicates a high thermal load with an increase of 39.7°C.

D. Comparison of Oil Performance

A comparison of engine performance with oil was conducted to evaluate the effect of oil type on engine rotational speed (RPM) stability at various loads and speed levels (Speed 1, Speed 2, and Speed 3). The main parameters analyzed were the RPM value at each load, as well as the decrease in RPM due to increasing loads, which represents the oil's ability to reduce friction and maintain engine performance.

1. Comparison of engine rotation speed with a comparison of 3 types of oil at Speed 1, Speed 2, Speed 3.

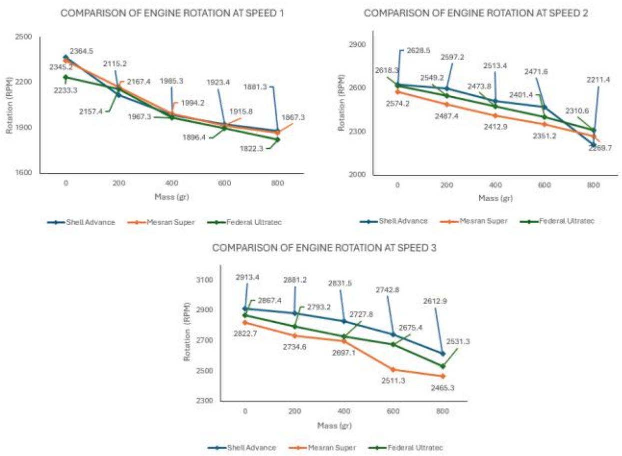


Chart 7. Comparison of 3 oils in Speed 1, Speed 2, Speed 3

Based on the comparison of Speed 1 to Speed 3, all oil types showed a decrease in RPM as the load increased from 0 to 800 grams, but with different performance characteristics. At Speed 1, Shell Advance consistently produced the highest absolute RPM, namely 2364.5 RPM at 0 gram load and 1881.3 RPM at 800 gram load, compared to Mesran Super (2345.2–1867.3 RPM) and Federal Ultratec (2233.3–1822.3 RPM), although Federal Ultratec had the smallest percentage decrease in RPM, indicating stability relative to load. At Speed 2, Shell Advance again recorded the highest initial RPM of 2628.5 RPM and remained superior until maximum load, while Federal Ultratec (2618.3 RPM) and Mesran Super (2574.2 RPM) showed a smaller decrease in RPM, but overall Shell Advance was better able to maintain a high absolute RPM, reflecting its lubrication effectiveness at medium speeds. At Speed 3, Shell Advance again showed the best performance with an initial RPM of 2913.4 RPM and a final RPM of 2612.9 RPM, higher than Federal Ultratec (2867.4–2531.3 RPM) and Mesran Super (2822.7–2465.3 RPM), and showed the smallest decrease in RPM, which indicates the best resistance of Shell Advance lubricant film under extreme conditions with high shear forces and temperatures.

E. *Comparison of Oil Temperature*

1. Comparison of engine oil temperature with 3 types of oil at Speed 1, Speed 2, Speed 3

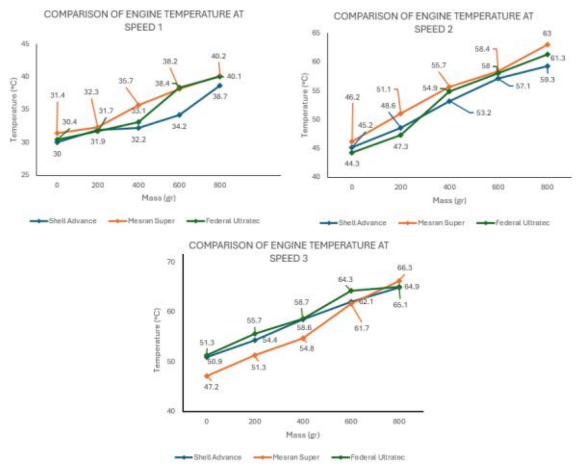


Chart 8. Comparison of 3 Oils at Oil Temperature at Speed 1

Based on the temperature comparison table at Speed 1 to Speed 3, all types of oils show an increase in engine temperature as the load increases from 0 to 800 grams, but with different characteristics. At Speed 1, the engine temperature increases from 30 °C (Shell Advance), 31.4 °C (Mesran Super), and 30.4 °C (Federal Ultratec) to 38.7 °C, 40.2 °C, and 40.1 °C, which shows that Shell Advance consistently produces the lowest temperature and has better heat dissipation capabilities at low rpm. At Speed 2, due to increased rotation and shear forces, the initial temperatures of 45.2 °C (Shell Advance), 46.2 °C (Mesran Super), and 44.3 °C (Federal Ultratec) increased to 59.3 °C, 63 °C, and 61.3 °C, respectively, where Shell Advance again showed the best thermal resistance, while Mesran Super and Federal Ultratec experienced greater heat generation. At Speed 3 as the most extreme condition, the engine temperature increased from 50.9 °C (Shell Advance), 47.2 °C (Mesran Super), and 51.3 °C (Federal Ultratec) to 64.9 °C, 66.3 °C, and 65.1 °C, which shows that Mesran Super experienced the highest temperature increase, while Shell Advance and Federal Ultratec were still able to maintain thermal stability, with Shell Advance showing the most stable engine temperature overall across various operating conditions.

CONCLUSION

The results showed that increasing the load from 0 to 800 grams caused a decrease in RPM and an increase in oil temperature for all oil types. Shell Advance consistently produced the highest RPM in all conditions, with a range of 2364.5–1881.3 RPM (Speed 1) and 2913.4–2612.9 RPM (Speed 3). From the thermal side, Shell Advance also showed a more controlled temperature increase, with a final temperature reaching 64.9 °C and a ΔT of 37.2 °C at Speed 3. Mesran Super experienced the highest temperature increase of up to 66.3 °C with a ΔT of 38.6 °C, while Federal Ultratec showed intermediate performance with a final temperature of 65.1 °C and a maximum ΔT of 39.7 °C. Overall, Shell Advance had the best lubrication stability and thermal resistance, followed by Federal Ultratec and Mesran Super.

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