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Oil based variation impact on fuel consumption of four-stroke 125 cc engine

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ABSTRACT

Oil is one of the crucial components in the lubrication system of four-stroke engines, particularly in motorcycles. Generally, engine oil is categorized into mineral oil, semi-synthetic oil, and fully-synthetic oil. The purpose of this research is to examine the effect of different base oil types on fuel consumption. The research was conducted using an experimental method, with the independent variable being the type of base oil: mineral oil, semi-synthetic oil, and fully-synthetic oil. The dependent variable of this research is fuel consumption. A four-stroke engine with a 125 cc carburetor was used as the test engine. Each test was conducted in five times at an engine speed 2000 rpm. Data analysis was performed using repeated measures ANOVA. The results showed that the use of different base oil types had a significant effect on fuel consumption. The average of fuel consumption was approximately 9.4 mL/min for mineral oil, 8.2 mL/min for semi-synthetic oil, and 6.9 mL/min for fully-synthetic oil. It can be concluded, that fully-synthetic oil results in the lowest or the most efficient fuel consumption compared to both mineral and semi-synthetic oils.

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1. INTRODUCTION

Motorcycles have become popular mode of transportation in recent years. Motorcycles are chosen because of their practicality in use. Generally, motorcycles nowadays use four-stroke gasoline engines, although there are still some motorcycles that use two stroke engines. A four-stroke engine is an internal combustion engine in which the piston reaches the top and bottom dead centers in four times, or during two revolutions of the crankshaft (Li, 2024).

In its operation, a four-stroke engine requires a lubrication system. The function of this system is to facilitate the mechanism of each engine component, increasing working life and performance of the engine (Thirumalaikumaran et al., 2021). One of the important components of the lubrication system is oil. Engine oil is a fluid produced from the separation process of elements found in crude oil, leaving behind a base oil that is then mixed with other substances, such as additives. Based on its base material and mixture, the types of engine oil commonly used in recent years are mineral-based oil, semi-synthetic based oil, and fully-synthetic based oil.

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Mineral oil is a hydrocarbon fluid derived from petroleum, which may contain sulfur, oleum, or undergo hydrogenation. This type of mineral oil mostly consists of saturated C15–C50 hydrocarbons (Wang et al., 2022). Synthetic oil, essentially, is a lubricant created through a chemical process that forms hydrocarbon chains with low molecular weight and molecular structures that are resistant to degradation (Kallas et al., 2024). Basically, semi-synthetic oil is a mixture of mineral oil and synthetic oil. This is intended to improve the resistance of mineral oil to degradation.

In addition to facilitating the engine's mechanism (as a lubricant), the functions of oil in a four-stroke engine include acting as a coolant, a cleaner, a sealant, and as a rust protection (Ďurišová and Janík, 2020). Oil is a vital component in both gasoline and Diesel engines. Oil is a working fluid that has viscosity. In general, oil viscosity is expressed in SAE. SAE stands for the Society of Automotive Engineers. Based on the types of oil viscosity available, they are generally classified into single-grade and multigrade.

When the gasoline engine is operating, it requires gasoline as its primary fuel. In previous research, the fuel consumption can vary in amount depending on various factors. The factors that can influence the amount of fuel consumed such as: engine capacity, riding or driving style, traffic conditions, road terrain, fuel quality, engine setup like spark plug configuration (Ardiyanta, 2020), carburetor of fuel injection system settings, the amount of air volume drawn by the engine (Purwanto et al., 2023), and even of the engine's lubrication system. In terms of lubrication, using oil with the appropriate viscosity and a high-quality lubricant that meets the recommended API service classification can reduce friction between engine components. This allows the engine to run more smoothly and efficiently in burning the fuel mixture. Conversely, if the oil used is not suitable or has deteriorated in quality, the engine will require more energy, and fuel consumption will increase. The lubricants with higher API service ratings contribute to improved fuel efficiency by providing better protection and reducing internal engine friction (Praharaj et al., 2020).

Considering the vital role of oil in supporting engine performance and efficiency, it is important to understand how the type of oil used affects fuel consumption. This research, which focuses on the influence of different types of oil – whether mineral, semi-synthetic, or fully-synthetic based oil on fuel consumption, is highly relevant in providing information and guidance for motor vehicle users, in choosing the right type of oil. The selection of oil should be based on quality of the oil, not the price.

In addition, the results of this research can serve as a basis for consideration by oil manufacturers and related parties in developing lubricants that not only protect the engine but also contribute to energy efficiency and emission reduction. Therefore, this research aims to analyze the extent to which oil type affects fuel consumption in gasoline engines, particularly in four-stroke motorcycles commonly used by the public.

2. RESEARCH METHODS

This research using experimental approach. In this research, the testing medium using 125 cc four-stroke gasoline engine. This research consists of three variables. The independent variable in this research is the type of based oil. The researcher used mineral based oil with SAE 10W-30, semi-synthetic oil with SAE 10W-30, and fully-synthetic with SAE 10W-30. All of them using for motorcycle engine. The dependent variable in this research is fuel consumption, which is in this research measured in mililiter/minute (mL/min). The relationship between variables is illustrated in Figure 1 below:

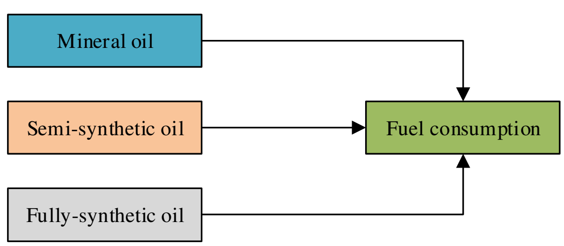

Figure 1. The relation of each variables

The author of this research not mixing oil between mineral, semi-synthetic, and fully synthethic oil each other. In this research, the researcher comparing, the result of each based oil classification.

Table 1. Variables description

No	Independent variable	Dependent variable
1	Mineral oil SAE 10W-30	Fuel consumption (mL/min)
2	Semi-synthetic oil SAE 10W-30	Fuel consumption (mL/min)
3	Fully-synthetic oil SAE 10W-30	Fuel consumption (mL/min)

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In addition to the two variables mentioned above, this research also includes controlled variable, which is explained in Table 2 below:

Table 2. Controlled variable

No	Item	Description
1	Motorcycle engine	125 cc carburetor type
2	Oil viscosity	10W-30
3	Fuel type	RON 90
4	Engine speed	2000 rpm
5	Spark plug gap configuration	0.8 mm
6	Intake valve clearance	0.05 mm
7	Exhaust valve clearance	0.05 mm

Data collection process describes in Figure 2 below:

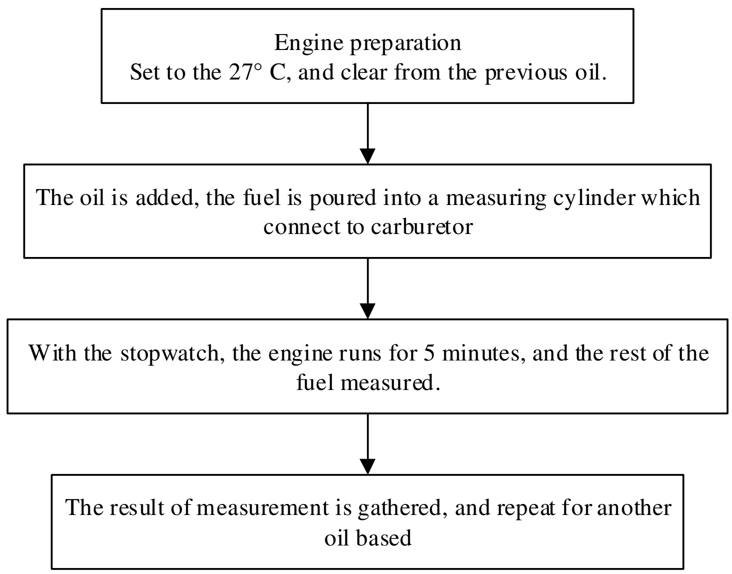

Figure 2. Data collecting process


Figure 3. Measuring cylinder connected to the carburetor

The data analysis used in this research is a repeated measure ANOVA with alpha 0.05. This analysis was chosen because repeated measures ANOVA is suitable for research with characteristics where data collection is conducted repeatedly. In this research, the data gathered 5 times for each type of based oil.

Table 3. Data collecting method

No.	Based oil	Fuel consumption (mL)
1		Test 1 (mL/min)
2		Test 2 (mL/min)
3	Mineral, semi-synthetic, or fully-synthetic oil	Test 3 (mL/min)
4		Test 4 (mL/min)
5		Test 5 (mL/min)

3. RESULTS AND DISCUSSION

After collecting the data, the result of this research explained in Table 4 below. Every fuel consumption data collected in 5 minutes engine run.

Table 4. Fuel consumption every base oil

No	Test time	Fuel consumption (mL/min)		
		Mineral oil	Semi-synthetic oil	Fully-synthetic oil
1	Test 1	9.6	8	6.6
2	Test 2	9.2	8.2	7
3	Test 3	9	7.6	6.8
4	Test 4	9.8	8.8	6.8
5	Test 4	9.4	8.2	6.9
Average		9.4	8.16	6.8

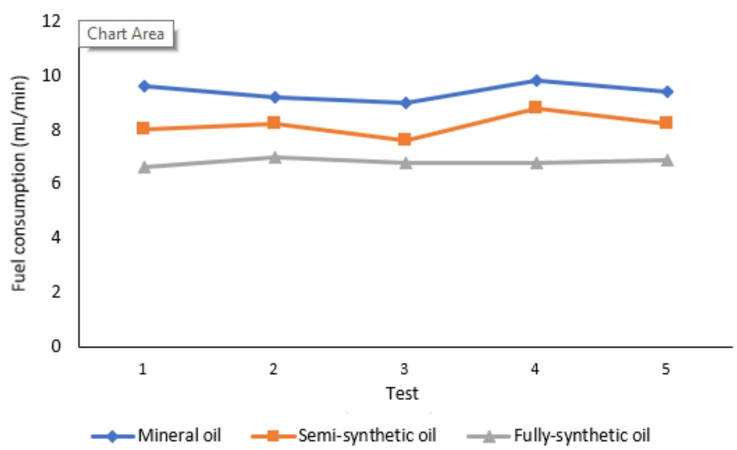

Figure 4. Fuel consumptions chart

After collecting data, the result of data analysis using repeated measures ANOVA shows in Table 5 below:

Table 5. Mauchly's test of sphericity

Within subjects effect	Mauchly's W	Approx. Chi-square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Oil_type	0.726	0.959	2	0.619	0.785	1.000	0.500

Based on Table 5, the significant's score is above 0.05 (0.619 > 0.05) which is can be interpreted as the first assumption is statisfied.

Table 6, named the test of within subject effect below shows the data analysis to analyze the significance correlation about oil base classification to fuel consumption. Computed using alpha 0.05.

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Table 6. Test of within subject effect

Source		Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared	Noncent. parameter	Observed power[a]
Oil_type	Sphericity assumed	16.649	2	8.325	119.493	0.000	0.968	238.986	1.000
	Greenhouse -Geisser	16.649	1.570	10.603	119.493	0.000	0.968	187.629	1.000
	Huynh-Feldt	16.649	2.000	8.325	119.493	0.000	0.968	238.986	1.000
	Lower-bound	16.649	1.000	16.649	119.493	0.000	0.968	119.493	1.000

From the Table 6 above, the result of the analysis can be interpreted that the type of oil has a significant effect on fuel consumption. The Table 6 shows that the significant score (sig.), less than 0.05.

Fundamentally, mineral oil and synthetic oil are two types of oil with different characteristics. Mineral oil contains natural petroleum components with non uniform carbon chains, which is very different from synthetic oil, where the manufacturing process involves synthetic materials. Mineral oil still contains sulfur about 0.03%, with a saturation level of 90% (Lee et al., 2022). Oils with high saturation levels have low aromatic content, as found in Group I oils, which can negatively impact their ability to dissolve additives such as dispersants, detergents, and anti wear agents. Due to the non uniform hydrocarbon chains, mineral oil exhibits higher internal friction between its molecules and less efficient flow between engine components, resulting in higher fuel consumption compared to synthetic oil.

Although saturated oils like mineral oil have a lower coefficient of friction, they may reduce boundary lubrication if not supported by additional additives such as esters or molybdenum. On the other hand, synthetic oils are made from PAO (Polyalphaolefin), which are fully-synthetic. These oils offer advantages such as thermal stability, resistance to oxidation and degradation, longer usage intervals compared to mineral oils, and a lower risk of sludge formation in the engine. Mineral oil tends to degrade more quickly, and this degradation leads to less effective lubrication over time, resulting in declining engine condition and increased fuel consumption.

Table 7. Oil classification based on API

Base oil category		Sulfur (%)	Saturates (%)	Viscosity index
Mineral	Group I (solvent refined)	> 0.03	< 90	80 to 120
	Group II (hydrotreated)	< 0.03	> 90	80 to 120
	Group III (hydrocracked)	< 0.03	> 90	> 120
Synthetic	Group IV	PAO synthetic lubricants		
	Group V	All other base oil not included in groups I, II, III or IV		

In terms of chemical structure, synthetic oil made from PAO (Polyalphaolefin) consists of highly uniform, branched molecules that are chemically controlled (Xu et al., 2024). This molecular uniformity results in a lower coefficient of friction (making it more slippery) and provides the advantage of more stable viscosity across a wide range of engine operating temperatures (high viscosity index). In contrast, mineral oil contains a complex mixture of non uniform molecules, with many aromatic compounds and straight chains. Due to this molecular structure, mineral oil generates relatively higher friction, especially at low or high temperatures. Therefore, based on the base material, synthetic oil can improve fuel consumption efficiency.

Not only based on the base material, the viscosity of the oil used also affects fuel efficiency. Using oil with low viscosity (a low SAE rating, close to 0) makes the oil thinner. Thinner oil can flow into narrower gaps inside the engine components, which helps minimize wear between components. As a result, the engine operates more smoothly and efficiently, ultimately improving fuel efficiency (Rovai et al., 2025). This is different from the use of thicker oil (higher SAE rating). However, using thinner oil can increase the rate of oil evaporation, whereas oil with higher viscosity can help minimize evaporation levels (Koyama et al., 2022). In this research, the viscosity of oil is same (10W-30), but the fully-synthetic oil gives less fuel consumption. Fully-synthetic oils are engineered with uniform molecular structures and advanced additive packages that reduce internal friction more effectively than conventional or semi-synthetic oils. Therefore, the users need to choose the oil viscosity based on the engine's mileage, and oil base type. Engines with higher mileage tend to have more wear compared to new engines, resulting more clearance between components. Users should adjust the oil's viscosity level and base material according to the specific needs of the engine.

In practical application, the use of fully-synthetic oil has shown the highest level of fuel efficiency across the tested samples. This outcome aligns with the theoretical advantages provided by the chemical structure of synthetic oils. Fully-synthetic oils tend to maintain their protective properties longer, which reduces internal engine resistance and allows for smoother operation even under high stress conditions. For users focused on performance, fuel savings, or engine longevity, especially in high demand environments or extreme climates, the additional cost of synthetic oil may be justified by the long term economic and mechanical benefits.

Additionally, it is important to consider environmental factors in the oil selection process. Lower fuel consumption, as enabled by more efficient oils, contributes directly to reduced emissions such as CO, CO_2, NOx and HC. This aligns with global efforts to lower the carbon footprint of personal and commercial transportation. In this context, choosing the right lubricant is not only a technical decision but also an environmental one (Tobar et al., 2024). Furthermore, the routine of oil changes provides benefits beyond maintaining fuel efficiency it also has a positive impact on the environment. Petrol engines will continue to perform optimally as long as the quality of the oil used is consistently well-maintained (Sheikh et al., 2024).

Despite the valuable insights obtained, this research has several limitations. One of the main constraints is that testing was conducted at a single engine speed, 2000 rpm. This limited scope does not fully represent the diverse operating conditions of a real-world engine operating conditions, which typically runs at various engine speed depending on load and terrain. Expanding the testing range to include different engine speeds would provide a more comprehensive understanding of oil performance under dynamic conditions. Additionally, the research was conducted using only one type of fuel, RON 90. Given that engines may be fueled with various octane ratings depending on regional availability and performance requirements, future research should explore the impact of different RON fuels on oil behavior and fuel efficiency. Another significant limitation is that the tests were performed on a stationary motorcycle. Real world riding or driving introduces additional variables such as road resistance, inclines, rider weight, and dynamic engine loads. Subsequent studies should incorporate moving vehicle tests across diverse terrain types and workload scenarios to obtain more representative and actionable data.

4. CONCLUSION

Based on the research conducted, it can be concluded that the use of various base oil types has a significant effect on fuel consumption. The average of fuel consumption is 9.4 mL/min for mineral oil, 8.2 mL/min for semi-synthetic oil, and 6.9 mL/min for fully-synthetic oil. It means the use of fully-synthetic oil provides the highest fuel efficiency, meaning that fuel used is less than the other oil based. This is evident from the smaller amount of fuel consumed (mL/min) compared to mineral oil and semi-synthetic oil.

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