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Analysis of Octane, Heating, and Viscosity Value of Pertalite and Turpentine Oil Mixtures on 4-Step Motorcycle Performance

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Abstract

Octane, heating, and viscosity value are important parameters that affect fuel quality. These parameters are related to combustion process and energy produced and affect vehicle performance. Main fuel is Pertalite with octane number of 90 (RON). The quality of Pertalite can be improved by adding turpentine oil as a bio-additive. This study analyzes effect of adding turpentine oil on these parameters and vehicle performance. Turpentine oil contains oxygenate, so long-term use has a lower risk to the engine. Various composition of turpentine oil for mixture with Pertalite are 0% (PMT 0%), 10% (PMT 10%), 20% (PMT 20%), and 30% (30% PMT) with a total volume of 100 (ml) of each sample mixture. A centrifuge (200 rpm) was used to ensure sample was evenly mixed. Results show addition of turpentine oil increases octane and heating value. The highest octane and heating values were PMT 30% samples, 94.4 (RON), and 39573.1 (KJ/Kg). Meanwhile, the lowest viscosity value was PMT 10%, which was 0.886 cSt. All fuel samples have a viscosity value according to the standard, which is below 1 cSt, so they can be used for testing on vehicles. Vehicle performance test shows that increase in octane and heating value will be followed by an increase in the number of torque and power. PMT 30% produced the highest torque and power numbers, 25.5 Nm (3000 rpm) and 12.10 hp (4000 rpm). An increase in the torque and power is proportional to the increase in specific fuel consumption, 2,377 Kg/Hour.hp (8000 rpm).

Keywords:
Turpentine oil, Torque, Power, and Specific Fuel Consumption.

1. Introduction

Energy consumption in the transportation sector in 2019 was 58.1 million Tonne of Oil Equivalent (TOE). This value is the largest compared to other sectors. Nearly 99.9% of final energy use in the transportation sector still uses fuel oil (BBM), and the remaining 0.1% uses gas and electricity. The need for fuel in Indonesia continues to increase in line with the increasing number of vehicles, especially motorcycles (121,209,304 units as of 2021) [1].

Pertalite is a type of fuel that has a Research Octane Number (RON) of 90 Pertalite is recommended for motorcycles with a compression ratio of 1:9.1 to 1:10,1. In addition, cars from 2000 and above, especially those that already use technology equivalent to Electronic Fuel Injection (EFI) and catalytic converters are also highly recommended to use this type of fuel [2].

The main performance parameters of a motorcycle include the value of torque, power, and specific fuel consumption. In a vehicle engine, combustion produces a force to push the piston, which then pushes the crankshaft a certain distance. The piston and crankshaft are what then produce a rotary force (torque). While power is the force of rotation in a certain period. Torque is expressed in units of Nm, while Power is in units of hp [3] [4].

In general, two methods can be used to increase the torque and power of the vehicle, namely engine modification and the addition of a fuel mixture. The second method was chosen in this study because it is simpler and has a lower risk of system failure. The fuel mixture used is a type of bioadditive from turpentine oil. Turpentine oil contains enough oxygen so that the combustion process in the combustion chamber becomes more perfect and can result in increased performance.

Meanwhile, Specific Fuel Consumption (SFC) is a motorcycle performance parameter that is directly related to the economic value of an engine in units of Kg/Hour.hp. By knowing the SFC, it will be able to calculate the amount of fuel needed to produce a certain amount of power in a certain time interval (between 1 hour – 2 hours) [2].

$$SFC = \frac{mf}{P} \tag{1}$$

where mf is the rate of fuel consumption which can be determined using the eq.2:

$$mf = \frac{b \times 10^{-3} \times \rho \times 3600}{t} \tag{2}$$

P is the vehicle power (hp); b is the volume of fuel under test (mL); ρ is the density of the fuel (gr/cm^3); t is the time required to spend the fuel (s).

Turpentine oil is often called the spirit of turpentine in the volatile liquid, derived from the distillation of pine tree sap. The distillation of pine resin consists of two main components, namely rosin (60%) and turpentine oil (10 - 17.5%). Turpentine oil is broadly divided into two types, namely those produced from pine resin and those produced from pine trees [5].

Research conducted by [6] shows the addition of turpentine oil will increase the torque value of the diesel engine. The research uses the main fuel from waste engine lubricating oil that has gone through the pyrolysis process. While the variations in the composition of the turpentine oil used were 0%; 10%; 20% and 30% of the main fuel. The highest torque value is 101.1 Nm and is at an engine speed of 2500 (rpm) when using a composition of 30% turpentine oil. Meanwhile [7] researched the specific fuel consumption of diesel engines. As a result, an increase in the composition of turpentine oil mixed with diesel fuel will be followed by fuel consumption. The composition of turpentine oil used in the fuel mixture is 0%; 25%; 50%; 75%; and 100% with the results of the fuel consumption sequentially being 0.24 Kg/Hour; 0.25 Kg/Hour; 0.43 Kg/Hour; 0.7 Kg/Hour; and 1.1 Kg/Hour. Research by [2] found that an increase in the octane number of fuel will be followed by an increase in the value of torque, power, and specific fuel consumption. The fuel used is premium (88 RON), Pertalite (90 RON), and Pertamax (92 RON).

This research is expected to be able to show the effect of adding turpentine oil to fuel based on three fuel parameters, namely octane, heat, and viscosity value. Furthermore, the sample of the fuel mixture was tested directly on the vehicle related to the value of torque, power, and specific fuel consumption.

The comparison of some characteristics between gasoline, diesel, and turpentine oil are shown in Table 1.

Table 1. Comparison of the characteristics of turpentine oil against fuel oil (gasoline and diesel) [7]

Properties	Gasoline	Diesel	Turpentine
Formula	C_4-C_{12}	C_8-C_{25}	$C_{10}H_{16}$
Molecular weight (gr/mol)	105	200	136
Composition (% wt)	C: 88 H: 15	C: 87 H: 16	C: 88,2 H: 11,8
Density (kg/ m^3)	780	830	860 s.d. 900
Specific Gravity	0,78	0,83	0,86-0,9
Pour point (^0C)	-40	-23	-50 s.d. -60
Boiling point (^0C)	30 s.d. 220	180 s.d. 340	150 s.d. 180
Viscosity (cSt@ 30 ^0C)	<1	3 s.d. 4	2,5
Latent heat of vaporization (kJ/kg)	350	230	285
Lower Heating Value (kJ/ kg)	43,890	42,700	44,400
Auto ignition temperature (^0C)	300 s.d. 450	250	305
Flammability limit (% volume)	1,4	1	0,8

2. Method

2.1. Motorcycle and Dynamometer Specification

This study uses a 2016 Honda Vario 125 FI motorcycle with a Continuously Variable Transmission (CVT) type automatic transmission. The motorcycle was used to test the effect of adding turpentine oil to the value of torque, power, and specific fuel consumption. Table 2 shows the specifications of the test vehicle:

Table 2. Motorcycle Specifications

Properties	Specifications
Fuel tank capacity	5,5 liter.
Engine type	4 Valves, SOHC 1 silinder.
Diameter x Step	52,4 x 57,9 mm.
Cylinder volume	124,8 cc
Compression ratio	11 : 1
Cooling System	Radiator
Fuel System	Injection (PGM-FI)

While the specifications of the dynamometer used to measure the torque and power of a motorcycle is shown in Table 3.

Table 3. Dynamometer spesifiactions

Properties	Specifications
Measurement Item	Speed, Rpm, Acceleration, Torque, Power.
Data Transfer	RS232-USB.
Maximum Torque	50 Nm
Maximum rpm	20.000 rpm
Maximum Power	50 hp
Maximum Speed	350 kmph
Diameter Roller	25 cm
Weight Roller	154 kg
Inertia Roller	1,2 kg.m2
Width	97 cm
length	195 cm
Application	Sport Devices

2.2. Sample Preparation and Research Scheme

The method used in this research is the experimental method. Pertalite fuel was mixed with turpentine oil bioadditive using a centrifuge at 200 rpm. This is done to ensure the mixture is evenly and homogeneously mixed without any separation of fractions to ensure the mixture is evenly and homogeneously mixed. Furthermore, the mixture was tested for octane, heating, and viscosity value. After obtaining these data, a mixture of Pertalite and turpentine oil was used on a motorcycle to test the torque and power values produced. The engine speed used in this study was started from 3000 rpm to 8000 rpm. To determine the effect of the volume of turpentine oil used in the fuel mixture on torque and power, the volume of turpentine oil was also varied. The total volume of test fuel for each sample is 100 ml. While the ratio of turpentine oil used is:

1. 0% with a PMT code of 0% which means that the overall sample is 100 ml of Pertalite type fuel;
2. 10% with a PMT code of 10%, which means that the sample is a mixture of 90 ml of Pertalite fuel with 10 ml of turpentine oil.
3. 20% with a PMT code of 20% which means that the sample is a mixture of 80 ml of Pertalite type fuel with 20 ml of turpentine oil;
4. and 30% with a PMT code of 30% which means that the sample is a mixture of 70 ml Pertalite type fuel with 30 ml turpentine oil.

The scheme of the vehicle and dynamometer shown in Fig. 1, with description: 1. Tachometer, 2. Torsiometer,3. Personal Computer, 4. Motor holder, 5. Speedometer, 6. Fuel tank, 7. Muffler and 8. Roller dynamometer

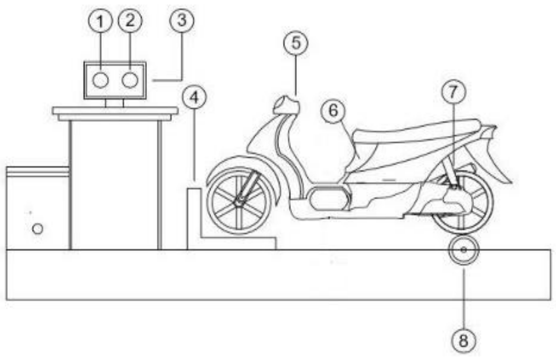

Fig. 1. Schematic of testing torque and power of a motorcycle using a dynamometer

3. Result and Discussion

Testing in conducted by the octane number using the Octane Number Meter Shatox SX-100k with an ambient temperature of 24.2 0C and a humidity of 55%. The results of testing the octane number were carried out three times for data collection and then the average value was taken (Table 4).

Table 4. Octane number test results

Mix Percentage	Octane Number (RON)
PMT 0%	90
PMT 10%	93,8
PMT 20%	94
PMT 30%	94,4

The test results show that the octane number of pure Pertalite is 90 RON. This is following the Pertalite type fuel specifications issued by PT. Pertamina (Persero) [8] which is 90 RON. If viewed as a whole, the addition of turpentine oil volume will increase the octane number of the mixture (Fig. 2)

The increase in octane number is influenced by the presence of oxygenated compounds in the bioadditive (turpentine oil). Turpentine oil is one type of essential oil that can be obtained from pine resin and can be produced from pine tree wood [9]. Some essential oil compounds have oxygenated compounds.

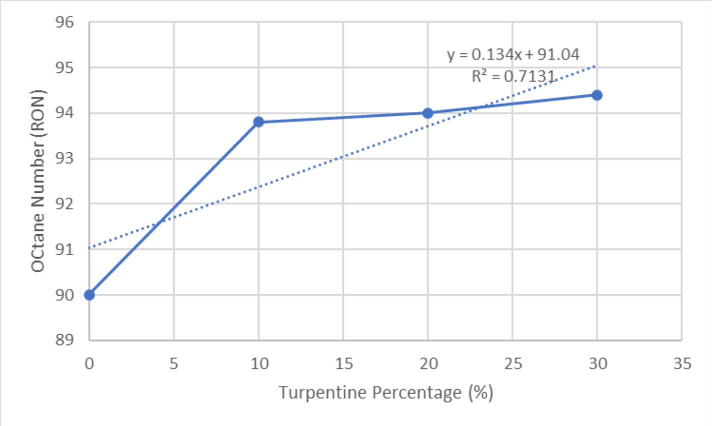

Fig. 2. The effect of adding turpentine oil on the octane number of the mixture

Oxygenate is an organic compound that can dissolve into fuel which can increase the octane number of the fuel [10]. With the presence of these oxygenated compounds, turpentine oil is safer to use than octane boosters from non-oxygenated materials for long-term use.

However, if seen from Fig. 2, it can be seen that the graph of the effect of adding turpentine oil on the octane number of the mixture has low linearity. This can be seen from the value of the coefficient of determination (R2) which is less than 0.9 which is 0.7131. Thus, it is possible that in mixtures above 30%, the octane number of the fuel will increase slowly and even tend not to increase.

Furthermore, the measurement of the heating value used an adiabatic type bomb calorimeter with the addition of oxygen gas pressure in it. The instrument used in measuring this heating value is the PAAR Instrument type 1241 EF PAAR (Table 5).

Table 5. Heating value test results

Mix Percentage	Temperature difference (^{0}C)	Specific Gravity	Heating Value (kJ/Kg)
PMT 0%	1,97	0,74	38632,9
PMT 10%	2,02	0,8	39099,8
PMT 20%	1,86	0,82	39361,2
PMT 30%	1,95	0,84	39573,1

The test results show that the heating value of pure Pertalite is 38632.9 kJ/kg. Same with octane number, the addition of turpentine oil volume is directly proportional to the heating value of the mixture. Here is the graph plot:

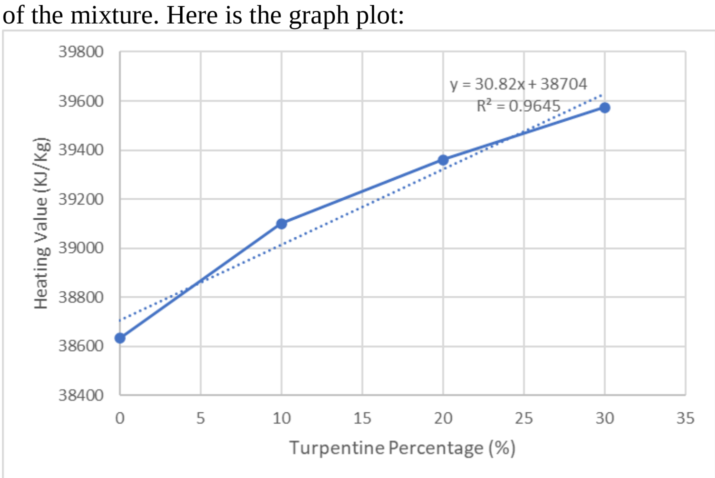

Fig. 3. The effect of adding turpentine oil on the heating value of the mixture

The value of specific gravity affects the mass of fuel injected into the combustion chamber. Fuel with a low specific gravity price indicates that the fuel component undergoes a longer atomization process at the injector and the by-products from the combustion process are still quite a lot [11]. The addition of bio additives will tend to increase the value of specific gravity so that the fuel component is atomized through the injector faster and the particle size is small. The by-product of the combustion process is also much reduced [12] [6]. This is also due to the presence of oxygenate compounds which will complete the combustion process of the mixture in the combustion chamber [10].

From Fig. 3, it can be seen that the graph of the effect of adding turpentine oil on the heating value of the mixture has high linearity. This can be seen from the value of the coefficient of determination (R2) which is more than 0.9 which is 0.9645. Thus, it is very possible for a mixture above 30%, the heating value of the fuel will experience a constant increase.

The next measurement is the measurement of viscosity value using an Ostwald viscometer. The principle used by this measuring instrument is to measure the time required for the liquid to flow at two predetermined points in a vertical capillary tube (Table 6).

Table 6. Viscosity value test results

Mix Percentage	Density (^{0}C)	Viscosity value (cP)	Viscosity value (cSt)
PMT 0%	0,74	0,711	0,923
PMT 10%	0,8	0,709	0,886
PMT 20%	0,82	0,734	0,895
PMT 30%	0,84	0,79	0,941

Generally, the viscometer still measures the dynamic viscosity value or the absolute viscosity of a test solution. Absolute viscosity is a measure of how a fluid resists flow in response to external forces and is usually expressed in units of centiPoise (1 cP = 1 mPa.s). To eliminate the influence of external forces, the viscosity of a liquid fluid is expressed in terms of kinematic viscosity which is expressed in units of centiStokes (cSt = 1 mm2/s). Kinematic viscosity (v) can also be expressed in terms of dynamic viscosity (μ) divided by the density of the fluid (ρ):

$$v = \frac{\mu}{\rho} \quad (3)$$

Fig. 4 shows that the ratio of the mixture of Pertalite and turpentine oil greatly affects the density of the mixed fuel. Where the more turpentine oil content in Pertalite, the greater the density.

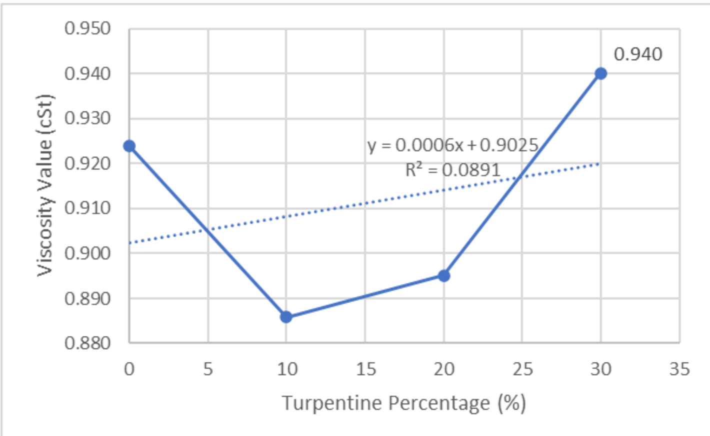

Fig. 4. The effect of adding turpentine oil on the viscosity value

This also affects the viscosity value of the mixed fuel. Fig. 4 shows that the effect of the ratio of the mixture of Pertalite and turpentine oil on the viscosity value is not linear.

Fuel with a higher viscosity will increase the problem of the atomization process and risk damaging the fuel injector. So that it will result in incomplete combustion and reduced engine performance and cause engine damage due to the deposition of solid particles that cannot be burned [13] [14]. The addition of bio additives which results in a decrease in the viscosity value allows the quality of the fogging to be maximized so that the combustion that occurs will be more complete. Lower viscosity values allow the formation of carbon deposits in the engine to be reduced and minimize injection system failures. In addition, the distribution of fuel will be easier because the pump power required to carry fuel from the tank to the combustion chamber is smaller [12].

From Fig. 4, it can be seen that the graph of the effect of adding turpentine oil on the viscosity value of the mixture has low linearity. This can be seen from the coefficient of determination (R^2) of 0.0891. This can happen because the characteristics of each mixed sample have absolute viscosity (cP) and density (g/ml) which are not linear as well. Sequentially the highest viscosity value was in the 30% PMT sample with a viscosity value of 0.940 cSt; PMT 0% 0.924 cSt; PMT 20% 0.895 cSt; and 10% PMT with a viscosity value of 0.886 cSt. The results of the measurement of the overall viscosity value have an appropriate value when viewed from Table 1, which is less than 1 cSt [7].

Table 7. Torque number test results

Engine Speed (rpm)	Torque Number (Nm) PMT0	PMT10	PMT20	PMT30
3000	20,7	22,2	25,1	25,5
4000	18,1	18,7	20,3	21,1
5000	14,5	15,1	15,7	16,2
6000	11,7	12,1	12,9	13,2
7000	8,6	8,8	9,8	10,2
8000	7,9	8,1	9,1	9,2

The test vehicle that was used is an internal combustion engine. The test vehicle performed 4 working steps and carried out combustion in the combustion chamber which was triggered by sparks. The combustion engine utilizes heat energy which is converted into mechanical motion and transmitted to the rear wheels. The output produced from the combustion engine is in the form of torque and power

The test results show that the engine with a mixture of Pertalite fuel with turpentine oil has a torque and power value greater than that of pure Pertalite (Fig. 5 and Fig. 6). This happens because, in the use of a mixture of Pertalite fuel with turpentine oil, the combustion pressure is relatively maximum.

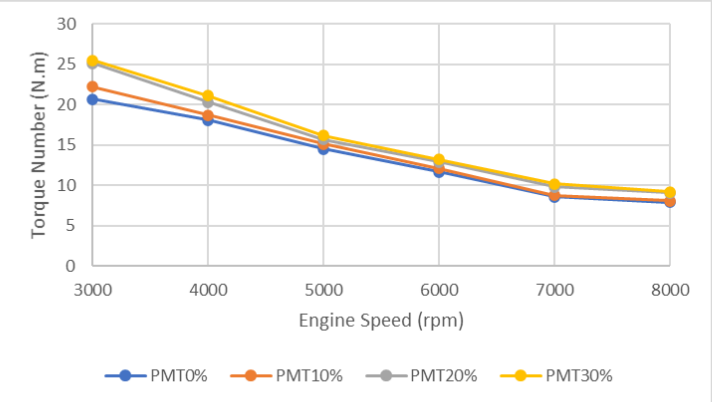

Fig. 5. The effect of the addition of turpentine oil on the torque number

These results are due to the support of a fast and efficient fogging process, compression pressure, and also proper ignition timing with a higher octane number so that the torque and power produced are also maximized. Meanwhile, in the use of Pertalite fuel without a mixture of turpentine oil, the combustion pressure is less than optimal because it has a lower octane number. Low-octane number fuels are flammable at low compression pressures and also an improper ignition [6][10].

Table 8. Power number test results

Engine Speed (rpm)	Power Number (hp) PMT0	PMT10	PMT20	PMT30
3000	8,90	9,50	10,80	10,90
4000	10,30	10,70	11,55	12,10
5000	10,35	10,75	11,25	11,60
6000	10,00	10,30	11,05	11,35
7000	8,60	8,90	9,85	10,25
8000	9,10	9,25	10,50	10,60

A dynamometer or dyno test is a tool used to measure vehicle engine performance in detail and in real time. The data generated is in the form of engine speed (rpm), torque value (Nm), and power (hp) of a test vehicle engine. The information will be processed, recorded, and displayed in graphical form on the screen. Based on its function, the dynamometer is divided into two, the engine dyno and the chassis dyno. The engine dyno measures power and torque at the flywheel. Meanwhile, the chassis dyno measures engine power and torque when the entire vehicle chassis is fully installed, as used in this study (Fig.6).

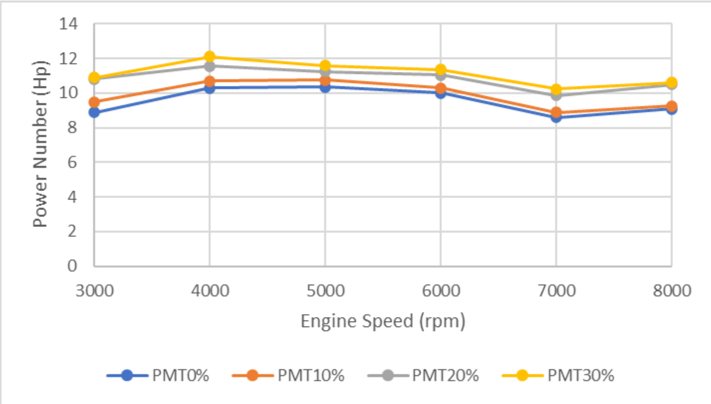

Fig.6 The effect of the addition of turpentine oil on the power number

Specific fuel consumption (SFC) testing shows that for all variations of the fuel mixture, the lowest specific fuel consumption is obtained when the engine speed is at 3000 rpm. The lowest specific fuel consumption in the test vehicle sequentially was the use of pure Pertalite fuel (PMT0), which was 0.340 Kg/Hour.hp at 3000 rpm; PMT10 of 0.348 Kg/Hour.hp at 3000 rpm; PMT20 is 0.350 Kg/Hour.hp at 3000 rpm. and PMT30 which produces a specific fuel consumption of 0.355 Kg/Hour.hp at 3000 rpm (Table 9.).

Table 9. SFC number test results

Engine Speed (rpm)	SFC Number (Kg/Hour.hp) PMT0	PMT10	PMT0	PMT30
3000	0,340	0,348	0,350	0,355
4000	0,417	0,441	0,448	0,454
5000	0,559	0,608	0,624	0,651
6000	0,832	0,964	0,954	0,986
7000	1,290	1,348	1,302	1,34
8000	2,090	2,075	2,342	2,377

The mixture of Pertalite and turpentine oil produces a higher consumption value compared to pure Pertalite. This is because the torque and power in the mixture of Pertalite and turpentine oil increase along with the addition of turpentine oil volume. So that the supply of mixed fuel entering the combustion chamber has increased compared to pure Pertalite fuel (Fig 7). The greater the power and engine speed produced, the greater the fuel consumption [15]. This is because at maximum rotation and loads the combustion process occurs rapidly, thus requiring large amounts of fuel [15] [16] [17].

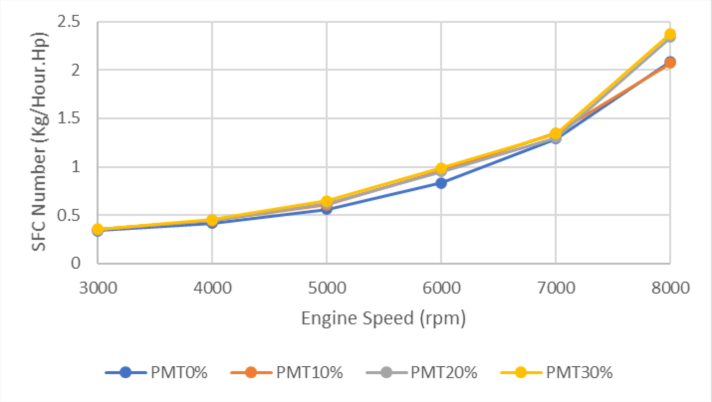

Fig. 7 The effect of the addition of turpentine oil on the SFC number

4. Conclusion

The test results show that the addition of turpentine oil volume will be followed by an increase in the octane number and heating value of the test fuel. The 30% PMT sample has the highest octane number and the heating value indicates the best value, namely 94.4 (RON) and 39573.1 (KJ/Kg). Meanwhile, the best viscosity value is at 10% PMT, which is 0.886 (cSt). Performance test results show that the addition of turpentine oil volume will increase the torque, power, and specific fuel consumption number. The 30% PMT sample produced the highest torque, power, and specific fuel consumption number when used on the vehicle, continuously 25.5 (Nm) at engine speed of 3000 (rpm); 12.1 (hp) at engine speed of 4000 (rpm); and 2,377 Kg/Hour.hp at engine speed of 8000 (rpm).

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