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Research Article

Performance of spark-ignition engine at various fuel octane numbers

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ABSTRACT

The paper describes the performance of a spark-ignition engine at various fuel octane numbers. This study was realised using a 150cc automatic motorcycle with a compression ratio of 10.6:1. The experiments were conducted on three types of gasoline with different research octane numbers (RON), namely 88, 90, and 92. The torque and power of the engine were evaluated using a dyno test, while fuel consumption was simultaneously monitored during the experiments. The data were then collected and analysed using Motorcycle Communication System (MCS). The MCS measurements indicated that fuel with RON 92 allows the vehicle to reach the top speed and rotation at a gas opening angle of 25° - 79°. Applying fuel with the proper octane number in an engine with a particular compression ratio can maintain optimal engine performance. Decreasing the fuel's octane rating from the recommended conditions based on the engine specifications causes a decrease in engine performance. Torque and power tend to drop, and fuel is not economical.

1. INTRODUCTION

The automotive sector is one of the most significant contributors to air pollution. Improved combustion chamber performance is a common strategy to increase thermal efficiency and reduce exhaust emissions [1]. Modern vehicle engines generally have higher specifications in working pressure, impacting the combustion process and temperature. However, if the fuel and combustion conditions are not suitable or optimal for the engine specifications, various abnormal requirements, such as initial ignition, further ignition, and knocking, may occur. When the engine's ignition is too advanced, combustion can occur rapidly, and cylinder pressure rises quickly while the piston is still trying to complete its compression stroke. In addition, an engine can be in optimal operating conditions due to inadequate fuel quality, for example, in terms of octane number. If the temperature in the combustion chamber is higher than the ignition temperature of the fuel, a knock occurs.

In practice, the SI engine performance is influenced by many factors, such as engine design parameters [2]–[4], kinds of fuel [5]–[8], and operating conditions [9]–[12]. The quality of the octane number is generally associated with the compression ratio, which relates to a more efficient combustion process and can meet the CO_2 emission threshold [13]. Exhaust emissions must be controlled, considering some of the adverse effects on human health and ecosystems [14], such as global warming and climate change [15], [16]. It is known that fossil fuels are a significant source of harmful pollutants [17]. The release of particulates (PM), hydrocarbons (HC), nitrogen oxides (NOx), and carbon monoxide (CO) due to combustion gases from the engine combustion process is a fundamental challenge for the use of fossil fuels [18].

Apart from the issue of exhaust gas emissions, most people assume that fuel with a high octane produces higher power than fuel with lower octane, and this certainly needs to be proven, considering that the combustion characteristics are closely related to self-ignition and the octane number of the power.

In Indonesia, various fuel variants have been marketed with different research octane numbers, such as 88, 90, and 92. This octane difference has been designed according to the vehicle's compression ratios. Thus, the combustion process can be more effective.

RON 88 is a liquid fuel used by most gasoline-powered motorcycles. It is a clear yellowish distillate fuel oil with an octane number of 88. This fuel has suitable anti-knock properties and can be used in engines with a compression limit of up to 9.0: 1 in all conditions. However, it is not recommended in motorcycles with high compression due to its potential knocking. This type of fuel has a maximum content of Sulphur (S) 0.05%, lead (Pb) 0.013% (unleaded) and Pb 0.3% (leaded), oxygen (O) 2.72%, dye 0,13 gr/ 100l, the vapour pressure of 62 kPa, the boiling point of 215 °C, and density of 15°C. It combines paraffin, olefins, naphthene, and aromatics hydrocarbons. Its compositions may vary according to the petroleum source and the refining process. Additionally, it has a minimum flame temperature of 360°C, a minimum research octane number (RON) of 88, a motor octane number (MON) of 83-90, a heating value of 44585 kJ/kg, and a specific gravity of 0.723 gr/cm^3.

RON 90 is one of the petrol products that has just been marketed to fuel oil consumers in Indonesia. It is normally produced by adding additives in the manufacturing process at an oil refinery. It is a fuel variant with a quality above RON 88, but it has a lower price than RON 92. It provides better combustion in vehicle engines with the latest technology than RON 88. Consequently, it seems particularly suitable for both two-wheeled and medium-sized vehicles (cars). The main composition of RON 90 is naphtha with RON 65-70. Mixing with the High Octane Mogas Component (HOMC) is a way to increase RON 92-95. In addition to HOMC, the additive EcoSAVE is added. This EcoSAVE additive is not meant to increase the RON but to make engines smoother, cleaner, and more efficient. Naphtha is a material with a boiling point between gasoline and kerosene.

Meanwhile, HOMC is a derived product of naphtha (petroleum component), which has a chemical structure of branches and rings (circumference) with a high-octane number, ranging from 92 to above 98 (perfect combustion power and faster instant). Most of them are either the results of further naphtha processing into products with high octane numbers or the effects of cracking heavy oil into HOMC. The formation of a high-octane number results from a catalytic cracking or a catalytic synthesis in the chemical reactor of the RCC/FCC/RFCC refinery unit or Plat Forming or other catalytic-polymerisation processes.

RON 92 is a type of fuel with an octane number of 92. It is highly recommended for gasoline-fueled vehicles with a high compression ratio (9.1: 1 to 10.0: 1). Additives are normally added to RON 92, so it can clean engines from accumulated deposits on their fuel injectors and combustion chambers. It no longer uses a mixture of lead, which can reduce motor vehicles' poison gas, such as nitrogen oxide and carbon monoxide. It is typically bluish in colour and has a maximum content of sulfur (S) 0.1%, lead (Pb) 0.013% (unleaded type) and Pb 0.3% (leaded type), oxygen (O) 2.72%, dye 0.13 gr/ 100 l, the boiling point of 205 °C, and density of 15°C. It is the latest generation of unleaded motor gasoline with complete additive contents that can clean the intake valve port of the fuel injector and the combustion chamber from carbon deposits. It is also recommended for gasoline-fueled vehicles with high compression ratios. Because of its higher octane content than RON 88, it is believed to provide better engine performance and maintenance. It has an octane rating of 92 with high oxidation stability and low levels of olefins, aromatics, and benzene, resulting in complete combustion in engines. Equipped with the 5th generation additive with the detergent property ensures that fuel injectors, carburettors, inlet valves, and combustion chambers remain clean to maintain optimal engine performance. Furthermore, it no longer uses a mixture of lead and other metals frequently added to other fuels to increase the octane value. As a result, it appears to become an environmentally friendly fuel.

Naturally, fuel with low octane is more flammable. The higher compression ratio in the engine requires higher octane fuel, and high-compression engines cause fuel to burn faster due to high pressure. Low octane fuel initiates the ignition process before the spark plug ignites when applied to an engine with a high compression ratio. The gasoline ignites before the spark plug when the piston goes up to compress. As a result, the piston seems to be struck by the combustion chamber explosion. This event is known as detonation or knocking. This phenomenon is investigated for its effect on engine performance.

In the study, experimental work has been performed to evaluate the impacts of three different kinds of fuel in the spark ignition (SI) engine on the combustion performance, primarily related to the abovementioned problems. The study determines the engine performance characteristics, including torque, power, and specific fuel consumption of various fuels.

2. MATERIALS AND METHOD

In this work, the evaluation of a spark-ignition engine on three various fuels has been performed experimentally. The fuels are RON 88, 90, and 92.

2.1. Preparation

A 150cc automatic motorcycle was prepared for this research. It was made in Vietnam (build-up) and assembled in 2017. It was also in good condition and under periodic maintenance, according to the accompanying manual published by the manufacturer. The specification of the tested engine is given in table 1.

Three types of gasoline, namely RON 88, 90, and 92, were used in this research. They were obtained from the official gas station with precise service standards. Each sort of fuel was provided 4 litres to be poured into the fuel tank on the motorcycle unit. The process of pouring gasoline into the motorcycle tank was by draining the tank first with a standard gasoline suction device. After the tank was completely drained, 4 litres of gasoline were poured into the tank, and the same technique was employed for each type of gasoline.

Table 1. Specification of the tested engine.

Parameter	Specification
Displacement	149.3 cc
Bore x Stroke	0.0573 m x 0.0579 m
Compression ratio	10.6: 1
Power (max)	10.8 kW / 8,500 rpm
Torque (max)	13.2 Nm / 6,500 rpm
Cooling System	Fluid cooling
Ignition Type	Full transistorised
Fuel system	PGM-FI
Oil capacity	0.8 liters
Dry weight	131 kg
Dimension (LxWxH)	1.923 m x 0.745 m x 1.107 m
Fuel tank capacity	4.2 litres
Transmission	V-Matic

2.2. Experiments

The measurements of this research were carried out using two tools, namely MCS (Motorcycle Communication System) and Dyno Test. MCS (Motorcycle Communication System) is a Japanese production tool intended for authorised repair shops throughout Indonesia (See Figure 1). The workshop for this research was located in Mataram, West Nusa Tenggara.

This tool principally diagnoses motorbikes using electronic control technology, allowing users to check and analyse electrical circuits integrated with the ECM and all sensor and injection system functions.

A 150cc automatic motorcycle was prepared for this research. The Motorcycle Communication System (MCS) has provided data on the throttle angle in degrees, engine speed in rpm, motorcycle speed in km/h, fuel injection time in milliseconds, and vehicle voltage sensors. Measurements were made by pulling the gas lever from idle to maximum rotation and then recorded for approximately 30 seconds.

Figure 1. MCS chain and data collection process for the motorcycle unit.

2.3. Formulations

According to the fundamental theorem, brake torque (BT) is calculated by:

$$BT = F \; x \; L \; (Nm) \quad (1)$$

where F is the force (N), and L is the length of the torque arm.

The water brake measures the brake power:

$$BP = 1.047 \; x \; 10^{-4} x \; BTx \; n \; (kW) \quad (2)$$

Where BP is the brake power (kW), n is the round of the engine, and BT is the engine's torque.

Brake-specific fuel consumption:

$$BSFC = \frac{mf}{BP} \left(\frac{kg}{kW}.hr\right) \tag{3}$$

Where BSFC is the brake-specific fuel consumption $\left(\frac{kg}{kW}.hr\right)$, and m_f is the fuel mass (kg/hr).

3. RESULTS AND DISCUSSION

This research has been carried out using a 150cc automatic motorcycle with three different types of gasoline, namely RON 88, 90, and 92. The results and discussion are as follows:

3.1. Motorcycle Communication System

Figure 2 gives the recorded data using MCS for three different fuels. Using RON 88, the vehicle experienced a gradual increase in both rotation and speed. At 7° throttle opening, rotation and speed are 4745 rpm and 33 km/hour, respectively. The growth continues up to 9140 rpm and 102 km/h after the throttle angle of 18°. In the range of 18° - 32°, the speed from 9140 rpm increases to 9545 rpm, and the speed increases from 102 km/hour to 107 km/hour. At an angle of 35° - 79°, the rotation varies from 9602 rpm to 9662 rpm, and the speed ranges from 108 - 109 km/h.

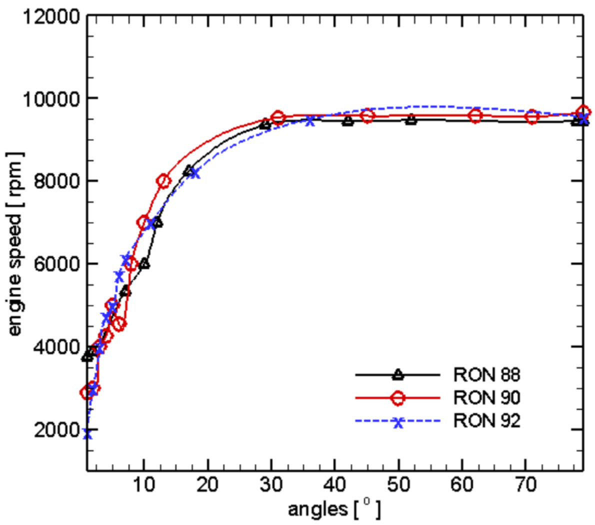

Figure 2. The characteristics of engine speed

With RON 90, there is a steady rotation increase from 3112 to 8873 rpm. The speed increases from 12 - 98 km/hr after shifting the angle from 2° to 23°. From 23° to 37°, the rotation moves from 8873 to 9323 rpm and the speed from 98 to 103 km/hr. Then, at 62° - 79°, the highest rotation is between 9486 - 9668 rpm, and the highest speed is between 107 - 108 km/hr.

Meanwhile, the vehicle's rotation and speed increase linearly from 3147 rpm and 12 km/hr to 9024 rpm and 101 km/hr at a range of 2° - 19°, when applied fuel with RON 92. Changes from 19° to 23°, the rotation slightly increased from 9024 to 9301 rpm, and the speed increased from 101 to 105 km/h. At an angle of 25° - 79°, revolutions range from 9618 to 9668 rpm and speeds from 108 to 109 km/h.

3.2. Engine Performance

Figure 3 shows brake torque at engine speed between 2000-9500 rpm, with variations of three fuels using different octane numbers. Engine torque looks higher with the increase in octane number, which is very noticeable, especially at mid-range. By the engine specification, the optimum torque reaches 13.04 Nm at an engine speed of 6500 rpm when the engine applies the RON-92 fuel variant. Meanwhile, torque decreases when using fuel with the RON number below it. These findings are similar to available trend data by other researchers [19][20].

The average torque reduction reaches 27.3% when the engine changes fuel from an octane number of 92 to 90. Meanwhile, the average torque decrease is up to 44.69% when changing fuel from an octane number of 92 to 88. It agrees well with available open literature trend data [21].

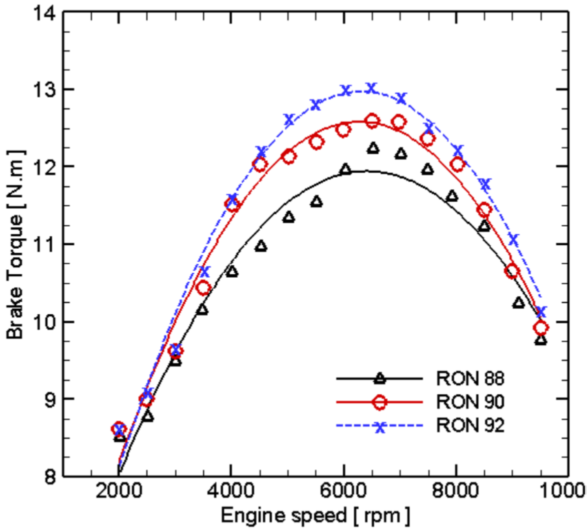

Figure 3. The characteristics of brake torque

In line with torque characteristics, the engine power can be expressed in Figure 4. Brake power reaches its peak at an engine speed of 8500 rpm, and decreases due to the weakening of torque at higher rpm. High and low octane number plays an essential role in power output, and several researchers note that the calorific value tends to be similar between low and high octane numbers [22][23], and there is a slight discrepancy between them [24][25].

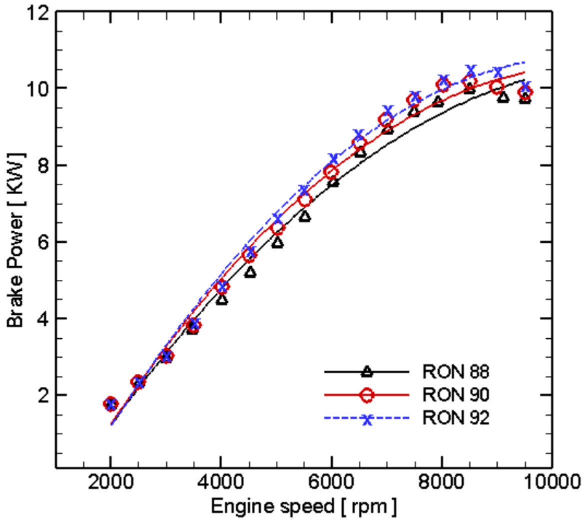

Figure 4. The characteristics of brake power

Figure 5 indicates the fuel consumption of three different fuel variations. Using a higher octane number looks more efficient because it follows the specifications of a high engine compression ratio. Meanwhile, using low-octane fuel tends to be a bit more wasteful, considering that this fuel is designed for engines with lower compression ratios. Therefore, the fuel used must be suitable to get more optimal combustion.

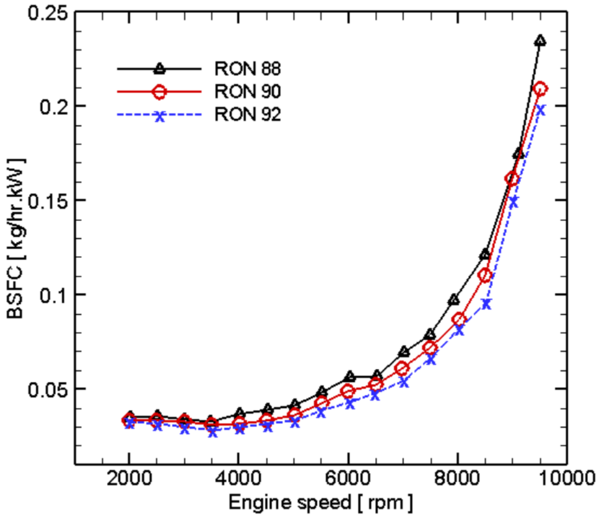

Figure 5. The characteristics of fuel consumption

4. CONCLUSION

The engine performance has been experimentally investigated on three fuel types: RON 88, 90, and 92. In summary, using fuel with a proper octane number in an engine with a specific compression ratio can maintain optimum engine performance. The decrease in the octane value of the fuel from the recommended conditions according to the engine specifications causes a reduction in engine performance. Torque and power tend to drop, and the fuel is more wasteful.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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