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Performance Of a 160 cc Four-Stroke Engine Using Non-Programmable Aftermarket CDI And Aftermarket Ignition Coil When Operating With Three Types Of Gasoline

(Kinerja Motor Empat-Langkah 160 cc yang Menggunakan CDI Aftermarket *Non-Programmable* dan Koil Pengapian Aftermarket Ketika Beroperasi dengan Tiga Jenis Bahan Bakar Bensin)

TEDDY NURCAHYADI, WAHYUDI, DWI ISNAINI RUSWANTO, FITHRIO MANGGALA RAMADHANI, BURHANNUDIN SIDIQ, WAHYU TRI HANDOKO

ABSTRACT

Ignition timing and output voltage must be re-tuned when the engine used different types of fuel. This research aimed to investigate the effectiveness of CDI and ignition coil upgrade, both separately and combined, when various types of fuel was used by the engine. This research was done on a 160 cc four-stroke engine of a Honda motorcycle with compression ratio 9:1. The types of fuel used by the engine in this research was RON 88, RON 90, and RON 95 gasoline fuels. The engine's torque was measured on an inertial type motorcycle chassis dynamometer. The fuel consumption data was obtained by on road test, the value of the data was calculated by dividing the distance being traveled with the volume of fuel being consumed. The result of this research showed that when RON 88 gasoline was used, the influence of aftermarket CDI and aftermarket ignition coil gave almost comparable impacts to the increase of torque. The combination of aftermarket CDI and aftermarket ignition coil was found to influence the largest torque increase percentage of 5.3% when RON 90 gasoline was used. When RON 95 gasoline was used, the aftermarket ignition coil influenced the largest torque increase percentage of 4.3% at lower engine speed and 7.4% at higher engine speed. The aftermarket CDI and aftermarket ignition coil, whether used separately or combined, always gave worse impact to fuel consumption when RON 88 and RON 90 gasoline was used. The opposite is true when RON 95 was used.

Keywords: Spark Ignition Engine, Ignition System, Aftermarket CDI, Aftermarket Ignition Coil

INTRODUCTION

Ignition system holds important role in spark ignition engine by providing ignition spark at sufficiently high temperature at the right moment needed by the engine. Two of the most important ignition components are Capacitor Discharge Ignition (CDI) and ignition coil. The main roles of CDI are to regulate the ignition timing and to raise electricity voltage before being supplied to the ignition coil. The aftermarket CDIs are often regarded to be better than OEM (Original Equipment Manufacturer) components in terms of higher ignition voltage, easier ignition timing mapping, and far higher engine speed operation limit. The impact of OEM CDI replacement with aftermarket CDI (unlimiter type) in a 110 cc four-stroke engine was studied by Alwi et.al. (2017). The result of the study showed that the use of the aftermarket CDI had caused 26.6 % and 4.6 % increase in engine's power and torque, respectively, at engine speed of 8000 rpm and 6500 rpm. The type of gasoline used in Alwi et.al. (2017) experiment, however, was not stated. Purnomo et.al. (2012) investigated the use of Hyper Band digital CDI on a 135 cc four-stroke engine using RON 88 gasoline fuel. In the data reported from the research, the use of the aftermarket CDI was only able to increase the engine's torque for up to 3.23% at 8000 rpm. Sigit et.al. (2013) investigated the use of a dual band CDI in a 150 cc four-stroke engine using RON 92 gasoline fuel. The use of the aftermarket CDI was reported to cause up to 7.1% increase in engine's torque at 8000 rpm. Machmud et.al. (2013) investigated the influence of advanced ignition timing to the performance of a 100 cc four-stroke engine using RON 88 gasoline fuel. The ignition advance variations was done in the experiment by varying the position of trigger magnet for 3^o and 6^o ignition advances. The ignition advance variations, reported in the experiment, had increased the engine's torque for up to around 6.9 % at 8000 rpm.

The roles of ignition coil are to raise the voltage higher and to supply it to the spark plug. The aftermarket coils are considered to be able to provide higher voltage for the spark plug if compared to the OEM components. Maulana and Wulandari (2016) had investigated the use of car ignition coils to replace the ignition coil of a 115 cc four-stroke motorcycle engine. The effect of the replacement was reported to produce increase in power and torque of up to 40 % and 20 %, respectively, at 3000 rpm engine speed. Lesser increase of power and torque were observed at higher engine speed. Engine fuel consumption was observed to be also higher when the non-OEM ignition coil was used. The experiment done by Suarnata et.al. (2017) had investigated the use of KTC ignition coil combined with OEM CDI to the performance of a 115 cc four-stroke engine. The use of the aftermarket ignition coil in Suarnata et.al. (2017) had made the engine to produce a better power output but at the expense of worse fuel consumption, if compared with the use of OEM CDI combined with OEM ignition coil. The type of the gasoline used by the engine, however, was not reported in Suarnata et.al. (2017). Anfarozi (2013) studied the influence of ignition coil output voltage to the performance of a 125 cc four-stroke engine using RON 88 gasoline fuel. The data of the study showed that the ignition coil with highest output voltage used in the experiment had been able to cause for largest decrease of 6.8% in engine's fuel consumption at 6000 rpm, highest increase of 7.9% in engine's torque at 6500 rpm, and highest increase of 21.7% in engine's power at 9000 rpm. Oetomo et.al. (2014) measured and compared the value of electrical resistance and output voltage of OEM ignition coil with aftermarket ignition coil. The aftermarket ignition coil was found to have 63.6% and 6% lower electrical resistance for its primary and secondary windings, respectively. The effective output voltage of the aftermarket ignition coil was calculated to have value of up to 73.3% higher than the output voltage of OEM ignition coil. With comparative benefit owned by the aftermarket ignition coil, it was reported to have caused the engine to deliver of up to 40.1% maximum increase and 13.7% average increase in power. Subroto (2009) compared the influence of two aftermarket ignition coils with an OEM ignition coil. The use of the ignition coil was reported to have caused up to 30% increase in torque and 43% increase in Specific Fuel Consumption (SFC), if compared with the OEM ignition coil.

Most of the previous studies investigate the influence of aftermarket CDI and aftermarket ignition coil separately to the performance of four-stroke engine without testing the effectiveness of the ignition components replacement when faced with different types of gasoline fuel. The replacement of OEM CDI and OEM ignition coil with their aftermarket counterparts is not always done in condition when more performance output is expected. Ignition timing and output voltage must also be re-tuned when the engine used different types of fuel. Therefore, the replacement of OEM CDI and OEM ignition coil with their aftermarket counterparts also needed to be done in this condition. Fuel with RON value lower than required will caused self-ignition and knock in a gasoline engine (Pulkrabek, 1997) and thus lowering the engine performance. Fuel with RON value higher than required will cause reduction on the engine performance due to its longer ignition delay. To overcome the problem related to the longer ignition delay, the ignition timing can be advanced so that the time available for the whole combustion process will also be longer. The aftermarket CDIs are usually tuned with advanced ignition timing. How well the aftermarket CDI combined with aftermarket ignition coil can improved engine performance when using fuel with different RON values is interesting to study. This research aimed to investigate the effectiveness of CDI and ignition coil upgrade, both separately and combined. The performance of each ignition system configuration when the engine used various types of fuel also being tested in this research.

EXPERIMENTAL SETUP

In this research, the effects of CDI and ignition coil replacement was studied, both individually and combined. The specification comparison of OEM and aftermarket CDI and ignition coil is presented in Table 1 and Table 2. The aftermarket CDI used in this research was a

BRT Powermax Hyperband CDI. As can be seen in Table 1, the aftermarket CDI has a higher output voltage than the OEM CDI. Other than the specifications listed in Table 1, the major difference of the aftermarket CDI compared to the OEM CDI is the presence of an unlimiter function which will disable the engine's maximum revolution speed restriction. The aftermarket CDI is a non-programmable type, which means that it cannot be used to fine-tune the ignition timing to match the engine's requirement at different operation conditions. Since the aftermarket CDI is intended to be used for racing, it is assumed that the aftermarket CDI has more advanced ignition timing.

TABLE 1. The specification comparison of OEM and aftermarket CDI

Specification	OEM CDI	Aftermarket CDI
Type	Digital DC System	Digital DC System
Operating voltage	12 VDC	8 to 18 VDC
Current consumption	0.1 to 0.9 A	0.1 to 0.9 A
Max output	250 V	300 V
Operation temp.	n/a	-15^{o} to 80^{o} C
Operation freq.	n/a	400 to 20,000 rpm

This research was done on a 160 cc four-stroke engine of a Honda motorcycle with compression ratio 9:1. The engine is air cooled and its fuel supply system is carburetor. The engine performance parameters being measured are torque and fuel consumption. The torque was measured on a Rextor Pro Dyno V 3.3 (inertia type motorcycle chassis dynamometer). The fuel consumption data was obtained by on road test, the value of the data was calculated by dividing the distance being traveled with the volume of fuel being consumed.

The aftermarket ignition coil used in this research is a KTC ignition coil which specifications is almost identical with the OEM ignition coil, except for the higher winding ratio and the higher output voltage. The configuration variation of ignition system tested in this research and its influence to the ignition characteristic is listed in Table 3. The use of the aftermarket ignition components was also tested by operating the engine using various type of fuel produced by Pertamina, which has different RON values of 88, 90, and 95.

TABLE 2. The specification comparison of OEM and aftermarket ignition coil

Specification	OEM Ignition Coil	Aftermarket Ignition Coil
Primary windings	100 turns, ø 1.5 mm wire	100 turns, ø 1.5 mm wire
Secondary windings	125,000 turns, ø 0.5 to 1 mm wire	150,000 turns, ø 0.5 to 1 mm wire
Output voltage	15 kV to 35 kV	60 kV to 90 kV

TABLE 3. The configurations of ignition system and its estimated ignition characteristic

No	Configuration	Est. Ignition Timing	Est. Ignition Voltage Value
1	OEM CDI & OEM Ignition Coil	Standard	Lowest
2	Aftermarket CDI & OEM Ignition Coil	Advanced	Medium
3	OEM CDI & Aftermarket Ignition Coil	Standard	Medium
4	OEM CDI & Aftermarket Ignition Coil	Advanced	Highest

Data provided by Heywood (1988) showed that difference in ignition characteristic will give more significant impact to engine's fuel consumption when air-fuel mixture approaching lean condition. In order to eliminate the influence of air-fuel mixture variations, the carburetor setting was kept unchanged throughout the experiment. The difference in performance parameters measured in this experiment is expected to be influenced only by difference in fuel types and ignition system configurations.

RESULTS AND DISCUSSION

The intensity of fuel evaporation and mixing at lower engine speed is lower than at higher engine speed due to the slower fluid motion (Pulkrabek, 1997). Based on the experiment result shown in Figure 1 to Figure 3, the different ignition system configurations were observed to be more capable to deliver impact at lower engine speed. The characteristics of the engine's torque increase found in this experiment is almost exactly the same as what had been found in the experiment of Maulana and Wulandari (2016). If calculated in increase percentage, however, the same value of torque increase will have higher increase percentage at low engine speed than at high engine speed due to the higher torque produce at the lower engine speed.

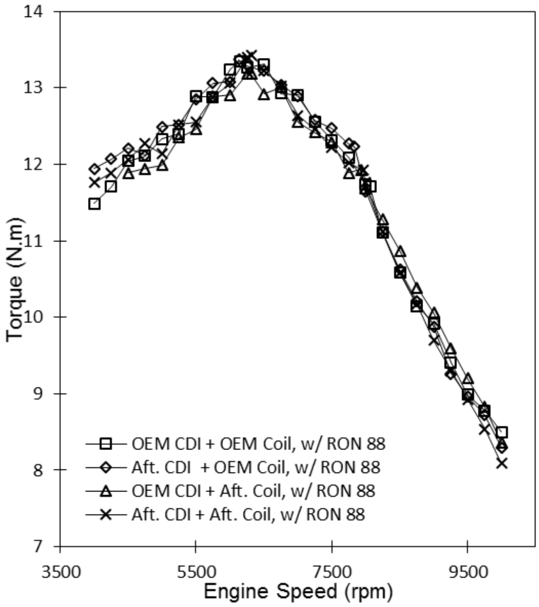

FIGURE 1. Engine's Torque when using various ignition system configurations with RON 88 gasoline as fuel

For each fuel type being used, the best engine's torque characteristic was achieved by different ignition system configurations. The engine used in this research has 9:1 compression ratio which according to the data provided by Pulkrabek (1997) should use gasoline fuel with RON value no lower than 88 as its standard fuel. Figure 1 shows that when the engine used RON 88 gasoline as fuel, the ignition system configuration #2 (aftermarket CDI combined with OEM ignition coil) and #4 (aftermarket CDI combined with aftermarket ignition coil) influenced a maximum torque increase of 1.4% and 1.3%, respectively. At high engine speed, however, the ignition system configuration #3 (OEM CDI combined with aftermarket ignition coil) was the configuration that able to give best maximum torque increase of 2.7% at 7750 rpm. This result had the same characteristic as the result of Anfarozi (2013). If engine's torque data in Figure 1 is related with engine's fuel consumption data in Figure 4, the ignition system configuration #2, #3, and #4 had caused the engine to deliver 11.6%, 10.7%, and 16.5%, respectively, worse fuel consumption if compared to the value delivered by the engine when using ignition system configuration #1 (OEM CDI combined with OEM ignition coil. Therefore, it is found that the ignition system configuration #3 achieved the largest percentage of torque increase with the smallest percentage decrease of fuel consumption.

When the engine used RON 90 gasoline fuel, the ignition system configuration #4 had made the engine to deliver the largest torque increase percentage of 5.3% at 5500 rpm, as shown in Figure 2.

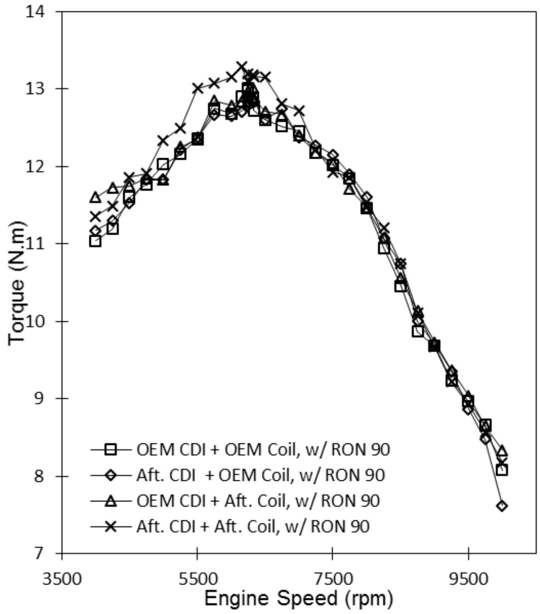

FIGURE 2. Engine's Torque when using various ignition system configurations with RON 90 gasoline as fuel

If compared based on octane number value, the combustion of RON 90 gasoline should have higher Self Ignition Temperature and longer Ignition Delay time than the combustion of RON 88 gasoline. Hence, for the same combustion chamber geometry and the same engine operating condition, the combustion of RON 90 require higher ignition temperature and longer time to complete than the combustion of RON 88 gasoline. The higher ignition temperature requires a higher ignition voltage and the longer combustion period requires the ignition timing to be advanced at an earlier period. Based from the ignition characteristic estimation in Table 3, both the ignition system configuration #2 and #4 should be able to fulfil the requirements for the combustion of RON 90 gasoline. According to data in Figure 2, however, ignition system configuration #4 was the configuration that enabled the engine to deliver its best torque characteristic. This means that the extra high ignition voltage produced by the ignition system configuration #4 had help to improve the engine's torque characteristic. Considering the fuel consumption data in Figure 4 for RON 90 gasoline fuel, the largest engine's torque increase percentage enabled by the ignition system configuration #4 was achieved with worst (13.7%) change percentage of fuel consumption. This means that the better engine's torque characteristic achieved with ignition system configuration #4 was not achieved solely by the ignition system but also by the more fuel quantity being used in combustion process.

The largest torque increase percentage of 4.3% at 5750 rpm and 7.4% at 10,000 rpm delivered by the engine when using RON 95 gasoline fuel was achieved when the engine used ignition system configuration #3, as being shown in Figure 3.

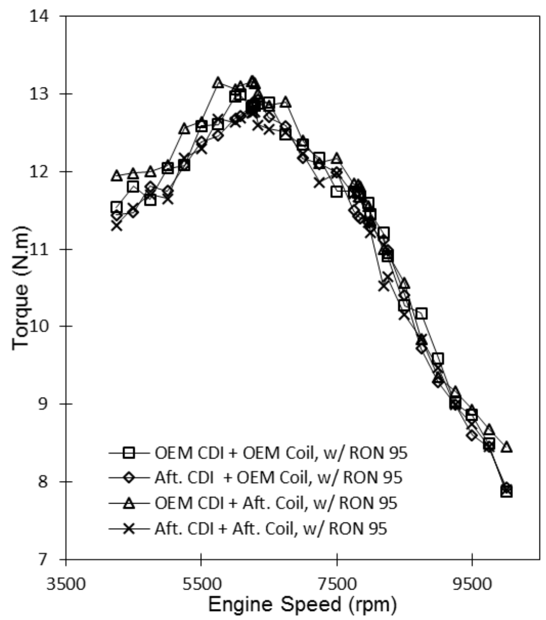

FIGURE 3. Engine's Torque when using all ignition system configurations with RON 95 gasoline as fuel

The combustion of RON 95 gasoline fuel should have a higher Self Ignition Temperature and a longer Ignition Delay time than the combustion of RON 90 gasoline fuel, therefore, a higher ignition voltage and an earlier spark ignition will be required for the combustion to yield the best result. It is interesting that ignition system configuration #3 could have a better result than configuration #2 and #4. It seemed that when using RON 95 gasoline fuel, the ignition timing advance could not give beneficial impact to the improvement of torque characteristic of the engine. The impact of higher ignition voltage of the aftermarket ignition coil was proven to be more prevalent than the influence of advanced ignition timing of the aftermarket CDI used in this research when the RON 95 gasoline was used by the engine. The inability of the aftermarket CDI used in this research to provide more impact to engine's torque characteristic was probably due to the degree of ignition advance it provided was far less than needed by the combustion of RON 95 gasoline fuel.

Taking the fuel consumption into consideration, the use of RON 95 gasoline fuel had also yielded a different engine's torque and fuel consumption characteristic if compared with the use of two other lower RON gasoline fuel. When using the RON 88 and RON 90 gasoline fuel, the best engine's torque characteristics was achieved with the worst fuel consumption. On the contrary, when using RON 95 gasoline fuel, the best engine's torque characteristic was also achieved with the best fuel consumption. This means that the best torque characteristic when using RON 95 gasoline fuel was influenced more dominantly by the use of ignition system configuration #3 rather than by the larger amount of fuel being consumed.

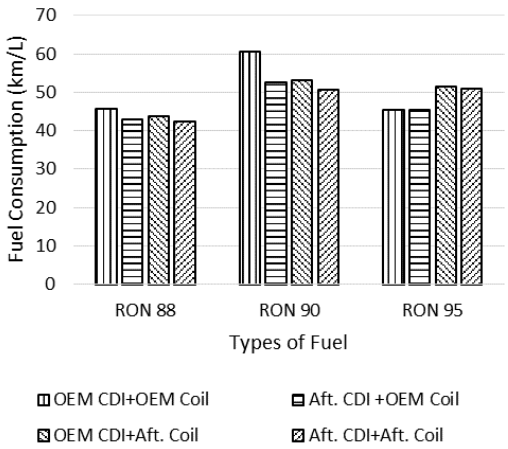

FIGURE 4. Engine's fuel consumption when using all fuel types with all ignition system configuration

The impact of fuel types and ignition system configurations to engine's fuel consumption is presented in Figure 4. The use of RON 90 gasoline fuel yielded the best fuel consumption for the engine. The largest difference in fuel consumption due to difference in ignition system occurred when the engine used RON 90 gasoline fuel, followed by RON 95, and the least difference in fuel consumption due to difference in ignition system occurred when the

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engine used RON 88 gasoline fuel. The ignition system configuration #1 exceeded the other ignition system configurations in term of the best fuel consumption when the engine used RON 88 and RON 90 gasoline fuel. When the engine used the RON 95, however, the ignition system configurations #1 was no longer able to contribute the best fuel consumption for the engine.

CONCLUSIONS

The impacts of four ignition system configurations and three gasoline fuel types to the performance of a 160 cc four-stroke engine had been investigated in this research. The following conclusions are made based on this research parameter and output data:

1. When RON 88 gasoline was used by the engine, the influence of aftermarket CDI and the influence aftermarket ignition coil used in this research gave almost balance impacts to the increase percentage of torque. The aftermarket CDI exceled at low engine speed with 1.4% increase percentage while the aftermarket ignition coil exceled at high engine speed with 2.7% increase percentage.
2. When RON 90 gasoline was used by the engine, the combination of aftermarket CDI and aftermarket ignition coil influence the largest torque increase percentage of 5.3% at lower engine speed.
3. When RON 95 gasoline was used by the engine, the use of aftermarket ignition coil influence the largest torque increase percentage of 4.3% at lower engine speed and 7.4% at higher engine speed.
4. The use of aftermarket CDI and aftermarket ignition coil, whether separately or combined, always gave worse impact to fuel consumption when the engine used RON 88 and RON 90 gasoline. When RON 95 gasoline was used, however, the aftermarket ignition coil and the combination of aftermarket CDI with aftermarket ignition coil were able to influence the engine to deliver an improved its fuel consumption characteristics.

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Authors :

Teddy Nurcahyadi

Mechanical Engineering Study Program, Engineering Faculty, Universitas Muhammadiyah Yogyakarta, Yogyakarta.

Email: nurcahyadi@umy.ac.id

Wahyudi

Mechanical Engineering Study Program, Engineering Faculty, Universitas Muhammadiyah Yogyakarta, Yogyakarta.

Email: wahyudi_stmt@yahoo.co.id

Dwi Isnaini Ruswanto

Mechanical Engineering Study Program, Engineering Faculty, Universitas Muhammadiyah Yogyakarta, Yogyakarta.

Email: dwi.isnaini@ft.umy.ac.id

Fithrio Manggala Ramadhani

Mechanical Engineering Study Program, Engineering Faculty, Universitas Muhammadiyah Yogyakarta, Yogyakarta.

Email: fithio.manggala@ft.umy.ac.id

Burhannudin Sidiq

Mechanical Engineering Study Program, Engineering Faculty, Universitas Muhammadiyah Yogyakarta, Yogyakarta.

Email: burhannudin.sidiq@ft.umy.ac.id

Wahyu Tri Handoko

Mechanical Engineering Study Program, Engineering Faculty, Universitas Muhammadiyah Yogyakarta, Yogyakarta.

Email: wahyu.tri@ft.umy.ac.id