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Research Article

Experimental Study of Spark Ignition Engine Performance under Different Electronic Control Units, Hole Injectors and Spark Plugs

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Abstract

The passage discusses the use of technology in vehicle fuel systems, specifically the injection system technology that is replacing conventional fuel systems. One crucial component of the fuel injection system is the Engine Control Unit (ECU), which controls the distribution of current to all engine components. While standard ECUs used on motorcycles today have limitations, racing ECUs provide more quality and can improve engine performance. The study aims to evaluate the engine's performance after modifications with an upgraded racing ECU using an 8-hole injector and racing spark plugs in the ignition system to enhance the motorcycle's performance. The methods and analysis section details the tools utilized, including the chassis dynamometer, and the parameters used in the study. The results and discussions section presents the collected data and compares it with previous studies to validate the observations.

Keywords: *engine performance, racing ECU, spark plug, hole injector*

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INTRODUCTION

Currently, the automotive technology world is developing very rapidly. Several innovations continue to be made to create more efficient vehicles. One of the applications of technology in vehicle fuel systems is the use of injection system technology, the successor technology to conventional fuel systems (carburetor). The injection system is the process of absorbing fuel into an electronically controlled combustion chamber through an existing sensor by adjusting the needs of the engine in order to produce perfect combustion.

One important component of the fuel injection system is the ECU (Engine Control Unit), which serves as a controller of the current distribution to all the engine components, for example, from the fuel pump to the injector. This ECU has several functions, such as injector timing (IT), ignition timing (IGT), and controlling the fuel supply. With this advantage, the amount of fuel mass and injection time can be controlled with precision. However, the very short time with variable speeds makes the standard ECU of the manufacturer used on motorcycles today have limitations, one of which is the less-than-maximum acceleration when used for high speeds and engine turns. Currently, a wide range of racing ECUs are available on the market that provide more quality compared to the standard ECU. This replacement of the ECU is predicted to improve the performance of the 4-step gasoline engine [1–3]. According to Afwan and Rahardjo [4], the use of different types of ECUs and injectors had an influence on the torque and power generated by motorcycles. Furthermore, according to Setyo and Utoro [2], the change in mapping the ECU to correct the amount of fuel and ignition time leads to a character of the engine that corresponds to the purpose of use.

Numerous studies [5–9] investigate the effects of racing ECUs on the performance and emissions of motorcycle engines. The studies found that racing ECUs can improve engine performance by increasing power output, torque, and engine speed while reducing fuel consumption. However, some studies have found that the use of racing ECUs may also increase emissions of pollutants such as NOx and CO. On the other hand, modifying a fuel system, such as adding a number of hole injectors [10–12] and an ignition system such as a spark plug [13–17], can significantly affect engine performance and emissions. It means the number variation of the hole injector can provide better fuel delivery to the engine, resulting in improved combustion efficiency and increased power output. Moreover, variations in the spark plug ignition system can generate a more potent spark that ignites the fuel mixture faster, leading to better acceleration and overall performance. These modifications can also improve the motorcycle's fuel economy and reduce emissions, making it more environmentally friendly. Thus, upgrading the racing ECU with these systems can be a cost-effective way to improve motorcycle performance without significant engine modifications.

To determine the effectiveness of these modifications, it is necessary to measure engine performance using the upgraded racing ECU. In this study, a racing ECU using an eight-hole injector and racing spark plug will be used to test engine performance. The data collected from the tests will also be analyzed to identify any areas where further improvements can be made. By evaluating the engine's performance after the modifications, we can understand the benefits of using the eight-hole injector and racing spark plug ignition system and optimize the motorcycle's performance to meet specific requirements. This study aims to provide valuable insights into upgrading motorcycle engines with minimal modifications to enhance their performance and efficiency.

METHODS AND ANALYSIS

Figure 1 illustrates the tools utilized in the investigation, including the chassis dynamometer, which is utilized to evaluate the engine power and torque of a single cylinder. Following the acquisition of data, it is transferred to a PC monitor for display.

Table 1. Engine spesifications

Engine Type	Gasoline Engine
Configuration	Single cylinder, 4 stroke
Comparison ratio	9.5:1
Displaced volume	108.2
Electronic Control Unit (ECU)	Standard, Racing ECU (BRT racing Juken 5 Turbo
Spark plug	Standard, Racing
Fuel delivery system	Injection (PGM FI)
Fuel specification	Premium
Number of hole injector	6 , 8

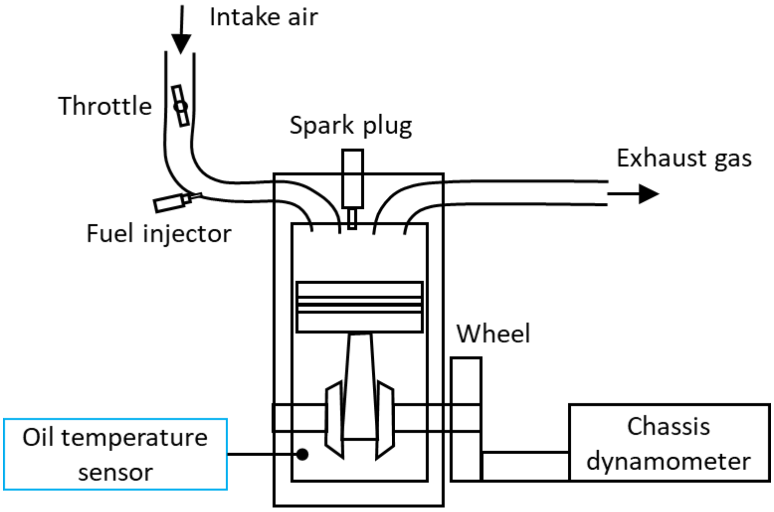

Figure 1. Optical set-up of chassis dynamometer

Prior research has employed this same chassis dynamometer, as evidenced by previous works [18–19].

The optical setup of a chassis dynamometer involves several crucial components, such as the intake air system, throttle, injector, spark plug, oil temperature sensor, chassis dynamometer, and exhaust gas measurement equipment. The intake air system is responsible for delivering air to the engine, while the throttle controls the amount of air entering the engine. The injector injects fuel into the engine, and the spark plug ignites the fuel to generate power. The oil temperature sensor monitors the temperature of the engine oil to ensure proper lubrication. The chassis dynamometer is used to measure the power output of the engine while it is under load. These components form a comprehensive optical setup that is essential for accurately measuring the engine's performance.

The research conducted utilized a single cylinder with premium fuel. Several parameters were employed in this study, including: Standard (consisting of a standard ECU, 6-hole injector, and standard spark plug); Type A (racing ECU, 6-hole injector, and standard spark plug); Type B (racing ECU, 8-hole injector, and standard spark plug); and Type C (racing ECU, 8-hole injectors, and racing spark plug), all with a compression ratio of 9.5:1. These parameters were adjusted for each of the three tests. The engine specifications can be found in Table 1.

RESULTS AND DISCUSSIONS

Validate current study observations with previous study

The results of the current study were compared with those of previous studies conducted by Solikin [20], and the comparison is depicted in Figure 2. The figure shows the torque and engine power at different engine speeds (rpm). It can be observed from the figure that the torque values decrease as the engine speed increases, a trend that is consistent across all the studies, both current and previous.

Furthermore, Figure 2 also illustrates that the engine power reaches its maximum value at 8,000 rpm, after which it decreases with the increase in engine speed. This behavior holds true not only for the current research data but also for the previous studies conducted by Solikin. These findings suggest that there is a tradeoff between torque and engine power, and the engine's rotational speed plays a crucial role in this tradeoff. The results of this study provide valuable insights for optimizing engine performance by balancing the torque and power characteristics of the engine across a range of rotational speeds.

The comparison of the torque and engine power values between the previous and current studies revealed that the former had higher values than the latter. Although the exact values of torque and engine power differed between the two studies, the overall trendline remained the same. It can be inferred that the compression ratio of 110 cc, which was the same in both studies, played a significant role in determining the torque and power characteristics of the engine.

Despite the differences in the absolute values of torque and engine power between the two studies, the similar trendline indicates that the engine's behavior remained consistent over time. It is important to note that torque and engine power values are not the only factors that determine an engine's performance; other factors such as fuel efficiency, emissions, and durability must also be considered when evaluating engine performance. Overall, the results of this comparison provide valuable insights into the behavior of engines with a compression ratio of 110 cc and highlight the importance of considering multiple factors when evaluating engine performance.

Effects of Electronic Control Unit, Hole Injector and Spark Plug on Torque and Engine Power

The graphical representation of the engine's torque resulting from the test is depicted in Figure 3. This figure shows the engine torque at different engine speeds (rpm) under standard, Type A, Type B, and Type C parameters. The graph demonstrates that engine torque decreases with an increase in engine speed.

Based on the comparison, the torque of the engine using Types A, B, and C is larger than the standard data at low turns (4000–5000 rpm). This is due to the racing ECU, which is designed to be more responsive, particularly in the settings of incineration and fuel that affect the combustion process. Even under standard conditions without any modifications to the incineration or fuel mapping, the racing ECU and optimal combustion process produce significant torque.

Furthermore, the addition of an 8-hole injector on Type B resulted in increased engine torque compared to using a standard ECU at low turns. This can be attributed to the higher engine performance of the racing ECU and the additional fuel injected due to the increased number of holes in the injector. The torque warning was only observed at 3000–4000 rpm and had a negligible effect above 5000 rpm. On the other hand, by using a racing hose in Type C, the lighting supply can meet the demands of the racing ECU and the additional fuel from the 8-hole injector, resulting in more optimal combustion and increased torque at low engine speed (rpm). The study revealed that the type C exhibited the highest torque value of 20 N.m.

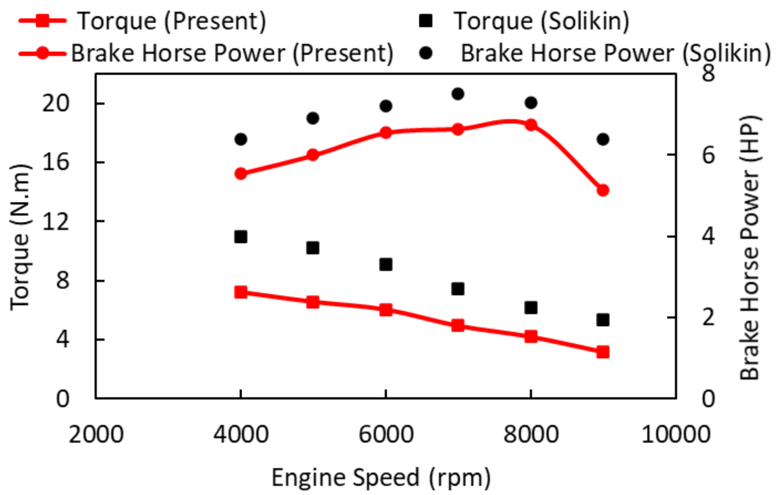

Figure 2. Comparison of torque and engine power in current study with previous study

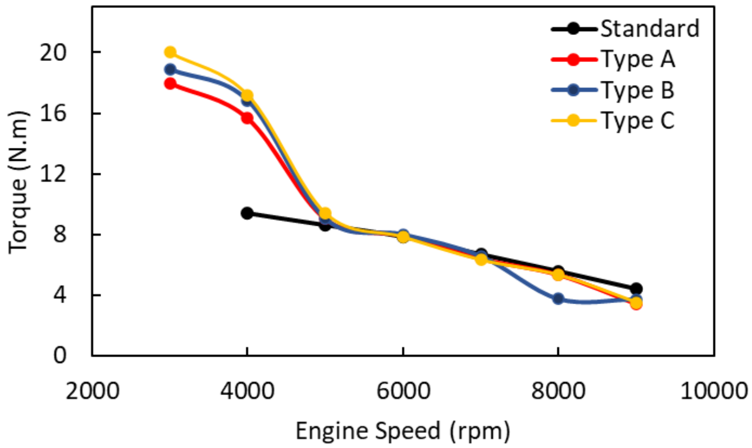

Figure 3. Torsion graphics under different ECU, hole injector, and spark plug

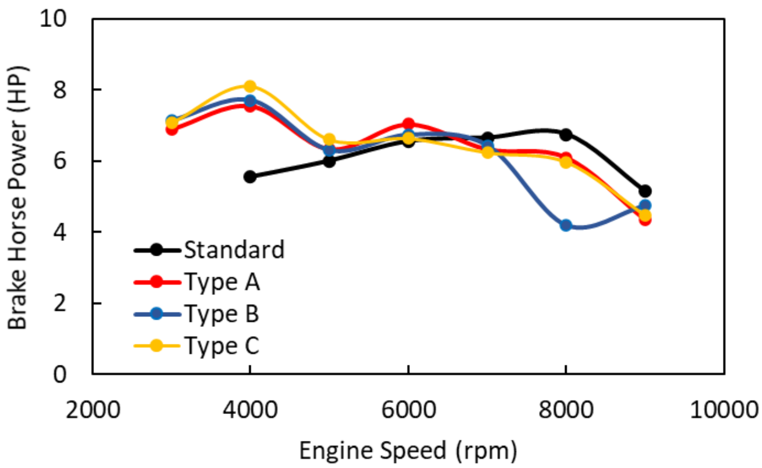

Figure 4. Engine power under different ECU, hole injector and spark plug

Figure 4 presents a graph of engine power at different engine speeds (rpm) obtained from the dynamometer chassis under standard, Type A, Type B, and Type C parameters. The graph demonstrates that the power output of the engine increases to a maximum at 8000 rpm and then decreases with the increase in engine speed during standard testing. However, when using racing ECUs on types A, B, and C, the maximum power occurs at

4000 rpm and then decreases with an increase in engine speed. This suggests that racing ECUs are more responsive at low engine speeds.

A comparison of the results reveals that engine power using racing ECUs on types A, B, and C is higher than that of standard engines at low engine speeds. In contrast, at high engine speeds, the engine power is greater using the normal ECU. This finding emphasizes the importance of considering the engine's operational range when selecting engine components and configurations. Moreover, it highlights the potential benefits of incorporating racing ECUs, which can provide higher engine power output at low engine speeds, into engine design and optimization.

In addition to the increase in engine torque with the addition of the number of injector holes, the power output of the engine also increases. Furthermore, the use of a racing plug spark on Type C resulted in a significant increase in engine power. Specifically, the power output of the engine reached a maximum of 7.7 HP for a single-cylinder 4-stroke engine. These findings suggest that modifications to the fuel injection system and ignition system can have a significant impact on engine performance.

The increase in engine power observed with the use of a racing plug spark on Type C can be attributed to several factors. Firstly, racing spark plugs have a different design compared to standard spark plugs, which allows for more efficient combustion and faster flame propagation. This results in a more complete combustion process, leading to an increase in engine power. Additionally, the use of a racing spark plug can allow for higher spark energy, which can ignite the air-fuel mixture more effectively and produce a more powerful combustion event.

The Impact of Electronic Control Units, hole Injector, and Spark Plugs on Brake Mean Effective Pressure (BMEP)

Bmep resulting from standard parameter testing; type A; type B and type C are shown in graphic form in Figure 5. In the context of engine performance testing, brake mean effective pressure (bmep) is an important parameter that describes the average pressure exerted on the piston during the power stroke of an engine cycle. Figure 5 provides a graphical representation of the variation of bmep at various engine speeds (rpm) under standard, Types A, B, and C conditions. The image shows that the bmep increases with the increase in engine speed until it reaches a maximum at low turns, and then it starts to decrease with further increases in engine speed.

Upon analyzing the results, it can be observed that all tests, irrespective of whether they use a standard or racing ECU, have the same value of bmep. This suggests that the addition of racing ECUs or an 8-hole injector has a limited effect on bmep, at least under

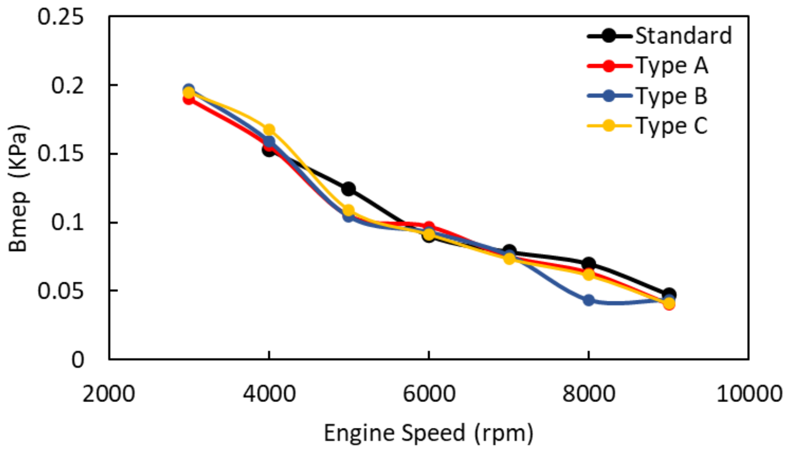

Figure 5. Bmep engine under different ECU, Hole Injector and Spark Plug

the testing conditions employed in the study. However, it should be noted that racing ECUs are designed to be more responsive, especially in terms of the lighting and fuel settings that affect the combustion process. Hence, in the case of racing ECUs, the impact of the increased responsiveness may be more pronounced at specific engine speeds.

Similarly, the addition of an 8-hole injector resulted in an increase in engine torque and power as described earlier, but the effect on bmep was limited. The maximum bmep recorded in the testing using an 8-hole injector was 0.197 KPa, which is higher compared to the standard testing but only marginally. Overall, the results suggest that while bmep is an important parameter in characterizing engine performance, it may not be significantly influenced by the addition of racing ECUs or 8-hole injectors in the tested conditions.

CONCLUSIONS

A study has been conducted on single-cylinder 4-stroke engines utilizing parameters such as standard, types A, B, and C. The findings of this research can be summarized as follows: The attainment of maximum engine power and torque is facilitated by utilizing racing ECUs in conjunction with an 8-hole injector and spark plug that are specifically designed for racing purposes and operate on Type C parameters. The utilization of racing ECUs, along with the quantity of apertures present on the injector and spark plug, significantly impacts the combustion process within the engine, consequently influencing the engine's overall performance. Furthermore, it was observed that the bmep calculation yielded nearly identical results during a specific rotation when utilizing a racing ECU and an 8-hole injector in comparison to the other experimental scenarios.

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DECLARATION OF CONFLICTING INTERESTS

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REFERENCES

[1] V Tristanto, Paryono, dan Sumarli, “Pengaruh Penggunaan Injektor Vixion dan Racing ECU Pada Sepeda Motor Yamaha Mio J Terhadap Daya Motor”. Jurnal Teknik Mesin, vol.24,no.2. 1-10, 2016.

[2] M Setyo dan L. Utoro, “Re-mapping Engine Control Unit (ECU) Untuk Menaikkan Unjuk Kerja Mesin Sepeda Motor”, Jurnal Mesin Teknologi (SINTEK Jurnal), vol.11 no.2, 2017.

[3] R M Rahman, D Widjanarko, dan M. Burhan Rubai Wijaya, “Perbedaan Unjuk Kerja Mesin Menggunakan Electronic Control Unit Tipe Racing dan Tipe Standar pada Sepeda Motor Automatic”, Jurnal Dinamika Vokasional Teknik Mesin, vol.3 no.2, Hal 138-143, 2018.

[4] Afwan, M. A., & Rahardjo, W. D. “Pengaruh Penggunaan Ecu Standar Dan Ecu Juken Dengan Variasi Injektor Terhadap Torsi Dan Daya Sepeda Motor Yamaha V-Ixion”. Automotive Science and Education Journal, 9(1), 25-30. 2020.

[5] Kwee, H., & Widodo, T. Effect of Racing ECU and Fuel Injection Timing on Performance and Emissions of Single Cylinder Motorcycle Engine. International Journal of Automotive and Mechanical Engineering, 15(2), 5254-5271, 2018.
[6] Lee, W. J., Yang, S. M., & Chang, C. M. Effect of ECU tuning on the performance and emissions of a small motorcycle engine. Applied Energy, 132, 171-179, 2014.
[7] Zulkifli, N. A., & Abdullah, M. Y.. Performance Analysis of Racing ECU on Small Capacity Motorcycle Engine. Procedia Manufacturing, 2, 292-298, 2015.
[8] Lee, K. H., Kim, J. K., & Lee, C. S. Effect of Racing ECU on Combustion Characteristics and Emissions of a Four-Stroke Motorcycle Engine. Journal of Mechanical Science and Technology, 32(8), 3835-3843, 2018.
[9] Wibowo, A. B., Muzakki, A. Z., & Siswanto, W. A. The effect of racing ECU on motorcycle engine performance. IOP Conference Series: Materials Science and Engineering, 891, 012072, 2020.
[10] Chang, Y., Lin, K., & Wu, T. Effects of injector nozzle holes on combustion characteristics and emissions of a diesel engine. Energy Conversion and Management, 64, 407-413, 2012.
[11] Huang, C., & Lin, Y. Influence of the number of nozzle holes on fuel spray characteristics of multi-hole injectors. Applied Energy, 115, 410-417, 2014.
[12] Teo, Y. C., & Yusoff, M. Z. Effect of nozzle hole number on spray and combustion characteristics in a direct injection engine. Journal of Mechanical Engineering and Sciences, 12(4), 3854-3867, 2018.
[13] Lin, K. Y., Lee, M. H., & Lin, C. Y. Effects of spark plug electrodes on combustion characteristics and engine performance of a motorcycle engine. Fuel, 90(3), 1032-1038, 2011.
[14] Ng, K. H., & Lee, Y. C. Performance and combustion characteristics of spark plug types on a small displacement engine. Applied Thermal Engineering, 90, 158-164, 2015.
[15] Agarwal, A. K., Das, L. M., & Sahoo, P. K. Studies on spark plug electrodes and their effects on gasoline engine performance and emissions. Energy Conversion and Management, 65, 277-283, 2013.
[16] Mohamed, E. A., & Ahmed, M. A.. Effect of spark plug types on performance and emissions of a single-cylinder motorcycle engine fueled with gasoline-ethanol blends. Journal of Cleaner Production, 156, 679-687, 2017.
[17] Yang, H., Jia, C., & Zhao, J. Effects of electrode gap and surface material of spark plug on performance and emission of gasoline engine. Applied Energy, 151, 29-36, 2015.
[18] Amaral AA, Saidatin N, Mahmud R, et al. Pengaruh ECU (Electronic Control Unit) dan Variasi tipe Jumlah Hole Injector Terhadap Performa Engine Single Cylinder 4 Langkah. Prosiding SENASTITAN Vol. 02, 2022.
[19] Mahmud R, Ilminnafik N, Amrullah A, et al., "Pengaruh Bahan Bakar LPG Sistem Manifold Injeksi Terhadap Performa Single Cylinder Spark Ignition Engine". JMESI: Journal of Mechanical Engineering, Science, and Innovation . vol.1 (1): 8-14. 2021.
[20] Solikin 2017, "Pengaruh Variasi Timing Injection dan Timing Pengapian dengan Menggunakan ECU BRT Juken 3 Terhadap Kinerja Motor 4 Langkah 110 CC, Universitas Muhammadiyah Yogyakarta, Fakultas Teknik, Jurusan Teknik Mesin, Yogyakarta, Skripsi.