Re-programming Electronic Control Unit for Increase Torque and Power a Motorcycle

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Abstract. This research aims to determine the performance difference of using a standard electronic control unit (ECU) compared to re-programming the ECU of a motorcycle. The experiment was carried out on a Honda CRF 150cc motorcycle manufactured in 2018. The research methods are experimental research and use descriptive statistic method. Research findings inform that the maximum torque of the standard ECU is 13.7 Nm at 4700 rpm, and the maximum power is 9.2 KW at 7000 rpm. The re-programming ECU has a maximum torque of 17.1 Nm at 5700 rpm, and a maximum power of 12.1 kW at 7200 rpm. The apparent increase in torque is around 80.11 % and in power is around 76 %. It can be concluded that the re-programming ECU provides a more optimized engine performance on a CRF150L motorcycle.

1. Introduction

The fuel supply system on motorcycles in the market today has changed from a conventional system that uses a carburetor to a fuel injection supply system. The fuel supply system that uses the injection type is an innovation that is continuously being developed to improve engine performance on motorbikes [1][2][3]. The application of the injection fuel supply system began to be applied to motorbikes with a limited number starting in the 90s, starting with a mechanical injection type fuel supply system then later developing into an electronic-based injection system [4][5]. There are two types of injection fuel supply systems, namely a mechanical injection system which is also known as a continuous injection system (K-Jetronic), and an electronic-based injection system called Electronic Fuel Injection (EFI) [6][7]. There are differences in the workings of the K-Jetronic and EFI injection systems. If in a continuous injection system, fuel is sprayed continuously into each intake manifold, while the electronic injection of fuel is sprayed electronically, the volume and time of spraying are done electronically [7]. There are several mentions of injection fuel supply systems, such as EGI (Electronic Gasoline Injection), EPI (Electronic Petrol Injection), and PGM-FI (Programmed Fuel Injection) [8][9][10].

Fuel put into the engine compartment depends on the order given by the Electronic Control Unit (ECU). The ECU will get information on fuel requirements and the actual state of the engine condition from several sensors installed on the engine. This technology has the advantage of producing an ideal fuel mixture, under ideal conditions it can reduce exhaust emissions such as CO, HC, and NOx from the combustion in the engine combustion chamber [11][12]. The injection system on a motorcycle engine allows controlling the amount of fuel flowed based on load parameters and engine speed for each cycle so that the mixture of fuel and air can be more homogeneous and precise according to engine needs [13][14]. The injection system on a motorcycle for special purposes such as racing will require a special ECU because it cannot be accommodated by a standard ECU [15]. A special ECU is required for higher
engine performance. For motorbikes that are used for special purposes such as racing, an increase in engine capacity, an increase in the compression ratio of the engine, as well as the length of time for opening the valve is widened, and enlargement and repair of the inlet port and exhaust port as well as replacement of the exhaust system [16]. To get the torque from a motorcycle for racing purposes, it is necessary to change the valve opening [17]. A motorcycle engine with specifications higher than the factory-made standard will require a greater fuel supply and a more advanced ignition angle [18]. The achievement of wide engine power is obtained from changes in engine speed that are higher than standard conditions, this will result in peak power (peak power) and peak torque (peak torque). For special purposes such as racing, a stand-alone ECU can be used [19]. ECU stand alone is an ECU that can be reprogrammed for special engine requirements for racing or can also be used for standard engines that have been changed from standard specifications. Reprogramming the ECU will change the duration and timing of fuel injection and ignition until the best performance is obtained [20]. Reprogramming from an ECU is also called re-mapping or mapping information and data that already exists [21]. The capabilities of the stand-alone ECU and existing features vary according to the hardware and software that supports them. Changing the mapping on the ECU to adjust the amount of fuel and ignition timing will produce an engine character that matches the intended use [22]. To avoid engine damage due to the late valve returning after opening (floating) when the engine speed is too high, the ECU Stand Alone can be adjusted by providing a speed limit by stopping the sparks or temporarily stopping the injected fuel (fuel cut). Maximum power will be obtained with the ratio of Air Fuel Ratio (AFR) at 12.6-12.8: 1. Without using a dynamometer and oxygen sensor, finding the ideal value will be difficult. However, an AFR value of 12.6-12.8: 1 will be a good benchmark for starting a new ECU mapping.

2. Research Method

2.1. Architecture Diagram

This paper cannot be separated from the general architecture, so it is designed as follows:

![Figure 1. General Architecture.](image)

The explanation in Figure 1:

- Perform analysis on a motorcycle ECU.
- Do the torque strength test.
- Reprogram the ECU for optimal results
- ECU Detection Model on reprogramming.

2.2. Material

In this research, a Honda CRF 150 L motorcycle with an engine capacity of 150 cc was used. Tests were carried out using the Dynotester Sportdyno v.3.3. The tests carried out include the torque and power test. The motorcycles tested in this study used Pertamax RON 92 fuel. The use of this fuel was adjusted to the fuel specifications used in the CRF 150 L 150 cc vehicle. The implementation of data collection techniques refers to the independent and dependent variables where to obtain valid data it is necessary to carry out several stages to obtain valid data.

The data retrieval sheet table is used to include the results of the engine torque and power test on a CRF 150L motorcycle. Torque and power data are listed in multiples of 500 rpm, this is done to increase the validity of the data obtained so that the results of data analysis are more relevant. The data analysis technique for testing ECU variations was carried out using descriptive analysis. The test parameters are influenced by the use of a re-programming ECU which can be used for mapping. The resulting treatment
results are torque and power data. This data is used as a comparison of the torque and power values in standard ECU use. The indicators used to read the torque and power values are the results obtained from the engine speed (rpm). The engine speed parameters used are 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000, 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000.

### Table 1. Torque Test Results.

| ECU No | ENGINE SPEED(rpm) | 1000 | 1500 | 2500 | 3500 | 4500 | 5500 | 6500 | 7500 | 8500 | 9000 |
|--------|-------------------|------|------|------|------|------|------|------|------|------|------|
| STANDARD  | 1  | 9.8  | 8.5  | 9.8  | 11.9 | 13.7 | 13.5 | 13.2 | 11.4 | 9    | 8.3  |
|         | 2  | 9.6  | 8.4  | 9.7  | 11.8 | 13.8 | 13.4 | 13.3 | 11.2 | 9.1  | 8.2  |
|         | 3  | 9.5  | 8.3  | 9.6  | 11.7 | 13.9 | 13.3 | 13.1 | 11.3 | 9    | 8.4  |
| AVERAGE | 2   | 9.6  | 8.4  | 9.7  | 11.8 | 13.8 | 13.4 | 13.2 | 11.3 | 9.03 | 8.3  |
| RE-PROGRAMING | 1  | 11.9 | 11.2 | 11.8 | 15.7 | 15.9 | 16   | 15.6 | 13.8 | 11.2 | 9.8  |
|             | 2  | 11.8 | 11.3 | 12.2 | 15.6 | 15.8 | 16.1 | 15.6 | 13.8 | 11.5 | 9.8  |
|             | 3  | 11.8 | 11.5 | 12.1 | 15.6 | 15.7 | 16   | 15.4 | 13.7 | 11.4 | 9.7  |
| AVERAGE    |    | 11.8 | 11.3 | 12   | 15.6 | 15.8 | 16.2 | 15.3 | 13.6 | 11.3 | 9.77 |

### 3. Result and Discussions

At this step, an algorithm is designed to reprogram ECUs. Reprogramming process to maximize the performance of the ECUs on a motorcycle. Motorcycles began to develop with the FI (fuel injection) application which led to pros and cons. Because the performance of FI is always side by side with the presence of an ECU on a motorcycle, the impact of the development of this application is that the workshop can detect damage to a motorcycle that focuses on ECU errors. Some who want to upgrade the technology consider the FI system to be an advance because it has an impact on saving fuel oil and low exhaust emissions (environmentally friendly). ECU is a module whose job is to control engine performance (determining the AFR value and ignition timing) by considering the input of many sensors.

However, the next step in testing torque is carried out based on table 1. In Table 1, you can see the results of the motorbike torque test results from the experiment using standard ECUs and reprogramming ECUs. This study uses a dyno tester V3.3 torque and power test equipment. Based on the test results it can be seen from Table 1 that the highest torque of a CRF 150L engine using a standard ECU occurs at 4500 rpm with a torque value of 13.99 N.m and the lowest torque at 9000 rpm is 8.3 N.m. The torque of the CRF 150 cc engine has increased by using a re-programming ECU where the highest torque occurs at 6000 rpm rotation of 16.3 N.m and the lowest torque is at 3000 rotation of 11.3 N.m. Table 2 shows the results of vehicle power testing resulting from experiments using standard ECUs and reprogrammed ECUs. The research was taken using the dyno tester V3.3 torque and power test instrument.

### Table 2. Power Testing Results.

| Engine Speed (Rpm) | Power (kW) |
|-------------------|------------|
|                   | Standard ECU | Re-programming ECU |
|                   | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average |
| **1000**          | 1.1 | 1 | 1.2 | 1.10 | 1.5 | 1.6 | 1.7 | 1.60 |
| **1500**          | 1.4 | 1 | 1.4 | 1.37 | 1.8 | 1.7 | 1.6 | 1.70 |
| **2000**          | 2.2 | 2 | 2.1 | 2.03 | 2.5 | 2.4 | 2.3 | 2.40 |
| **2500**          | 2.6 | 2.5 | 2.6 | 2.57 | 3.1 | 3 | 3.2 | 3.10 |
| **3000**          | 3.1 | 3.2 | 3.3 | 3.20 | 3.6 | 3.5 | 3.4 | 3.50 |
| **3500**          | 4.4 | 4.4 | 4.2 | 4.33 | 5.9 | 5.8 | 5.7 | 5.80 |
| **4000**          | 5.8 | 5.7 | 5.9 | 5.80 | 6.8 | 6.7 | 6.7 | 6.73 |
| **4500**          | 6.6 | 6.7 | 6.6 | 6.63 | 7.6 | 7.5 | 7.6 | 7.57 |
Based on the test results it can be seen from Table 2 that the highest power of the CRF 150 L engine using a standard ECU occurs at 7000 rpm with a power value of 9.3 kW. The CRF 150 L engine power has increased by using a re-programming ECU where the highest power occurs at 6500 rpm rotation of 10.7 kW. Figure 1 is a visualization of the engine torque test results, the dotted line is the test result using a standard ECU and the connecting line is the test result using the Iquteche ECU. Based on the graph, there is a dynamic change in torque from low to high rotation.

Figure 2. Torque ratio.

Figure 3 is a visualization of the engine power test results, the dotted line is the test result using a standard ECU and the connecting line is the test result using re-programming ECU. Based on the graph, there is a dynamic change in power from low to high rotation. The results of the power test through the dyno tester test tool presented in Figure 2 can be tested theoretically. Theoretical testing is carried out to increase the validity of the test results. The results of the power test through the dyno tester test apparatus should not be different at too high an interval. The average torque produced by the CRF 150 L engine using a standard ECU is 11.2 N.m at 1500-9500 rpm engine speed. While the average torque produced by the CRF 150 L engine from using the re-programmed ECU is 13.5 N.m at 1500-9500 rpm engine speed.

Overall torque on the vehicle increased by 36.58% where initially the average torque of the standard ECU was 9.65 N.m and the ECU re-programming was 13.18 N.m. This happened because of an increase
in the fuel supply to the ECU re-programming at the low rotation. Mapping of fuel at a lower speed of 2000 rpm-3500 rpm with the percentage of fuel supply increased by 30%. Torque is a measure of the engine's ability to produce work. Torque is useful for overcoming vehicle speed resistance or for increasing vehicle acceleration.

The average power obtained by using a standard ECU is 4.49 kW at 1500-9500 rpm engine speed. While the average power obtained by using the ECU reprogramming is 6.02 at 1500-9500 rpm engine speed. The power in the vehicle increased by 33.99% where previously the maximum power obtained in the use of the standard ECU was 6.71 kW and the ECU re-programming was 7.70 kW. This happens because of an increase in torque that occurs. The fuel supply to the ECU re-programming at low speed has an impact on the engine output. Mapping fuel at lower speed 2000 rpm - 3500 rpm with the percentage of fuel supply increased by 30%.

The decrease in power that occurs in the engine when the engine speed is getting higher, is due to the timing injection mapping which is prioritized for the lower rotation. The higher the crankshaft rotation but the decreased torque results at the final rotation have an impact on the power produced. Where the power at the end of the rotation decreases. In his book, Heywood, (1988) adds that the power (P) sent by the engine and absorbed by the dynamometer is the result of torque and rotational speed. Theoretically, when motor power increases, motor power also increases because power is the product of torque and shaft rotation. In the test results, the torque has decreased at high rotation, so that the power obtained decreases.

After getting a test on Torque strength, a new model was created in the ECU reprogramming where the ECU can carry out its detection process based on the theory of the Certainty Factor (CF) theory to accommodate certainty factor (CF) inexact reasoning to describe the level of expert confidence in the problem. that is being faced. Certainty Factor (CF) shows a measure of the certainty of a fact or rule. Certainty Factor notation is as follows:

\[
CF[H, E] = CF[H] \times CF[E] \quad (1)
\]

Where
- \( CF[H] \) is a measure of user confidence
- \( CF[E] \) is a measure of expert confidence

And the rules for the same conclusion are:

\[
CF \text{ combination } CF[H, E] i = CF[H, E_i] + CF[H, E_i + 1] \times (1 - CF[H, E_i]) \quad (2)
\]
\[
CF \text{ combination } CF[H, E] \text{ old} = CF[H, E] \text{ old} + CF[H, E] \times 3 \times (1 - CF[H, E] \text{ old}) \quad (3)
\]

So based on the above equation, you must first know the symptoms of damage to the motorcycle ECU as shown in Table 3.

| NO | Damage Symptoms          |
|----|--------------------------|
| G1 | Indicator Light Is On    |
| G2 | Waste of Oil             |
| G3 | more carbon dioxide smoke|
| G4 | Vibrating Machine        |
| G5 | RPM is unstable          |

So that based on the symptoms in Table 3, an algorithmic journey was formed to be able to carry out the process of diagnosing damage to the ECU in getting the ECU reprogramming under the objectives of this paper. From the results of the combine calculation based on equations (1), (2), (3) of the combined designer where the results of \( CF[H, E] \) old \( 8 \times 100 \) (fixed) = 0.8480 * 100 = 84.80% So a conclusion is drawn the result is 84.80% trouble with the sensor in the ECU on the motorcycle. Thus, the calculation
of certain factors to diagnose or detect damage to the ECU in the ECU reprogram got the percentage level of confidence of 84.80%.

![Figure 4. New Model with Diagnostic ECU.](image)

From Figure 4 it can be seen that in the input and output process there is an algorithm with the CF approach where CF can perform diagnostic calculations on ECU damage. So that this model will create a security line on the ECU so that vehicle users can find out the state of the ECU by applying the internet of things (IoT) application.

4. Conclusion
Based on testing the performance of the engine on a CRF 150 L vehicle with the use of a re-programmed ECU, and the fuel used by the Pertamax type, the following conclusions are obtained: 1) There is an increase in engine performance on CRF 150 L vehicles with the use of ECU = programming that affects motorcycle torque and power. The data obtained are 22.42 N.m of torque and 7.70 kW of power, and 2) There are differences in engine performance in Vario 125cc vehicles with the use of ECU re = programming which affects the torque and power of the motorbike. The data obtained were analyzed descriptively where the torque increased by 36.58% and the power increased by 33.99%, whereas in the application of the CF algorithm it is used to detect damage to the input and output processes of the ECU and the calculation of certain factors to diagnose or detect damage to the ECU in the ECU reprogram got the percentage level of 84.80% confidence.

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