Performance Analysis and Characterization Hybrid Two Wheeller Vehicle with Using a Chassis Dynamometer

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***Abstract*—The extraordinary growth in means of transportation, especially vehicles with internal combustion engines, has made state laws and regula-tions increasingly stringent. Regulations regarding energy consumption used for passenger and personal mobility and the emissions produced in order to reduce pollution. A hybrid vehicle combines two energies pro-duced from various sources such as an ICE and an electric motor to be-come a hybrid electric vehicle (HEV). This research discusses hybrid elec-tric vehicles on 2-wheeled vehicles which can be used as a solution that can be developed further before pure electric vehicles (EV) replace motor-ized vehicles (ICE). This research was done experimentally, by carrying out tests on a dynamometer and on the road testing. The main material used in this research was a Honda PCX 150 vehicle. The results of the test on the dynamometer showed that the performance of the internal combus-tion engine (ICE) had a torque of 11.12 Nm and a power of 8.20 kW at 7000 rpm. Testing the electric motor (EV), obtained torque results of 11.7 Nm and 2.33 kW power. The road test results for internal combustion en-gine consumption to consume 1 liter of fuel, capable of covering a dis-tance of 54.55 km. Electricity consumption from 100% to 0% SOC can cover a distance of 46.31 km. Hybrid consumption 1 liter of fuel and bat-tery full 100% capable of covering a distance 57.79 km, with battery con-dition reduced 16%.**

Keywords - internal combustion engine, electric motor, hybrid vehicle, dynamometer, energy consumption

I. INTRODUCTION

The extraordinary growth in means of transportation, especially vehicles with internal combustion engines, has made state laws and regulations increasingly stringent. Regulations regarding energy consumption used for passenger and per-sonal mobility and the emissions produced in order to reduce pollution. As energy conservation and emission reduction figure prominently in their respective national development strategies, countries are increasingly stringent with energy and emission regulations that put forward higher requirements for the development of all vehicles [1]. The Indonesian government's support is stated in Presidential Decree number 55 of 2019 concerning the acceleration of the battery based electric motor vehicle program for road transportation. As well as the Minister of Transportation's regulation number PM 65 of 2020 concerning the conversion of motorbikes with internal combustion engines to battery based electric motorbikes [2] [3].

Internal combustion engines (ICE) are engines in which the combustion of fuel (generally fossil fuels) mixed with air occurs in the combustion chamber [4]. Fossil fuels used in internal combustion engines are an energy source that is consumed continuously and exhaust emissions resulting from combustion residues contribute to pollution. These exhaust emissions contain several chemical compounds that can have negative impacts on health and the environment [5]. Despite industry efforts to face this challenge by innovating, such as using turbochargers, valve variations to increase fuel efficiency, and exhaust gas recirculation (catalytic converter) to reduce emissions [6].

An electric vehicle (EV) is a vehicle with an electric drive powered by a battery. Electric vehicles can be a positive solution to reduce the use of fossil fuel based motorized vehicles. One of the advantages of EVs is that they produce low emission gases, thereby reducing global warming. And electric vehicles offer safe, comprehensive, efficient and environmentally friendly energy [7] [8]. The disadvantages of electric vehicles are categorized into 3 namely, operational costs, complete infrastructure and mileage performance [9]. Electric vehicles are actually not a new technology in the automotive world [10]. It's just that the development of electric vehicles recently has been very rapid due to encouragement from various parties and current conditions. However, significant and instant technological changes from motorized vehicles (ICE) to electric vehicles (EV) are very difficult for the public to accept because they require re-adaptation to technological developments. The emergence of hybrid vehicle technology, as a transition tool that can educate and bridge between ICE and EV for the public. A hybrid vehicle combines two energies produced from various sources such as an ICE and an electric motor to become a hybrid electric vehicle (HEV) [11]. Various relevant studies examine the application of two wheeled hybrid electric vehicles as a means of transport that is feasible to use, such as several previous researchers, Tong & Jwo, designing a hybrid electric motorbike, namely the Tact 50cc scooter [12]. Asei et.al, design, simulation and conversion of a conventional 125cc motorbike into a hybrid electric motorbike [13]. Moradin et.al, design of a power system for a hybrid electric motorbike consisting of a 125cc internal combustion engine, connected to an electric engine [14]. Restrepo et.al design and implementation of a functional model of an electric hybridisation kit for the modification of a 125cc manual transmission motorcycle [15]. This research discusses hybrid electric vehicles on 2 wheeled vehicles which can be used as a solution that can be developed further before pure electric vehicles (EV) replace motorized vehicles (ICE).

II. METHODS

This research was done experimentally, by carrying out tests on a dynamometer and on the road testing. The main material used in this research is a Honda PCX 150 vehicle. Before the modification process into a hybrid vehicle with the addition of an electric motor on the front wheels, a review of the vehicle base and the electrical component materials to be used was carried out. So you will get a design that suits your needs as a hybrid vehicle. The properties of ICE engine vehicles and electric motors can be seen in table 1 below:

TABLE 1. PROPERTIES OF ICE ENGINE VEHICLES AND ELECTRIC MOTORS

Honda PCX 150		Electric motor	
Specification	4 steps	Specification	BLDC hub
Bore x Stroke	60 x 55.5 (mm)	Watt	2000 (W)
Power	10.8 (Kw)	Volt	48 - 72 (V)
Torque	13.2 (N.m)	Heavy	7.2 (Kg)
Tank	8.1 (L)		
Empty Weight	131 (Kg)		

The battery used is a LiFePO4 type which has good storage characteristics and high charger discharger capability. The temperature of the LiFePO4 battery is also more stable, which ensures better battery performance. The properties of the battery used can be seen in table 2 below:

TABLE 2. LIFEPO4 BATTERY PROPERTIES

Parameter	Mark	Unit
Individual voltage	3,2	Volts (V)
Number of Series circuits	20	Series (S)
Total voltage	60	Volts (V)
Total capacity	23	Ampere Hour (AH)

Fig. 1. Hybrid vehicle

The test steps for the dynamometer are as follows:

1. Raise the motorbike on the BRT Super Dyno 50L dynamometer test equipment and position the front wheel on the roller for EV testing and the rear wheel on the roller for ICE testing. This is done alternately. The testing on a dynamometer shown in Figure 2.
2. Install the belt so that the motorbike does not move during testing.
3. Install an engine speed indicator (rpm) on the coil cable to read the ICE engine speed.
4. Turning on the computer connected to the dynamometer.
5. Turn on the blower to cool the engine.
6. Run the engine idle for approximately 5 minutes to get the optimal engine temperature.
7. Rotate the gas throttle to reach full throttle spontaneously when the engine is idling until the engine speed limiter. After that the gas throttle is closed until the engine speed is idle.
8. On the computer screen the torque and power measurement results will appear, then print out.
9. Turn off the motorbike engine. After the ICE test has been tested, then replace the EV test with almost the same test steps, the only difference is that you need to equalize the engine speed between the electric motor and the dynamometer roller.

Fig. 2. Testing on a dynamometer

In the road testing, only one performance indicator is taken, namely fuel consumption and electricity consumption. ICE fuel consumption testing refers to the method of consuming 1 liter of fuel. This method was chosen because it regulates fuel measurements in light vehicles, aiming to obtain data on fuel consumption or the driving method used. Meanwhile, EV and HEV electricity consumption testing relies on data produced by a data logger which is then combined with net metering system analysis calculations. The type of road used is for daily commuters, where there are roads that experience several traffic jams and roads that vary in contour, where there are smooth and bumpy roads. The testing process uses 1 rider with a body weight of 65 kg.

III. Results and Discussion

A. Dynamometer Testing

Based on factory specifications, the Honda PCX 150 engine has a torque performance of 13.2 Nm and a power of 10.8 kW (Table 1). The performance value is greater because the measurement process is carried out directly on the machine shaft. Figure 3 is the result of testing an internal combustion engine on a dynamometer carried out on the rear wheels of a vehicle, so the measurement results are smaller than the factory measurement process. This is due to the presence of transmission, clutch, gear ratio reduction which affect the results of the machine's performance. The internal combustion engine test results data on the dynamometer has a torque performance of 11.12 Nm and a power of 8.20 kW at an engine speed of 7000 rpm.

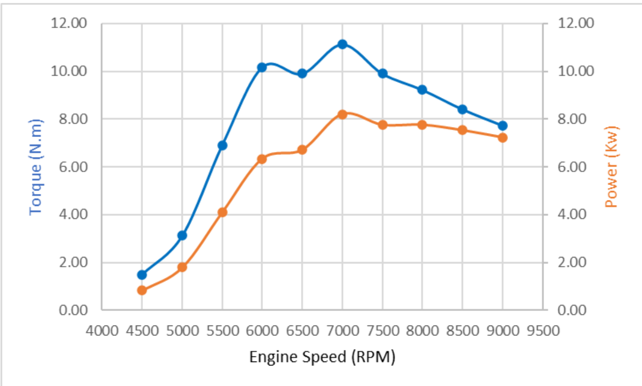

Fig. 3. ICE test graph

As a note, the hybrid motorbike in this research uses an electric motor on the front wheels so that the results of the torque performance test on the ICE are used as a reference for the setting process to obtain the performance characteristics of the electric motor. It is feared that the very large torque of the electric motor at low engine speed will cause the front wheels to spin faster due to excess torque. This process is carried out to get the performance of the electric motor (EV) to be balanced with the internal combustion engine (ICE).

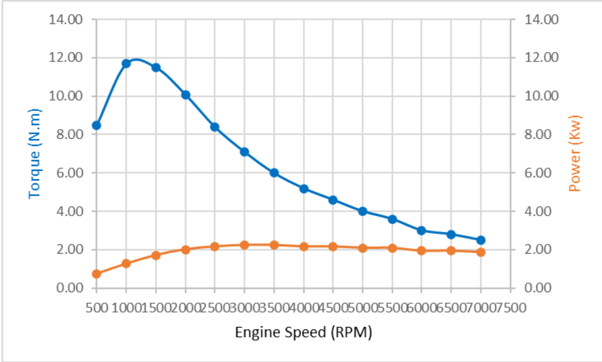

Fig. 4. EV test graph

Based on figure 4, the electric motor test has a torque performance of 11.7 Nm at an engine speed of 1000 RPM and a power of 2.33 kW at an engine speed of 3000 RPM. The greatest torque performance results are not much different from internal combustion engines (ICE), but the peak torque appears at low engine speed. The power output of an electric motor is very small compared to an internal combustion engine (ICE), but is flat in almost every engine speed range. The performance results of the electric motor (EV) were obtained after going through the setting process on the controller with a 60 V 23 Ah battery with a 35 A setting on the controller.

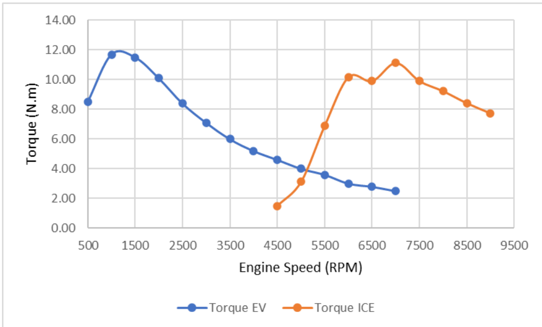

Fig. 5. ICE -EV torque comparison graph

Seen in figure 5, the torque between the ICE and EV crosses at an engine speed of 5000 rpm. The electric motor in a hybrid vehicle assists the internal combustion engine at low engine speeds and then stops or switches to fully driving the internal combustion engine. Based on the results of this comparison, it becomes an initial analysis to create a 2-wheeled hybrid vehicle with an appropriate configuration.

B. The Road Testing

Based on factory test data, the Honda PCX 150 is capable of covering a distance of 41 kilometers per liter. This data uses the ECE-R40 testing method, a series of tests carried out in a laboratory whose output is emission levels and fuel consumption. This test is not specifically for measuring fuel consumption, but from the emission test results you can calculate fuel consumption by looking at the carbon element. When a real test is carried out (on the road), the fuel consumption results will be different. Influencing factors include traffic jams, road conditions, rider weight, driving style and other factors.

Fig. 6. ICE the road test results

The road ICE test results shown in figure 6 greater results than the factory claims, this is due to the testing process being different from the factory. The testing process involves consuming 1 liter of fuel. Through the process of draining the vehi-cle tank and refilling it with RON 90 pertalite fuel. The results obtained were that 1 liter of fuel could cover a distance of 54.55 km with an average speed of 35 km/hour. The time required for this testing process is 1 hour 34 minutes.

Fig. 7. EV the road test results

The road EV test results shown in figure 7 that with one 100% charging process until the battery runs out 0%, it can cover a distance of 46.31 km with an average speed of 30 km/hour. The time required to complete this testing process is 1 hour 33 minutes. The condition of a 100% SOC battery has a voltage of 68.68 volts and a 0% SOC has a voltage of 56.35 volts.

Fig. 8. Hybrid the road test results

The road hybrid test results shown in figure 8 with 1 liter of fuel and 100% full battery capable of covering a distance of 57.79 km, with an average speed of 34 km/hour. In this test, the distance that can be covered by 1 liter of fuel with the help of an electric motor. The battery condition is reduced by 16% from the battery condition of 100% SOC to 84%.

IV. Conclusion

There are many parameters of hybrid vehicles that need to be developed. To determine the performance and characteristics of a 2 wheeled hybrid vehicle, it is necessary to test it on a chassis dynamometer. From the research that has been carried out, the conclusions obtained are as follows:

1. The results of the test on the dynamometer showed the performance of the internal combustion engine (ICE) with a torque of 11.12 Nm and a power of 8.20 kW at 7000 rpm. Testing the electric motor (EV) on the dynamometer showed a torque of 11.7 Nm and a power of 2.33 kW.
2. Based on the test results above on the dynamometer between ICE and EV, the torque results graph crosses at an engine speed of 5000 RPM.
3. The results of the road test showed that the fuel consumption was 1 liter of fuel, capable of covering a distance of 54.55 km. Electricity consumption from 100% to 0% SOC can cover a distance of 46.31 km. Hybrid consumption 1 liter of fuel and battery full 100% capable of covering a distance 57.79 km, with battery condition reduced 16%.

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