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Analysis of Peak Torque, Peak Power, and Acceleration Time on Electric Motorcycles Conversion Using a V-Belt Power Transmit System.

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ABSTRACT

Converting ICE (Internal Combustion Engine) motorcycles into electric motorcycles is one of the ways to accelerate vehicle electrification. The power capacity of the BLDC (Brushless Direct Current) motor used to drive this motorcycle is 2 kW. The power transfer system from the motor to the rear wheels uses a V-belt with a transmission ratio of 5,46: 1. The purpose of this research is to determine the amount of peak torque, peak power, and acceleration time produced by the motor. The method used to test the performance of the motor is using a dynamometer. The test results show that the peak torque produced by the motor is 23 Nm at 650 rpm, the peak power is 6 hp at 2480 rpm, and the acceleration time from 0 to 72 km/h is 9,58 seconds. The ICE of motorcycles produces a peak torque of 8,43 Nm and a peak power of 8,87 hp. Analysis based on test results shows that the BLDC motor 2 kW produces a peak torque 14,57 Nm above the ICE motorcycles but the peak power is 2 hp below the ICE motorcycles. These results indicate that the conversion of electric motorbikes is feasible to use.

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INTRODUCTION

The transportation sector contributes a significant amount of air pollution, especially in urban areas which results in climate change due to the greenhouse gas effect, so that electric vehicle technology is needed to reduce this condition [1]. Electric motorcycles have the benefit of reducing the negative effects of land transportation on the environment in developing countries and obtaining economic benefits for riders by switching the use of internal combustion motorcycles to electric motorcycles [2].

The number of motorcycles in Indonesia has increased significantly in 2017 reaching approximately 113 million units and the number will continue to increase in the coming, it is necessary to convert internal combustion engine motorcycles into electric motorcycles [3]. The Indonesian government is preparing regulations on the legality of converting electric motorcycles which so far are still in the form of prototype products and have passed the idea identification stage and the concept validation stage, where several prototypes are being made and which one is the best. The Indonesian government has also partnered with OEM (Original Equipment Manufacturer) ICE (Internal Combustion Engine) motorcycles to develop this innovative product [4].

The components needed to perform the conversion are a BLDC (Brush Less Direct Current) motor, controller, and battery [3]. The use of an electric motor as a driving machine to replace the function of a combustion engine must have high of torque, speed and efficiency, the battery is a device for storing electrical energy consumed by electric motors through adjustments by the controller according to acceleration [5]. BLDC motor is a type of DC motor that does not use a brush, so it does not require brush replacement maintenance, this motor has many advantages such as high efficiency, high power, high torque to energy ratio, high-speed operation, simple driving method, and low cost [6].

The transmission system used on internal combustion motorcycles of the automatic type uses a CVT (Continuously Variable Transmission) transmission system, but various electric motorcycles on the market do not use CVT because of speed and torque performance, subject to motor specifications and cannot automatically respond to topographical changes. in speed variability [7]. Models of power transfer systems from the electric motor to the rear wheels on electric motorcycles use a system through the driver gear to the driven gear connected by a chain or poly chain with gear ratios. [8].

Converting an electric motorcycle requires a conversion kit consisting of a BLDC motor, controller, and battery, where the function of the BLDC motor is to convert electrical energy into mechanical energy, the controller functions as a power regulator from the BLDC motor to power, and the battery functions as a power source electricity required by the electric motor [3].

According to the power performance requirements of the vehicle, the external characteristic parameters of the BLDC motor must meet the maximum power and maximum torque requirements, the BLDC motor must ensure that the electric vehicle must be able to provide sufficient torque during acceleration and the torque meets the maximum gradient, resistances when vehicle running such as road surface resistance, air resistance, acceleration resistance, and incline resistance are the basis for calculating of motor power to be used [9].

METHODOLOGY

The methodology used in this research is to test the ability of converted electric motorcycles using a dyno test machine so that peak torque [10], peak power [11] and acceleration time can be determined. The methodology used in this research is to test the ability of converted electric motorcycles using a dyno test machine so that peak torque, peak power and acceleration time can be determined. The steps in testing the ability of electric motorcycles are determining the electric motor to be used, doing the conversion and installing a power transmit system, preparing a dyno test machine, conducting tests and analysing test results.

2.1 Electric motorcycles technical data

The technical data used to convert an internal combustion engine motorcycle into an electric motorcycle is shown in the following table.

Table 1. Technical data of ICE (Internal Combustion Engine) motorcycles.

Description	Specification
Engine capacity	110 cc
Fuel system	Carburettor
Maximum power	8,87 hp / 8000 rpm
Maximum torque	8,43 Nm / 6500 rpm
Diameter wheel	0.5 m

Table 2. Technical data of electric motorcycles conversion

Items	Description
Electric motor type	BLDC
Electric motor power	2 kW
Maximum motor speed	22500 rpm
Battery type	Lithium-ion
Battery capacity	72 V / 20 Ah
Total weight	155 kg
Diameter wheel	0.5 m

2.2 Determine of electric motor

The electric motor used to replace the ICE (Internal Combustion Engine) is a BLDC motor [12]. The

calculation to determine the power capacity of a BLDC motor is based on the magnitude of the wheel rolling resistance force [13], air drag resistance [14], acceleration force [15], and climbing (gradient) force [16] using the following equation:

$$\mathbf{P = m.g.\mu.v + 0.5.\rho.A.C_d.v^3 + \delta.m.v.\frac{dv}{dt}}$$

Where P is the electric motor power, m is the overall mass of the vehicle, g is the gravitational acceleration constant, μ is the rolling resistance coefficient between tire and road surface, v is the vehicle velocity, ρ is air density, A is vehicle frontal area, Cd is the air resistance coefficient, δ is the transfer coefficient of rotating mass and dv/dt is vehicle acceleration. Base from the calculation using equation above, this electric motorcycles using BLDC motor 2 kW.

2.3 Conversion and installing a power transmit System

At this step, the conversion is carried out by installing the conversion kit consisting of installing the electric motor on the bracket, installing the battery, installing the controller, installing the software, and installing the power transmitting system.

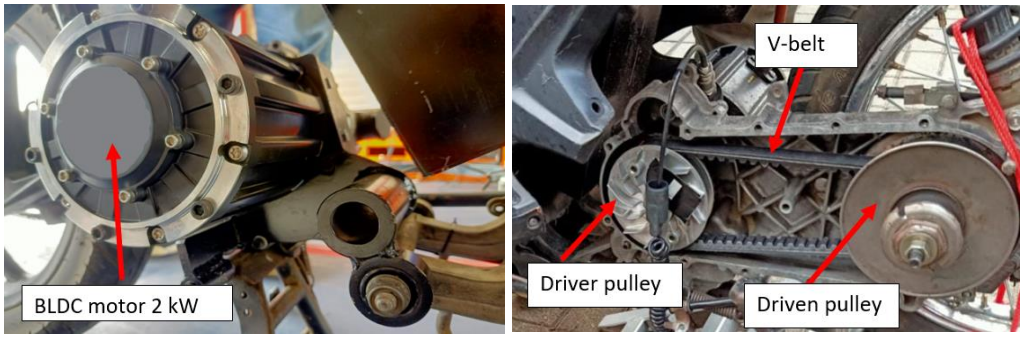

Figure 1. Experiment setup of the electric motorcycles

The function of the CVT (Continuously Variable Transmission) system on this electric motorcycle is disabled and the CVT mechanism is locked which a driver pulley (Dr1) diameter of 105 mm and a driven pulley (Dn) diameter of 80 mm. In the differential gear box consist of driver gear and driven gear with diameter Dr2 is 18 mm, Dn2 is 43 mm, Dr3 is 15 mm, and Dn3 is 45 mm.

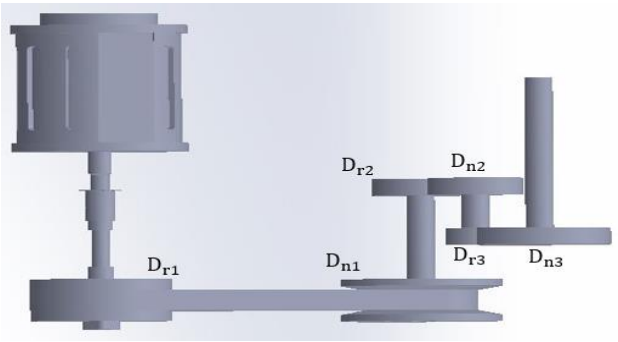

Figure 2. Power transmission system diagram

To calculate the ratio of the power transmission system [17] on this electric motorcycle, you can use the following equation:

$$\mathbf{i = \frac{D_n}{D_r} = \frac{D_{n1}}{D_{r1}} x \frac{D_{n2}}{D_{r2}} x \frac{D_{n3}}{D_{r3}}}$$

$$i = \frac{80}{105} x \frac{43}{18} x \frac{45}{15} = 5.46 : 1$$

The transmission ratio in this power transmission system of electric motorcycles is 5.46.
To calculate the rotation (n) of the motor and the speed (v) of the vehicle can use the following equation,

$$\mathbf{n = \frac{v.i.60}{2.\pi.wr}}$$

Where, n is electric motor rotation (rpm), v is vehicle speed (km/h), i is transmission ratio, wr is wheel radius.

2.4 Electric motorcycles performance test

Tests were carried out using a dyno test machine Super Dyno 50L to determine peak torque, peak power, and acceleration time from rest to maximum speed.

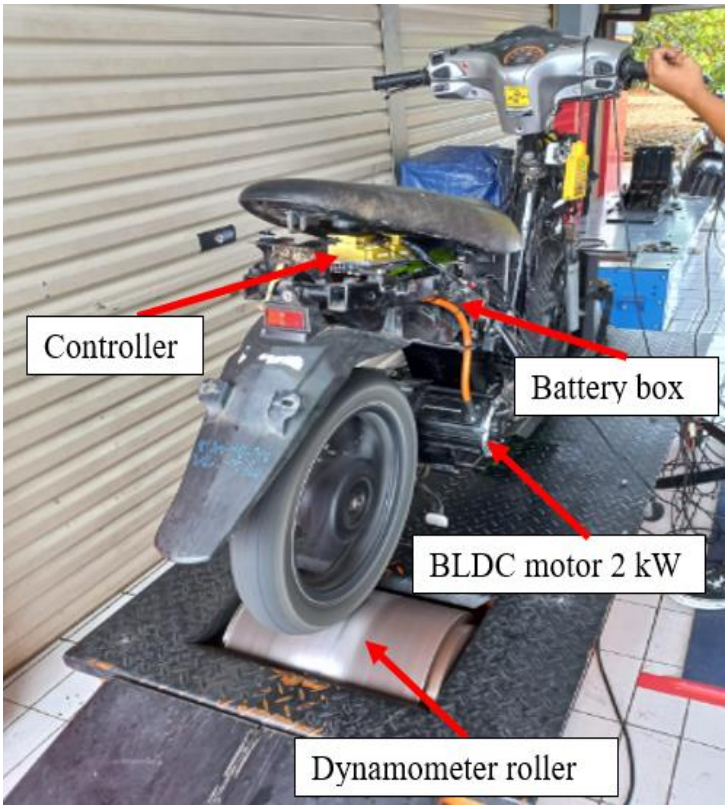

Figure 3. Dyno test

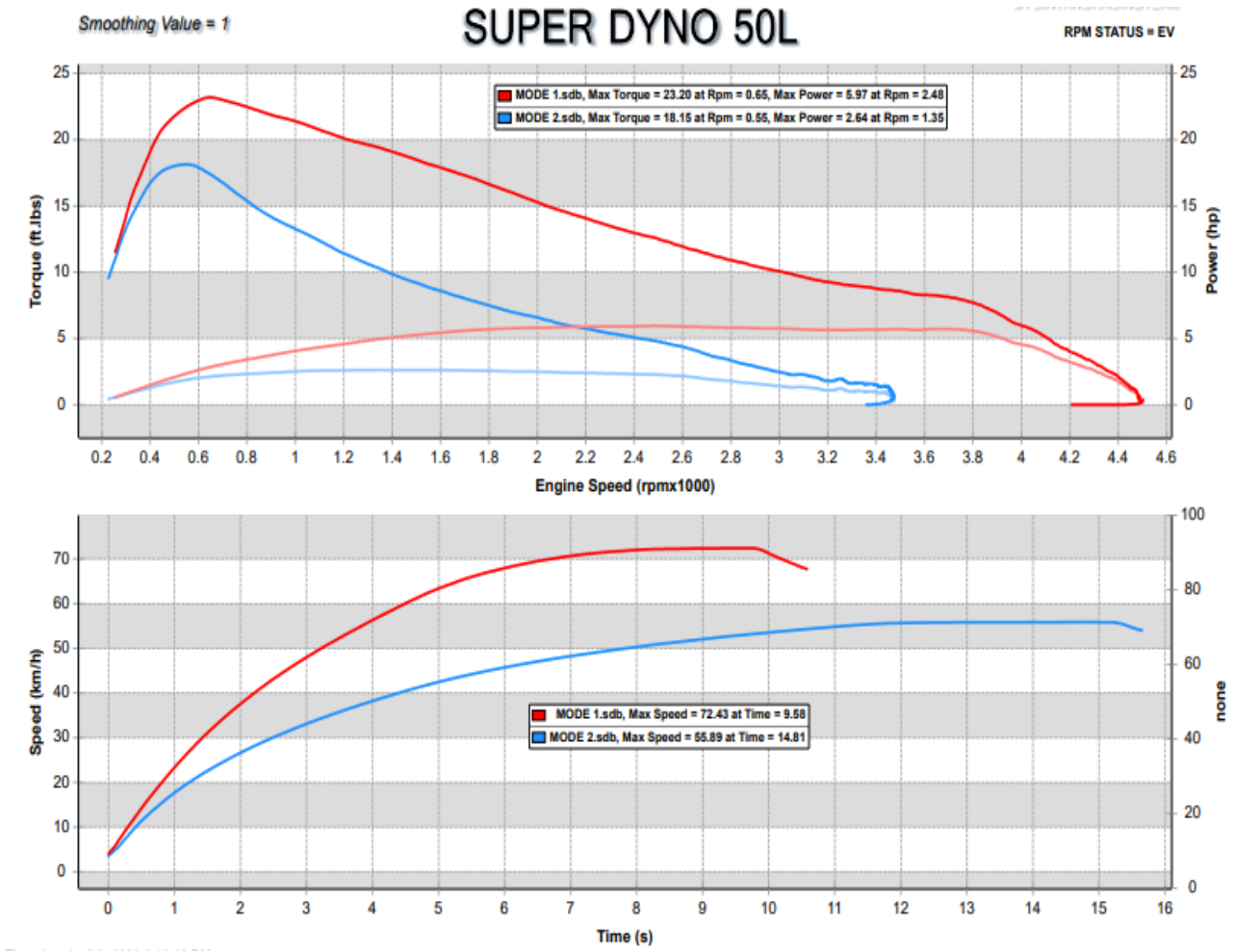

Figure 4. Graph of dyno test result

RESULT AND DISCUSSION

The results of the dyno test show the amount of peak torque, peak power, and acceleration time of an electric motorcycles from 0 to 70 km/hour.

3.1 Peak torque

The dyno test results show the amount of torque according to the speed variation as shown in the table and graph below.

Table 3. The amount of motor torque from the dyno test results.

Motor speed (rpm)	Motorcycles speed (km/h)	Motor torque (Nm)
250	4	12
578	10	22
650	12	23
1158	20	21
1738	30	17
2318	40	13
2896	50	10
3476	60	7
4056	70	5

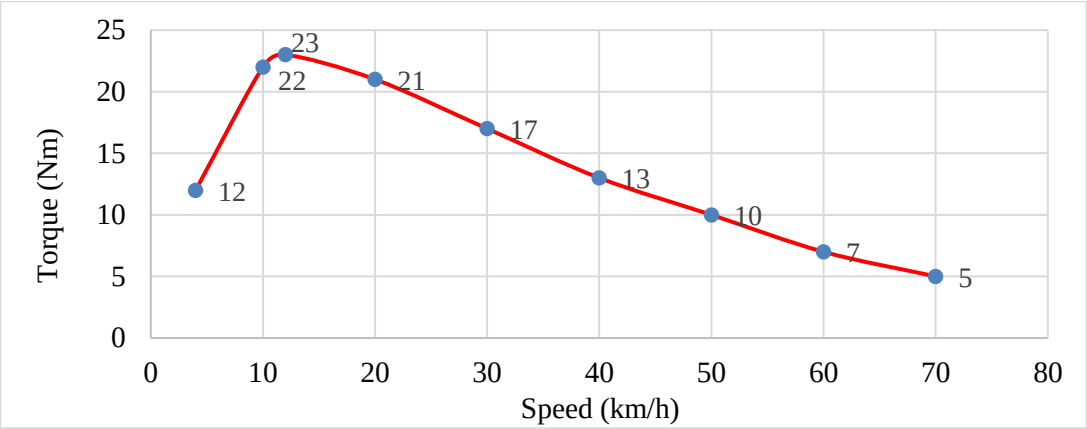

Figure 5. Graph of motor torque

3.2 Peak power

The dyno test results show the amount of motor power according to the speed variation as shown in the table and graph below.

Table 4. The amount of motor power from the dyno test results.

Motor speed (rpm)	Motorcycles speed (km/h)	Motor power(hp)
250	4	0,5
578	10	2,5
1158	20	4,5
1738	30	5,5
2318	40	5,9
2480	43	6,0
2896	50	5,9
3476	60	5,5
4056	70	4,5

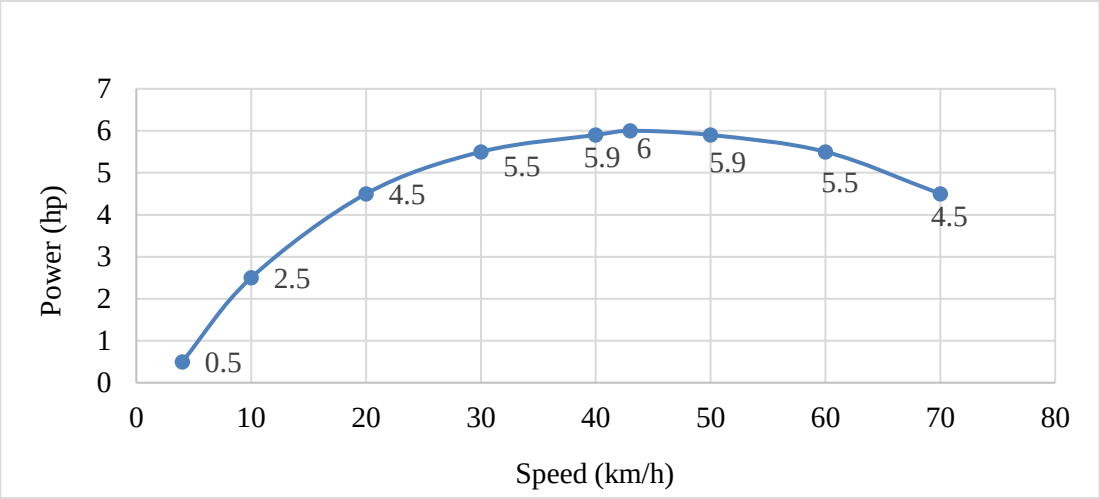

Figure 6. Graph of motor power

3.3 Acceleration time

The dyno test results show the acceleration time when electric motorcycles accelerated from 0 to 70 km/h as shown in the table and graph below.

Table 5. Acceleration time

Acceleration from and to (km/h)	Times(s)
0 - 4	0,10
0 - 10	0,25
0 - 20	0,75
0 - 30	1,35
0 - 40	2,20
0 - 50	3,25
0 - 60	4,50
0 - 70	6,75
0 - 72	9,58

3.4 Analysis

From the data from the performance testing of electric motorcycles using the dyno test machine, an analysis of peak torque, peak power and acceleration time can be carried out and it can also compare these data with the specifications when the motorcycle was still using an internal combustion engine. When the motorcycle was still using an internal combustion engine, the engine's peak torque was 8,43 Nm at 6500 rpm and peak power was 8,87 hp at 8000 rpm. Meanwhile, after the conversion to an electric motorcycle was carried out, the test results showed a peak torque capability is 23 Nm at 650 rpm electric motor rotation and a peak power is 6 hp at 2480 rpm electric motor rotation. This electric motorcycle can accelerate from 0-72 km/h and takes 9,58 seconds. The following is a comparison table between the performance of an internal combustion engine motorcycle and after conversion.

Table 6. Performance comparison

Description	ICE motorcycles	Electric motorcycles conversion
Peak torque	8,43 Nm / 6500 rpm	23 Nm / 650 rpm
Peak power	8,87 hp / 8000 rpm	6 hp / 2480 rpm

From the data above, it can be said that the torque generated by the electric motorcycles is higher than the internal combustion engine motorcycles, but the power of the electric motorcycles is lower than the internal combustion engine motorcycles.

CONCLUSION

The ability of electric motorcycles converted from combustion engine motorcycles with a capacity of 110 cc is capable of producing a peak torque of 23 Nm at 650 rpm electric motor rotation and this exceeds the torque before conversion, which is only 8,43 Nm at

6500 rpm engine rpm. The electric motor is capable of producing a peak power of 6 hp at 2480 rpm, in this case, the peak torque is lower than before the conversion, which was 8,87 hp at 8000 rpm. This electric motorbike can accelerate from 0-70 km/h in 9,58 seconds. So that the conversion of electric motorbikes is feasible to use.

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