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Design of the 3 kW Electric Motor Cycle

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Abstract. This paper presents an electric motor design by using a 3 kW multiphase brushless direct current (BLDC). The research found that initial motor capacity is not easy found as torque is effected by mechanic and passenger masses and the rotation per minute (rpm) is affected by gear arrangement. By using two gear arrangements, 48 V 25 AH battery source, a commercial mechanical frame, the implementation results 35 km/h speed, travels at 4.1 km requires 0.3 kW. The cost is much lower than the petrol based motor.

1. Introduction

As an essential transport mode, motorcycle is very common in tropical countries such as in Indonesia since the weather and environment are not friendly for pedestrian. The number of motorcycle runs in the Indonesian road reaches 85 millions according to the AISI [1].

It can be said that all the running motorcycle in Indonesia use petrol as the power source. It was found that the petrol requirement in Indonesia reaches 1.6 million barrel per day [2]. It can be thought that the usage of the fossil energy is inefficient as its greater than national product about 834 thousand barrel per day [2]. Therefore alternative solutions are required. A more friendly fuel is needed. The liquid gas based public transport has been provided by the government. It can found that some buses available in Jakarta use liquid gases. However, the secure of this fuel usage remains a problem. Despite, this challenge, efforts should be made continuously as fossil energy source decreases continuously.

The electric vehicles have been a warm issue in efficient renewable energy driven transports. Many researches exist and more are coming. Electric car has been proposed in many ways, and the competition challenges are also conducted in many countries. For instance, Universitas Sumatera Utara as the oldest university in Sumatra island of Indonesia, has been the winner some minimum energy usage car competition [3]. The electrical engineering within this university also participates in electrical vehicle competition [4].

This paper focuses on electrical motorcycle design for student laboratory activities. Despite the absence of the novel method, the implementation is rather practical and useful for student experiment purpose. The more academic research has been conducted in [5], [6]. The designed motorcycle is aimed at power source of 3 kW. In order to do so, device components requirement is analyzed, starting from the battery to the mechanical frame.

2. Research Methods

In order to realize the expected electric motorcycle, Figure 1 shows the design steps involved in this research. Design is started by the power source calculation, the electric motor specification, electric motor controller, electrical wiring, motor-wheel connection and transmission, and mechanical frame.

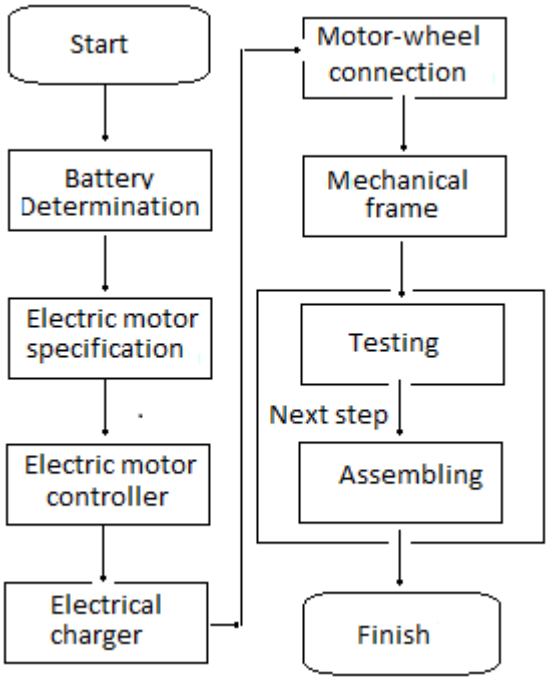


Figure 1. Research step

The next step is component purchasing and finally component assembly. By the time this paper written, the designed electric motorcycle is not yet finished and tested.

The torsion moment (momen putir, MP) is calculated based on Equation 1 considering input power P and rotation per meter (n):

$$MP = \frac{60xP}{2x3{,}14xn} \quad (1)$$

The output power is determined by the work done by the electric motor and the speed achieved. Equation 2 shows the formula. The efficiency is given by Equation 3.

$$P_{out} = W \times V \quad (2)$$

$$\eta = \frac{Pout}{Pin} x100\% \quad (3)$$

The battery capacity is determined by the Equation 4 where the charging duration (t) depends on battery capacity (ampere hour, AH), battery voltage (V) and the required power (P).

$$t = AH \times V/P \quad (4)$$

Battery should be able to store enough charge to produce current for a specific time. Further battery should not add significant mass to motor. In order to do so, this research arranges 13 series and 5 parallel Lithium battery of 3.7; 5AH to produce 48 V; 25 AH. Figure 2 shows the packed battery. And to allow charging, a commercial 48 V and a 2 A charger was purchased.

Figure 2. The packed Lithium battery and a charger

Charging the battery uses a commercial charger as shown in Figure 3.

Figure 3. Commercial charger

The assumed total mass of passenger and motor is about 136.5 kg. This mass and torque relation is hardly found as the efficiency changes to load. However, by considering these problems and the expected average speed of 35 km/h, the 400 rpm, the 3 kW BLDC motor is purchased as shown in Figure 4.

Figure 4. The 3 kW 48 V BLDC motor

Since BLDC requires hall sensor control, IC 3525, a pulse width modulation (PWM) IC, is employed with schematic given in Figure 5.Additional devices that have been purchased, include a speedometer, motor cycle lighting and other components.

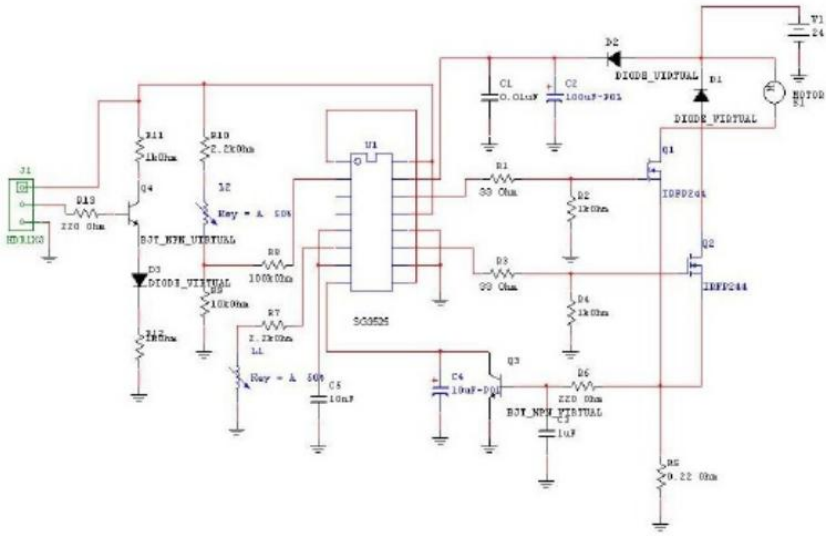
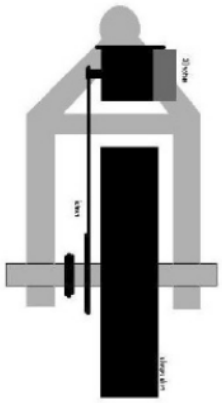
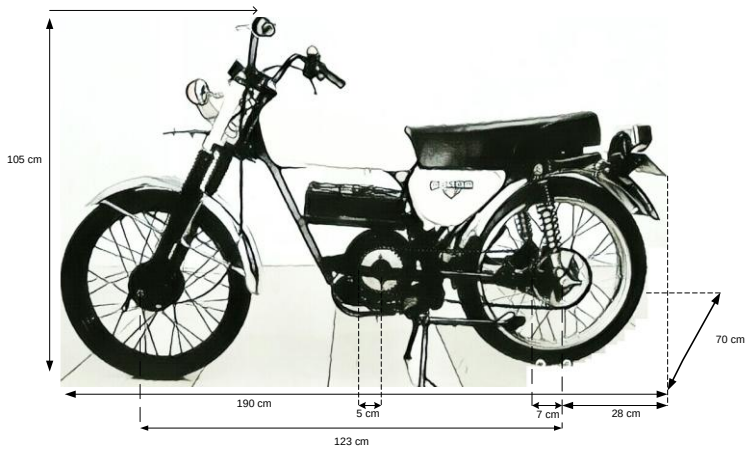


Figure 5. PWM circuit

Motor is indirectly connected to wheel by using a chain as shown in Figure 6.a. The schematic of mechanical plan is shown in Figure 6b.



(a) Motor-wheel connection



(a) Mechanic plan

Figure 6. Mechanic design

3. Design results

A multiphase brushless direct current (BLDC) [7] is commonly motor used for electric vehicle. BLDC motor does not use brush for current supply. Permanent magnet (Figure 7) acts as rotor. In order to move phase current, the motor requires hall sensors to detect magnetic position. As a result, BLDC requires a specific controller. Some advantages of BLDC motor are, smooth torsion, high efficiency, long lifetime, smooth working on any speed. The realized electric motor is shown in Figure 8.

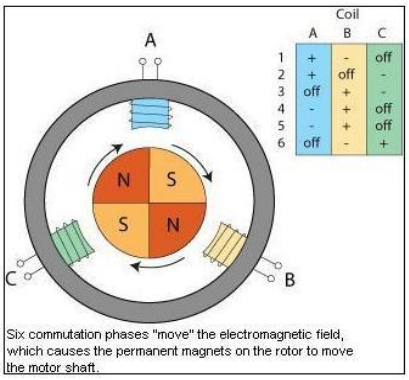


Figure 7. BLDC motor

Figure 8. The designed electric motor

In order to determine the motor requirement, the power is calculated based on the approximated passenger and motor masses. The motor mass depends on the mechanic, motor and battery masses. The approximated motor mass is 20 kg. As the selected mechanic frames as shown in Figure 6 with gear diameter 10 cm and 14 cm, the total approximated motorcycle mass is 71.5 kg. In order to achieve speed of 9.72 m/s, the measured total work is 25. 64 N, at this speed, motor rotates up to 400 rpm. The calculated average efficiency is 71.4%.

At motor evaluation, in order to travel 4.1 km, the battery requires charging up to 1 hour 35 minutes which results 0.2025 kWh total energy. For 10 km distance, battery charging runs for 3 hours 33 minutes with total energy of 0.499 kWh. By comparing the total energy exhausted by the petrol based motor, the electric motor expends lower cost about Rp 5160,- for 100 km, much lower compared to petrol motor, Rp 6650,- for 35km.

4. Conclusions

This paper has reported the design work of a 3kW electric motorcycle. BLDC motor is employed to drive 71.5 kg motor mass. The designed motor achieves average efficiency of 71.4%. It requires about 0.2024 kW for traveling up to 4.1 km with maximum speed of 35 km/h. The total expense is much lower than petrol motor.

Acknowledgement

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References

[1] AISI, "Domestic Distribution in 2018," *Indones. AISI - Asos. Ind. Sepedamotor*.

[2] B. Migas, "Konsumsi BBM Nasional," 2017.

[3] Ambarita, H., Siregar, M. R., & Kawai, H. (2018, March). Study on aerodynamics characteristics an urban concept car for energy-efficient race. In IOP Conference Series: Materials Science and Engineering (Vol. 343, No. 1, p. 012025). IOP Publishing.

[4] Howlader, A. H., Chowdhury, N. A., Faiter, M. M. K., Touati, F., & Benammar, M. A. (2014, March). Development of energy efficient battery electric car for Shell Eco-Marathon competition-Qatar University experience. In Ecological Vehicles and Renewable Ene.

[5] Buja, G., Bertoluzzo, M., & Mude, K. N. (2015). Design and experimentation of WPT charger for electric city car. IEEE Transactions on Industrial Electronics, 62(12), 7436-7447.

[6] Paterson, S., Vijayaratnam, P., Perera, C., & Doig, G. (2016). Design and development of the Sunswift eVe solar vehicle: a record-breaking electric car. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 230.

[7] "Salehifar, M., Moreno-Eguilaz, M., Putrus, G., & Barras, P. (2016). Simplified fault tolerant finite control set model predictive control of a five-phase inverter supplying BLDC motor in electric vehicle drive. Electric Power Systems Research, 132, 56-66.

[8] Torque calculation. 2018. Simple electric motor.