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Analytical Conversion of Conventional Car to Electric Vehicle Using 5KW BLDC Electric Motor

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Abstract: The automotive industry is witnessing a paradigm shift towards sustainable and eco-friendly transportation solutions. This project aims to contribute to this transition by converting a conventional internal combustion engine (ICE) car into an electric vehicle (EV) using a 5 kW Brushless DC (BLDC) electric motor. The conversion involves the removal of the traditional engine components and the integration of an electric propulsion system. The key components of the conversion include the BLDC motor, motor controller, battery pack, and associated power electronics. The BLDC motor is chosen for its efficiency, reliability, and compact design, making it suitable for retrofitting into existing vehicles. The motor controller manages the power supplied to the BLDC motor, ensuring optimal performance and efficiency. The project explores the challenges and solutions encountered during the conversion process, including adapting the vehicle's chassis to accommodate the new components, integrating a charging system, and addressing safety considerations. Additionally, efforts are made to optimize the overall weight distribution and maintain the vehicle's original handling characteristics. Performance testing is conducted to evaluate the acceleration, top speed, and overall efficiency of the converted electric vehicle. The results are compared with the original performance specifications of the conventional car to assess the success of the conversion. This project not only showcases the technical feasibility of converting conventional cars to electric vehicles but also highlights the environmental benefits associated with reducing reliance on fossil fuels. The findings contribute valuable insights to the growing field of electric vehicle conversions and promote sustainable transportation solutions.

Keywords: Battery; Brushless; Controller; Converting; Motor.

Introduction

Emissions from vehicles using conventional internal combustion engines are a major source of urban pollution (Park et al., 2012). To give a clearer picture of the impact, a car that consumes 7.8 liters of fuel per 100 km and travels 16,000 km will annually emit 3 tons of carbon dioxide into the air (Parinduri et al., 2018). Pollution generated from combustion, such as CO2 and NOx gases, has contributed to global warming and the greenhouse effect (Desantes et al., 2020).

In order to deal with deepening climate change, electric vehicles (EVs) have emerged as an alternative in reducing greenhouse gas (GHG) emissions and improving energy security (Kang et al., 2016). The conversion of conventional vehicles to electric vehicles

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involves replacing the internal combustion engine with an electric motor and the fuel system with a battery, making it a very interesting research topic in the transportation and energy technology sectors. This research offers a golden opportunity to change urban transportation patterns, reduce carbon emissions, and create a more sustainable and environmentally friendly mobility future.

Air Poluttion

Air pollution is a major problem in Jakarta, is caused by various factors such as transportation, population density, land use, and industrialization. The city's air quality is often in violation of the national air quality standards, and the levels of particulate matter (PM10 and PM2.5) are among the highest in the world (Li et al., 2019). Air pollution refers to the release of pollutants into the air-pollutants that can be detrimental to human health and the planet as a whole (Zhang et al., 2021). According to the World Health Organization (WHO), the primary cause is fine particles with a diameter of 2.5 micrometers or less (PM 2.5), which can penetrate deep into the lungs, heart, and bloodstream, leading to diseases, including cancer (Efendi & Fahmi, 2021).

Electric Vehicle

Electric vehicle holds promise in revolutionizing global transportation for eco-friendly and sustainable mobility, reducing air pollution, greenhouse gases, and health risks (Requia et al., 2018). These vehicles lack an internal combustion engine and do not utilize any form of liquid. Fuel Electric cars are powered by batteries in order to operate, these electric cars can reach a range of 160 to 250 km on a full charge. For higher classes, the range can be even further reaching up to 500 km (Kang et al., 2016). These mileage ranges are also affected by road condition, driver's age, road condition, climate, and battery type (Zikirillo & Ataboyev, 2023).

Conversion

Electric cars and conventional (gasoline) cars are very different in terms of the technology used. For the same segment, electric cars have an average price 50% higher (Zulfikri, 2023). These electric cars use lithium-ion batteries that cost hundreds of thousands of dollars. Naturally, everyone is looking for ways to make electric cars cheaper. One way to do this is to consider converting internal combustion engine (ICE) vehicles to electric vehicles (Eydgahi & Long IV, 2011). The process of converting an ICE vehicle to an electric vehicle involves replacing ICE-related parts, such as the combustion engine, exhaust system, and fuel tank, with EV parts, such as the electric motor, controller, battery and inverter. Most converters use a converter plate to connect the electric motor to a conventional transmission and maintain power delivery to the wheels (Raksodewanto, 2020). Thus, vehicles that originally used internal combustion engines can be converted to more environmentally friendly electric vehicles.

Center Of Gravity

The Center of Gravity is generally located about half the height of the vehicle. In designing a vehicle, the center of gravity can be compensated according to the speed of the vehicle because it will affect the stability of the vehicle while driving, especially on terrain that is not flat, such as climbs and descents (gradients) and when cornering. The center of gravity is calculated from the lowest point of a vehicle, where the wheels are attached to the track. In the equation below,

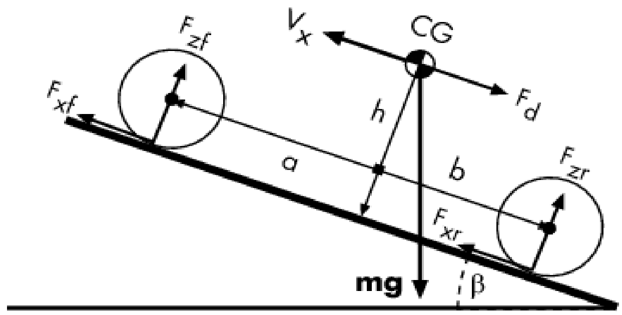

Figure 1. Diagram Gradien

$$h = \frac{F_{z,f}\,(R\sin\beta + a\cos\beta) + F_{z,r}\,(R\sin\beta - b\cos\beta)}{mg\sin\beta}$$

Wheel radius (r) = 6,2 cm = 0,062 m
Tire height (R - r) = 45% x 528 mm = 237,6mm = 0,2376m

Total wheel diameter (R)
R = 0,062 m + 0,2376 m
R = 0,2996 m

Method

The methodology of electric vehicle conversion can be divided into several stages, namely:

Planning

In this stage, the planning of the electric power system to be applied to the vehicle is conducted. Several factors to consider include the size and weight of the vehicle, required power, range capacity, and battery charging time. Additionally, component selection such as electric motor, battery, and motor controller is also carried out in this stage.

Design

At this stage, we will conduct the body and chassis design process of the Kancil car using SolidWorks, while determining the optimal position for its electrical components.

Calculate

At this stage the design that has been made is tested and determined the center of gravity to determine the stability of the vehicle at this stage data is needed:
Mmax = Maximum vehicle weight = 830 kg
θ = incline angle = 20°
Wheel Base =2.1m
r = Radian velg = 6,2cm
Wheel high = 25,8cm

Result and Discussion

To choose the right electric motor, the first step we need to do is determine the power required by the motor. In mechanical engineering, power is usually measured in horsepower (hp), where 1 hp equals 746 watts. Therefore, if we were to calculate 13.5 horsepower from the previous internal combustion engine power in kilowatts (kW), the result would be 10.071 or 10 kW. With reference to the calculations that have been carried out, we will now consider the use of a hub drive motor with a power of 10 kilowatts (kW).

Figure1. Electric Motor

Battery

Battery selection for electric motors is a crucial step in the design that can significantly affect the performance and success of the motor. Key factors to consider include energy capacity, battery type, weight, durability, recharge cycles, and reliability. The decision should be based on a comprehensive evaluation of the needs and intended use of the electric motor. We combined the batteries in parallel to obtain a battery specification of 60V with a current strength of 92A.

Controller

The controller is an electronic device that regulates the flow of electricity from the battery to the electric motor, controlling the speed, direction of movement, and efficiency of the vehicle. In this electric car, the controller used is a controller that has been integrated into the electric motor.

Design

The design that has been done relates to the placement of electrical components on the Kancil car, which involves the placement and arrangement of components such as electric motors, batteries, and controllers.

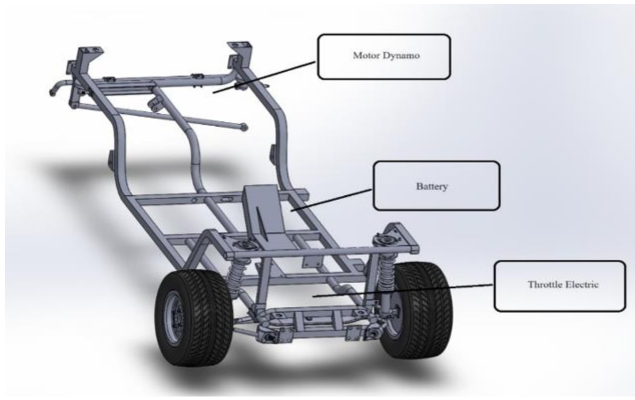

Figure 2. Design Chasis

Employ the SolidWorks software application to meticulously craft the comprehensive body design model of a Kancil automotive vehicle, ensuring precision and accuracy in the digital representation.

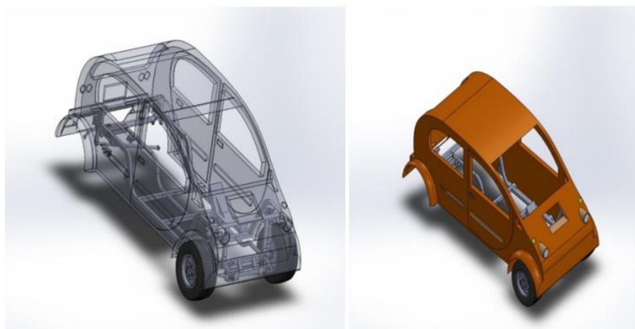

Figure 3. Design Body Vehicle

Control circuit design in electric vehicles has an important role in controlling and regulating various aspects of vehicle performance, including electric motor drive, battery energy management, energy regeneration during braking, and safety and stability systems.

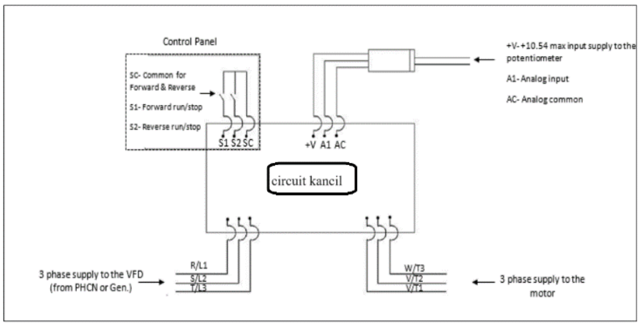

Figure 4 Developed control circuit of the EV

Calculate

Center of Gravity

In this calculation, information is needed about the front wheels of the car (F_(z, f)) and rear wheels (F_(z, r)) which can be obtained through the following equation

1. $F_{z,f}$

$$F_{z,f} = 45\% \times m \times g$$
$$F_{z,f} = 45\% \times 830\text{kg} \times 9{,}81\ m/s^2$$
$$F_{z,f} = 3664{,}03\ \text{N}$$

2. $F_{z,r}$

$$F_{z,r} = 55\% \times m \times g$$
$$F_{z,r} = 55\% \times 830\ \text{kg} \times 9{,}81\ \text{m/s}^2$$
$$F_{z,r} = 4478{,}2\ \text{N}$$

From equations (1) and (2) can be obtained the distance from each center of the wheel shaft to the center of gravity. The distance between the center of gravity and the center of the front axle, denoted by a is

$$a = \frac{2l\ F_{z,r}}{mg}$$
$$a = \frac{2 \times 2{,}1\text{m} \times 4478{,}2\ \text{N}}{2(3664{,}03 + 4478{,}2)\ \text{kg} \times 9{,}81\ \text{m/s}^2}$$
$$a = 0{,}11\ \text{m}$$

While the distance between the center of gravity and the center of the rear axle, denoted by b, is:

$$b = \frac{2l\ F_{z,f}}{mg}$$
$$b = \frac{2 \times 2{,}1\text{m} \times 3664{,}03\ \text{N}}{2(3664{,}03 + 4478{,}2)\ \text{kg} \times 9{,}81\ \text{m/s}^2}$$
$$b = 0.096\ m$$

Then determine the center of gravity through the equation h assuming the car is above an inclined plane at a certain β angle. In the above conditions, the car is assumed to be moving uphill at a gradient of β = 20°.

$$h = \frac{F_{z,f}\,(R \sin\beta + a\cos\beta) + F_{z,r}\,(R\sin\beta - b\cos\beta)}{mg\sin\beta}$$
$$h = \frac{3664{,}03\,(0{,}299\sin 20° + 0{,}11\ \cos 20°) + 4478{,}2\,(0{,}299\sin 20° - 0{,}096\cos 20°)}{1065{,}996 \times 9{,}81 \times \sin 20°}$$
$$h = 0{,}252\ \text{m or } 25{,}2\ \text{cm}$$

Chasis Testing

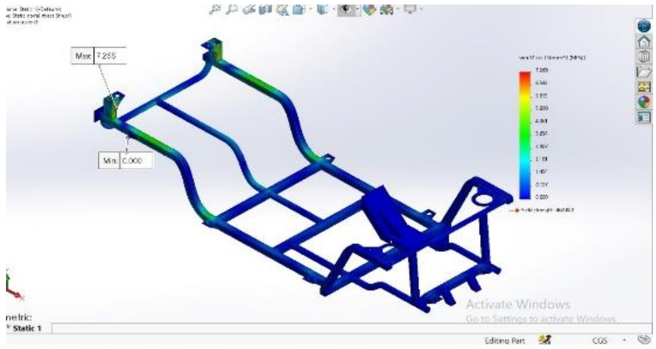

Figure 5. Chasis Testing

The test was carried out using solidwork, where the figure shows that the placement of more weight on the back can still be withstood, give a more detailed explanation.

Power-train Characteristic

Based on the data collected from the dynamometer, we calculate those data measured from the hub resulted in the torque and power produced by the powertrain. From the data collected at 4th gear, the torque reached peak number by 64 Nm and the peak power is 13 HP. By using statistic approximation of third order polynomial, we could map the graph of the performance characteristic of the motor.

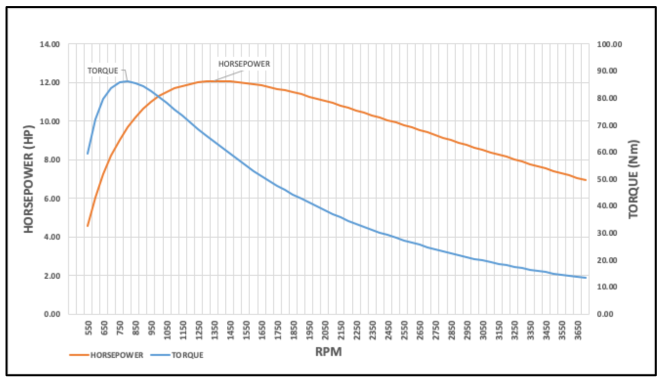

Figure 6. Powertrain characteristic Force Generated by the ehicle (Tractive Effort)

The tractive effort value is used to measure the capability of the vehicle to withstand the resistance force acting on the vehicle. On this experiment we simulate force by combining all the three resistance forces with the variance of speed the vehicle travels and the road inclination.

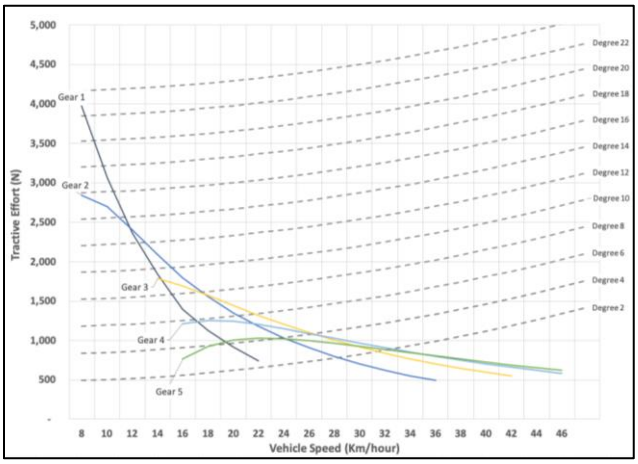

Figure 7. Tractive Effort vs Resistance Force

As shown in figure 7, we could determine the gear need to be used to counter the varying resistance force by road inclination. We could also determine the maximum vehicle speed of each gear used by the vehicle on which it is 46 km/h. Indonesian Toll Road regulated that the minimum speed vehicle needs to travel is 60 km/h [9] on which EV haven't pass. By referencing to the Indonesian National Standard of city roads inclination geometry, it is mandated that the inclination can't pass 8% [10], based on the result EV already passed the standard.

The following are the results of measuring the voltage and amperage of a 3-phase AC motor where when the measurement uses the Power Quality Analyzer (PQA), the measurement is done by running the vehicle without a load by lifting the front wheel and varying the rotation of gear shifting 1 to 4 with maximum speed as following: • The maximum speed of 1st gear is 20 km / hr • The maximum speed of 2nd gear is 40 km / h • The maximum speed of 3rd gear is 60 km / h • The maximum speed of 4th gear is 80 km / h . From these results, the measurement results of the current and voltage on the 3-phase motor (attached) are obtained and when the displacement conditions occur a very high amperage spike, this if it occurs continuously will result in the ability of the battery to run out quickly.The following are the results of measuring the voltage of a 3-phase AC motor where when the measurement uses a Power Quality Analyzer (PQA) which is measured by running the vehicle. Measurement of voltage and average current shows conditions that are not much different where at each gear shift there is a surge in both the increase and the voltage, even though the two currents have a higher number than the change in voltage. Large changes in current due to each displacement require a large amount of power to accelerate the rotation and load which in the context of electric motor loads is dominated by changes in current while the voltage is relatively more stable.

The research was conducted by testing the torque conversion vehicle. Experimental data on torque and horse power with the results of the rpm rotation before. From the measurement results of horse power (HP) to the speed of each gear shift condition (1-5) where the value of the 1st gear HP has a low resistance to speed with a relatively higher HP than 5th gear and the highest is the gear. 4th because it has the longest resistance with the relatively high HP value. Likewise in the Torque measurement results against the speed of each gear shift condition (1-5) where the 1st gear Torque value has low resistance to speed with The torque is relatively higher than the 5th gear and the highest is 4th gear because it has the longest resistance with the highest relatively high Torque value. Describing the various possibilities to get optimal results, in this case there are 2 possibilities by using 2 gear combinations are used to get the optimum value between hors e power, torque and rpm.

Conclusion

The characteristics of the production factors of Paddy Rice Farming with Zero Tillage System are: paddy field area of 0.25 - 2.0 ha with an average of 0.73 ha, seed requirement of 8 - 60 kg/acre with an average of 30-36 kg/acre, compost fertiliser is given 0.25 - 2 tonnes/acre, Urea fertiliser is given 25 - 200 kg, NPK Phonska fertiliser is given 25 - 200 kg, herbicide is given 1 - 3 litres, insecticide is given 1 - 2 litres, labour consists of labour within the family and labour outside the family, including: Male Labour and female labour and capital consists of cash (privately owned and borrowed), hoes, and knapsack sprayers.

The amount of labour for farming Rice with Zero Tillage System can be reduced by up to 145%, especially in land preparation activities, because without tillage, only spraying the remaining rice stalks and weeds is done.

The characteristics of rice production are: Total production of 800 - 6,200 Kg/acre, with an average of 2,262.80 Kg. The selling price of rice production received by farmers was IDR 7,500/kg - IDR 7,800/kg, with an average of IDR 7,710/Kg.

Based on the data collected and simulation of the real-world scenario uses of Makara Electric Vehicle 02, it is concluded that this vehicle is not ready to be used, the reason being it hasn't managed to perform as the standard suggest, particularly on the minimum of speed on toll road that vehicles need to travel. This could happen because of the battery performance of lead-acid battery is not suitable enough to be used and paired with the driveline configuration it is currently using, for that the motor performance and the transmission paired together, has managed to deliver the performance as it is specified and as it is needed to conquer the real-word usage.

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Author Contributions
FZ: Developing ideas, analyzing, writing, reviewing, responding to reviewers' comments; DAS, MA, SP, TR: analyzing data, overseeing data collection: RS, RF, SP, RN, MT, MR reviewing scripts, and writing.

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Conflicts of Interest
The authors declare no conflict of interest.

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