Research Inventy: International Journal of Engineering And Science
Vol.13, Issue 12 (December 2023), PP 12-17
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

The effect of vehicle speed on energy consumption of electric vehicle Faculty of Engineering University of Mataram

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Abstract: *The use of electrical energy for vehicles is currently very relevant because its efficiency is relatively high and is environmentally friendly, due to, it does not emit exhaust gases emission. Indonesia has a huge potential to develop electric vehicles because there is a lot of nickel available to be processed into batteries. However, it is necessary to consider the level of energy use of the electric vehicle that will be made. How much does speed influence the use of electrical energy, or at what speed does an electric vehicle provide the greatest efficiency in energy use. This research is intended to study how much vehicle speed influences energy consumption and also to obtain the vehicle speed range with the lowest energy use efficiency in autonomous electric vehicles, Faculty of Engineering, University of Mataram. The results show that increasing the speed of electric vehicles will increase energy consumption and the longer the usage time will also increase the use of electrical energy. The lowest electrical energy consumption is obtained at a speed of 30 km/hour with a usage time of 15 minutes, namely 0.18752 kWh.*

Keywords*: Electric vehicles, Battery, Vehicle speed, Electrical energy, Energy consumption*

Date of Submission: 24-11-2023 Date of acceptance: 07-12-2023

I. INTRODUCTION

In Indonesia, transportation is a daily necessity, almost all aspects of life cannot be separated from transportation. Every year the use of transportation is increasing, from the Central Statistics Agency in 2021, it was noted that the vehicle ownership of the Indonesian population reached 143,797,227 vehicles of all types of fossil fuel vehicles (BPS, 2021). Cars are one form of transportation that is widely used, cars use an internal combustion system that uses fossil fuels as the driving energy which contributes quite a bit to air pollution. Carbon monoxide (CO) and hydrocarbon (HC) are dangerous pollutants which will certainly be very detrimental to human health. Apart from these two gas contents, every day fossil fuel vehicles will release carbon dioxide (CO_2) gas remaining from combustion into the atmosphere which can increase the negative impact of the greenhouse effect (Purnomo, 2018, Jiang et al., 2018). The various negative impacts caused by internal combustion vehicles make the automotive industry continue to innovate, one of which is the electric motor as a driver for electric cars which is expected to be able to overcome existing problems. Various groups, both academics and professionals, are starting to think about saving petroleum fuel and the environmental impacts caused by vehicles with internal combustion engines. Electric vehicles are a solution to this problem because they use environmentally friendly energy and do not cause pollution (Jatmiko et al., 2018)

Even though electric vehicles are known as environmentally friendly vehicles and do not produce exhaust emissions, electric vehicles have limited energy stored in the battery and must be recharged when used (Ristiana et al., 2018). Due to the limited charging speed and battery capacity for most electric vehicles available today, the use of electric cars is limited and requires their operation to a certain extent. In this case, energy consumption is a determinant of the extent to which electric cars can be operated (Skuza & Jurecki, 2022). Electric cars only rely on energy stored in the battery pack, BEV type electric cars can reach a distance of 100 to 250 km on one full charge. For higher classes, the distance can be further, reaching 300 to 500 km (Fotouhi et. al, 2020). Empirical data have shown that energy consumption in electric vehicles is usually higher than stated by the manufacturer based on the driving cycle (Weiss et al., 2020). Based on research conducted by (Petersen et al., 2021; Badin et al, 2013) grouped the factors that influence the energy consumption of electric cars into four categories, namely: driving style (speed, acceleration, aerodynamics and positive/negative kinetic energy) road topology (inclines and curves), traffic density (congestion, barrier-free and road type) and environmental factors (temperature).

Electrical power is the ability of electrical equipment to do work due to changes in electrical work and changes in electric charge per unit of time (Lovely and Rusli, 2012). The amount of electrical power is influenced by electrical voltage, current strength and electrical resistance, electrical power is expressed in Watts (Adriana and Masrianor, 2017). Meanwhile, electrical energy is the amount of electrical power consumed by electrical equipment in a certain period of time, which can be calculated from measuring the current and voltage acting on a device. The amount of electrical energy consumed by electric motors is influenced by various factors (Badin, et.al 2013)

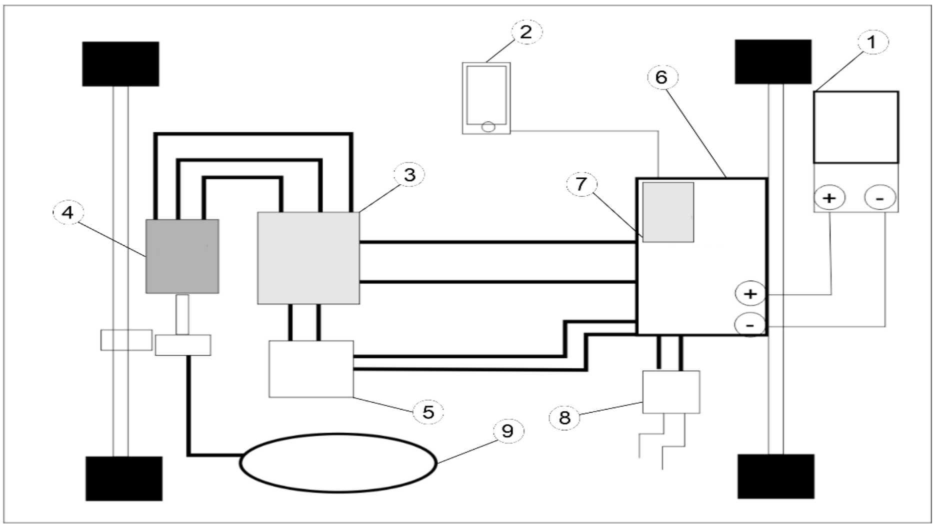
Electric motor efficiency can be defined as the ratio of the motor output power used to the input power of the electric motor (Manalu, 2012). The energy consumption of a vehicle is the amount of energy used in kilo Watt hours (kWh) or can also be expressed in kilo Joules, however the term kWh is more commonly used in measuring the energy consumption of a vehicle. The energy capacity stored in electric vehicle batteries is usually expressed in kilo Watt hours (Fotouhi et al., 2020) so that the length of battery life can easily be calculated, as is generally the case for gasoline-powered vehicles using fuel measured in liters/km or gallons/ miles (Mediouni et al., 2022).

Based on several problems above, analyzing the energy consumption of electric cars is very important to do. The factors that influence the energy consumption of electric cars are so complex, there has been no detailed and specific research that discusses the influence of electric car energy consumption based on variations in speed and time. Therefore, the author is interested in conducting research on this matter, the author carried out tests on an electric car that is being developed by the Faculty of Engineering, Mataram University. By carrying out research on the energy consumption of electric cars, it is hoped that it will be able to help design energy-efficient and environmentally friendly city car models which are being developed by the Faculty of Engineering, University of Mataram.

II. EXPERIMENTAL PROCEDURE

In this research, an experiment was used to measure the parameters of the strength of the electric current and the magnitude of the voltage difference in the electric vehicle circuit at various variations in vehicle speed. The placement of the test equipment in this research was designed as shown in the following test scheme.

Figure 1 schematic of the test equipment. 1 volt meter, 2 BMS display monitor, 3 controller, 4 PMSM motor, 5 auxillary batteries, 6 main batteries, 7 BMS, 8 battery charger, 9 speedometer

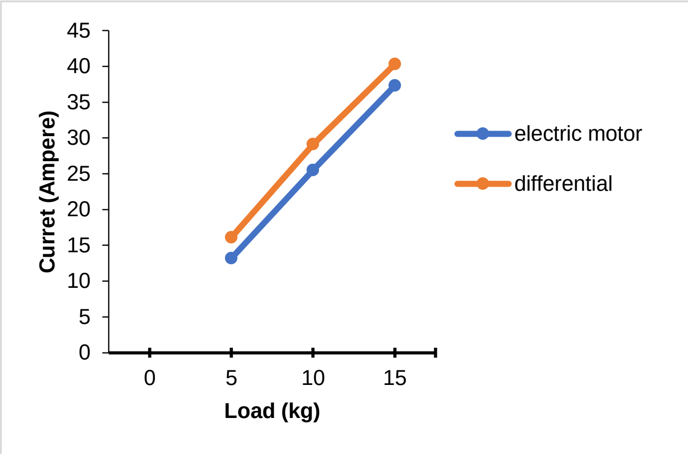


In the testing process, the electric car with a 10 kW motor is supported in a steady state with a jack and it is ensured that the electric car battery is fully charged and the car is in good condition. Check the battery power before carrying out the test and record the power condition parameters, voltage and battery capacity. Then the car is started and the gas pedal is pressed with predetermined speed and time variations, namely 30 km/hour, 40 km/hour and 50 km for 15 minutes, 30 minutes and 45 minutes. Data was taken three times for each variation of speed and time and during the test the initial and final battery percentages as well as the initial and final voltage were recorded.

III. RESULTS AND DISCUSSIONS

Data analysis was carried out using formulas contained in the theoretical basis to find the value of electrical energy consumption for each speed variation in order to determine the phenomena that occur. The following is the data obtained from observing variations in speed of 30 km/hour and taking 15 minutes to carry out the data calculation stage, namely as follows:

Figure 2. Relationship between loading mass and electric current in electric motors and differential

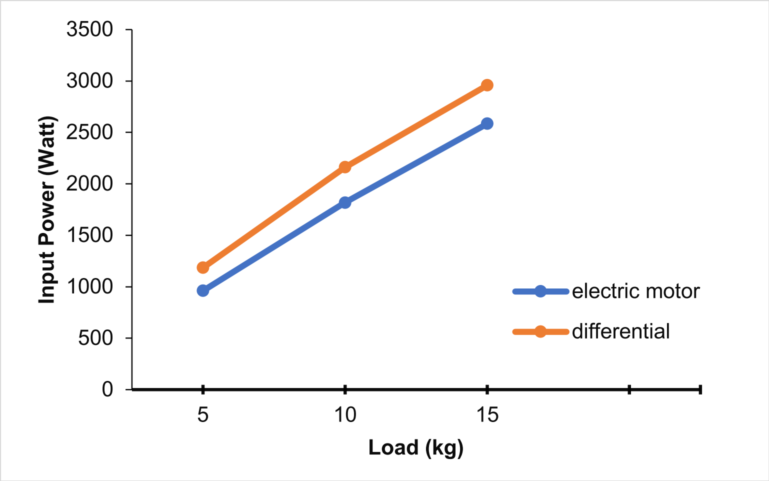


Collecting electric current data for each load variation is carried out using an ampere measuring tool as input data for testing electric motors and differentials which are measured on the positive battery output cable. Electric current is measured in electric motor tests and differential tests with various added loading masses. Electric current data will be used to determine the amount of input power required by the electric motor and differential at each load

Figure 2 above shows that the loading mass and electric current have a directly proportional relationship, the higher the loading mass, the greater the electric current released by the battery. The highest electric current value was obtained when the loading mass was 15 kg, namely in the electric motor test it was 37.3 Amperes and in the differential test it was 40.3 Amperes, while at the loading mass of 10 kg, the amount of electric current decreased, namely 25.2 Amperes at electric motor testing and 29.1 in differential testing. Meanwhile, the lowest current was obtained with a load mass of 5 kg, namely 13.2 Ampere in the electric motor test and 16.1 Ampere in the differential test.

The research results show that the higher the loading mass, the greater the electric current emitted because the loading on the electrical output shaft will result in the motor's effort to move being greater so that the electric current emitted will also be greater. Similar results were obtained in research (Badin et.al 2013). Where the results of the loading test show that increasing the passenger load will affect the flow. Where the current will increase with additional load. In other words, the greater the passenger load, the higher the current required to move an electric car.

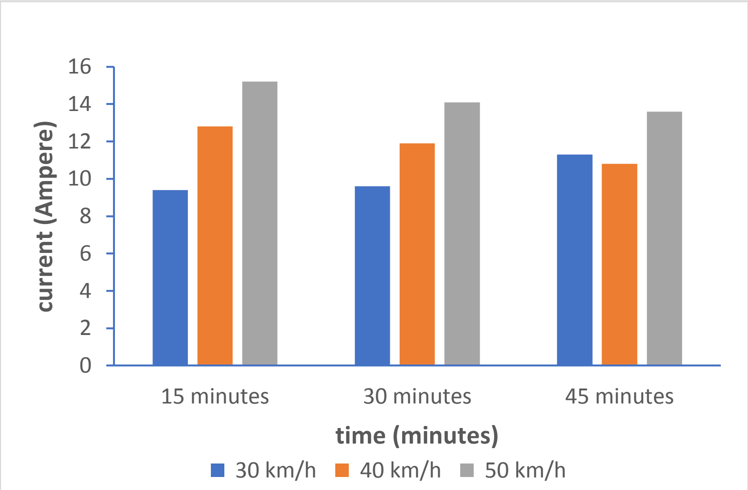
Figure 3. Relationship between load mass and input power on electric motors and differential



The input power in electric motor testing and differential testing is obtained through a calculation process between voltage and electric current. The graph above shows that the relationship between load and input power is directly proportional, where the greater the mass of the load, the greater the input power produced. The largest input power value was obtained at a loading mass of 15 kg, namely 2584.89 Watts in the electric motor test and 2958 Watts in the differential test. Meanwhile, with a loading mass of 10 kg, the input power value is 1818.2 Watts in the electric motor test and 2162 Watts in the differential test. The lowest input power value was obtained at a loading mass of 5 kg, namely 961.5 in the electric motor test and 1185 in the differential test.

The test results show that the greater the loading mass, the greater the input power because the input power has a directly proportional relationship to the electric current. If the voltage is constant and the electric current value is high, the resulting input power will also be high. This means that the greater the load given to the electric motor, the greater the power required. This was also found in Kuswardana's research, 2016, where the output power depends on the vehicle load.

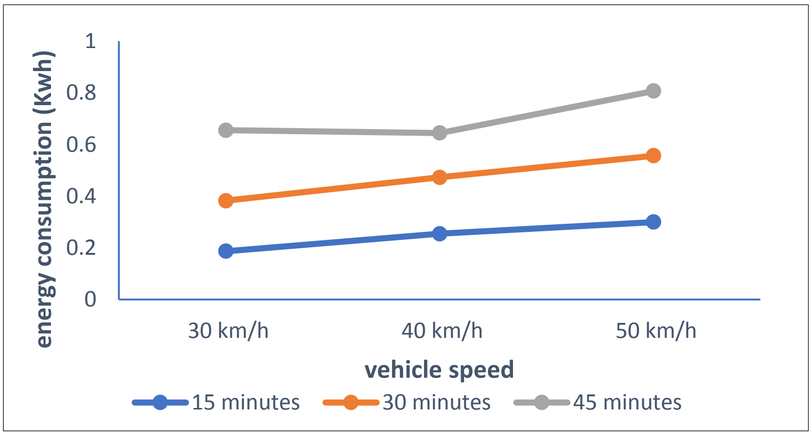
Figure 4. The amount of electric current consumed at various vehicle speeds



Based on Figure 4, you can see the electric current consumption of electric vehicles at various speeds during a certain time period. The amount of electric current that flows to the electric motorbike is relatively the same for various periods of use, but the faster the vehicle goes, the electric current usage tends to increase. This is because at higher speeds the electric motor will spin faster, the resistance to that rotation will also be higher. At higher speeds, the vehicle will encounter stronger air resistance. This means the motor has to work harder to overcome air resistance, which requires more power. At higher revs, there is increased internal resistance within the motor itself. This includes friction in bearings and other mechanical components. As the motor rotates, the energy loss due to this resistance also increases.

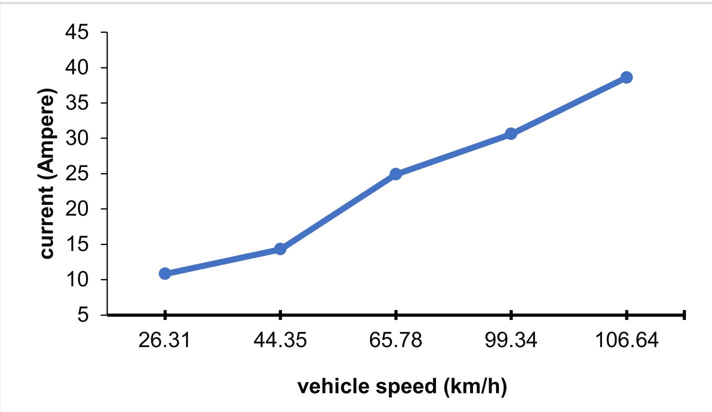
Figure 4 above shows that speed and electric current have a directly proportional relationship, the higher the speed, the greater the electric current released by the battery. At a speed of 30 km/hour with a time of 15 minutes, 30 minutes and 45 minutes each produces a current of 9.4 Ampere, 9.6 Ampere and 11.3 Ampere. At a speed of 40 km/hour with the same time variations, an electric current of 12.8 Ampere, 11.9 Ampere and 12.3 Ampere is obtained. And finally, at a speed of 50 km/hour with the same time variation as the previous speed, the current was obtained at 15.2 Ampere, 14.1 Ampere and 13.6 Ampere. From the data obtained, the highest current value was at a speed of 50 km/hour with a time of 15 minutes, namely 15.2 Ampere, while the lowest current value was obtained at a speed of 30 km/hour with a time of 15 minutes, namely 9.4 Ampere. The research results show that the higher the speed, the greater the electric current released because the need for electric current on the motor will increase as the speed increases. The results of the test show that increasing speed will affect the current, where the current will increase with increasing speed. This means that the faster the vehicle, the higher the current required to move the electric car.

Figure 5. The amount of electrical energy consumed at various vehicle speeds.



The energy consumption value of an electric car is obtained through a calculation process using the formula between power (kW) and time (hours), in Figure 5. above, it shows that speed and time are directly proportional to energy consumption, where the greater the speed and the longer the time, the more energy consumption also increases. At a speed of 30 km/hour with a time of 15 minutes, 30 minutes and 45 minutes respectively, the energy consumption is 0.18752 kWh, 0.3828 kWh and 0.6556 kWh. At a speed of 40 km/hour with the same time variations, the energy consumption is 0.2547 kWh, 0.4734 kWh and 0.7313 kWh. Then at a speed of 50 km/hour with the same time variations, the energy consumption is 0.30008 kWh, 0.5567 kWh and 0.8074 kWh. From the test, it was found that the highest energy consumption was obtained at a speed of 50 km/hour for 45 minutes amounting to 0.8074 kWh and the lowest energy consumption was obtained at a speed of 30 km/hour for 15 minutes amounting to 0.18752 kWh.

Figure 6. Relationship between electric current strength and vehicle wheel speed



The circumferential wheel speed test was carried out on the wheels of an electric car but without the vehicle load in order to determine the circumferential speed and electric current consumption at each speed. From figure 6 above, it shows that the relationship between the circumferential speed and the electric current emitted by the battery is directly proportional, the higher the circumferential speed of the wheel, the greater the current emitted. The highest electric current was emitted at a speed of 106.64 km/h, namely 38.6 Amperes, while the lowest electric current was emitted at a speed of 26.31 km/h, namely 10.8 Amperes. The test results show that the higher the circumferential speed of the wheels, the higher the electric current required, meaning that when an electric car drives at an ever-increasing speed, the current consumption of the electric motor will increase.

IV. CONCLUSION

Based on the analysis and discussion above, a conclusion can be drawn that increasing the speed of electric vehicles will increase energy consumption and the longer the usage time will also increase the use of electrical energy. The lowest electrical energy consumption is obtained at a speed of 30 km/hour with a usage time of 15 minutes, namely 0.18752 kWh.

Conflict of interest

There is no conflict to disclose.

ACKNOWLEDGEMENT

The author would like to thank the Department of Mechanical Engineering, Faculty of Engineering, University of Mataram for the support of the facilities provided. Thanks are also expressed to colleagues who have contributed to the completion of this paper

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