Design of Prototype Electric Car using 4 Motors as Future City Car in Indonesia

Widodo[1] and Mochamad Syamsiro[1]

[1]*Departement of Mechanical Engineering, Janabadra University, Jalan Tentara Rakyat Mataram 55-57 Yogyakarta 55231*

Keywords: Electric Vehicle, City Car, Energy Consumption, Performance.

Abstract: The availability of non-renewable energy used by motorized vehicles will eventually run out. According to Ministry of Energy and Mineral Resources, crude oil reserves in Indonesia are declining. In 2030 or next 11-12 years, oil in Indonesia will be run out. In the other hand, fuel consumption increase significantly for 13.5 million barrels, from 374.7 million barrels to 388.2 million barrels. Electric vehicles for the future of alternative solutions are emerged by this situation. This study aims to design, fabricate and tested the electric car as the future city car in Indonesia. The test results of electric cars are as follows: 1) the average speed of 8 km mileage was 12.52 minutes; 2) the uptake is tested at a distance of 10 meters with a slope of 25° by 1387,266 watts; 3) the acceleration and deceleration of 100 meters followed by braking and the stop distance after braking was 5.3 takes 8.643 seconds; 4) The acceleration was 2.49 m/s2 and 50 total Energy consumption of Energy used in 8 km was 587,782 Wh.

1 INTRODUCTION

The increasing numbers of fossil fuel vehicles makes humans dependent and lead to energy crisis. The availability of non-renewable energy used for motor vehicle fuel has gradually diminished over time. The demand for fossil fuel continuously increases. Another problem that arises from vehicles with fossil fuel is environmental pollution. Pollution is caused by carbon dioxide in exhaust gas as a result of combustion. Excessive carbon dioxide will cause long-term effects such as various respiratory diseases, the greenhouse effect. In 2030 or next 11-12 years there will be run out of oil in Indonesia.

In the other hand, fuel consumption increase significantly for 13.5 million barrels, from 374.7 million barrels to 388.2 million barrels (of Energy and of Indonesia (MEMRI), 2019). Therefore, the alternative energy sources have been developed such as pyrolytic oil from waste plastic and tire as partial substitute for fossil fuel (Syamsiro et al., 2018); (Syamsiro et al., 2019a) and also tested in the combustion engine to assess the thermal performance of that fuel (Syamsiro et al., 2019b). However, the combustion based engine was still used in this system, so that the alternative engine need to be developed to solve these problems.

Electric vehicles for the future of alternative solutions are emerged by the petroleum supplies crisis; moreover fossil fuel generates air pollution and noise in our society and environment (Bambang et al., 2011).

Exhaust gas emissions such as CO, NOx, SOx, HF are polluting the environment, thus the emission of exhaust gas must be in accordance with the laws and regulations so that it is safe for the environment. Hydrogen fluoride is a compound of hydrogen and fluorine with the chemical formula of HF. Fluorine is in halogens elements group, which all combine with hydrogen in the same way to form hydrogen halide. At room temperature and normal pressure, hydrogen fluoride is a colorless gas with a boiling point of 19.5° C, and allows it to exist as a liquid at room temperatures. Hydrogen fluoride can be produced by the reaction of metal fluorides. Hydrogen fluoride is very toxic and very corrosive. Inhaling gas damages the respiratory system and can cause pulmonary edema and death.

Nitrogen oxide (NOx) is a type of air pollution; NOx is a group of gas which mainly consists of two main components, namely nitric oxide (NO) and nitrogen dioxide (NO2) gas, and other very small amounts of nitrogen oxides. NO is a colorless and odorless gas, in contrary NO2 is brown reddish and has a strong odor. In general the NOx gas formation reaction process is as follow:

Widodo, . and Syamsiro, M.
Design of Prototype Electric Car using 4 Motors as Future City Car in Indonesia.
DOI: 10.5220/0009877600430047
In *Proceedings of the 2nd International Conference on Applied Science, Engineering and Social Sciences (ICASESS 2019)*, pages 43-47
ISBN: 978-989-758-452-7

$$N_2 + O_2 \rightarrow 2NO$$
$$2NO + O_2 \rightarrow 2NO_2 \quad (1)$$

Nitrogen oxides (NOx) is formed from oxidation of nitrogen molecules in fuel combustion process, consisting of 95% NO and 5% NO2. SOx (sulfuroxide) is one of the components of pollutants in the atmosphere resulting from the combustion process of oil and coal and other processes containing sulfates (Wark et al., 1998). SOx gas is very dangerous for living things because it plays an important role in the accumulation of acid in the air which causes acid rain (Benitez, 1993). In certain concentrations SOx can cause lung disease and respiratory problem, especially for people with asthma, bronchitis, and other respiratory diseases (Bruce and Bruce, 2003).

CO (carbon monoxide) is a colorless and odorless gas produced from an incomplete combustion process from carbon-based materials such as wood, coal, fuel oil and other organic substances (Grant and Clay, 2002). Claude Bernard in 1857 discovered that the toxic effect of carbon monoxide caused by the release of oxygen bonds from hemoglobin into carboxyhaemoglobin.

The energy produced from fossil fuels is increasingly expensive and scarce and one day it will surely run out, Indonesia's oil production is now far less than the needs of the population and industry, currently it is estimated to have a deficit of around 500,000 barrels/day (BP Statistical Review Of World Energy) as seen in Figure 1 ((BPS), 2010)

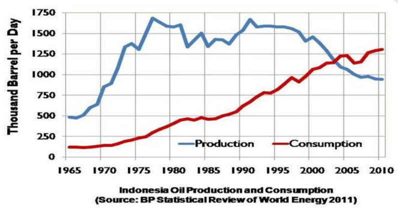

Figure 1: Petroleum production and consumption in Indonesia

2 METHODOLOGY

2.1 Battery

Electric cars are vehicles that are driven by an electric motor, using electrical energy stored in batteries or other energy storage. Electric Energy is converted into mechanical energy by a motor. The power from the electric motor is then transmitted to the wheel so that it becomes the rotating energy which drives the wheels of the car.

2.2 Frame or Chassis

Chassis is an important part of the vehicle. Chassis serves to support and mount the components in the vehicle. For this reason, material selection must be considered in accordance with its use. In selecting the most important material is the analysis of mechanical properties, namely the concept of the voltage acting on the structure and the stress of the material used. From this analysis we can find the maximum voltage and deflection. Once the maximum voltage and deflection is known, we can determine the material and size of the material. In this analysis we use the 2009 Autodesk Inventor software (Curtis and Loren,).

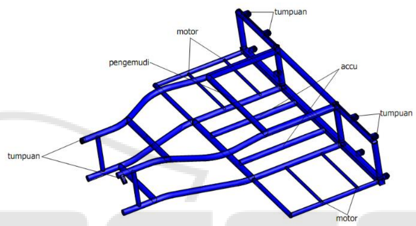

Figure 2: Chassis of an Electric Car

2.3 Motor

Before determining the motor power, the first consideration is vehicle's trail force the following data are known:

a) Wheel Base (L): 1500 mm
b) Center Weight (l1): 754 mm from the front axle
c) Center Weight (l2): 746 mm from the rear axle
d) Weight point height (h): 250 mm
e) Vehicle weight (W): 250.10 = 2500 N
f) Glinding resistance coefficient (fr): 0.3

Wheel adhesion coefficient with road surface (μ): 0.3 using the rear wheel drive then the vehicle's trail force can be calculated (Mott, 2009).

$$F = \frac{\mu W(l1 - f_r.h)}{L - \mu.h} = \frac{0,3.2500.(0,754 - 0,3.0,25)}{1,5 - 0,3.0,25} = \frac{750.0,679}{1.5 - 0,075} = \frac{509,25}{1,425} = 357,4N \quad (2)$$

So the force needed to drive the car is at least 357.4 N. From this calculation, the BLDC 500 watt motor is able to move. The performance of the BLDC 500 watt motor is as follows:

Table 1: Reference table for motor determination of electric car (Champion and Arnold, 1954)

Torque(Nm)	Voltage (volt)	Current (ampere)	Input Power (watt)	Rotation (rpm)	Output Power (watt)	Efficiency (%)
1.2	48.07	2.422	116.4	720.6	9.5	8.2
1.7	48.09	3.445	165.7	719.5	13.4	8.1
2	48.06	3.444	165.5	720.7	14.2	8.6
2	48.04	3.456	116	720.7	14.3	8.6
2	48.07	3.448	165.7	718.5	14.9	9
3.7	48.02	4.333	208.1	718.2	27.5	13.2
7.5	48.01	4.687	225	715.7	56.5	25.1
11	47.99	4.849	232	712.4	79.8	34.4
19	47.96	5.934	284.6	707.9	142.6	50.1
26	47.9	6.973	334	702.4	190	56.9
41	48	9.725	466.8	697.6	297.4	63.7
52	47.6	11.618	553.01	690.5	373.3	67.5
67	47.79	13.289	660.1	686.2	480.8	72.4
85	47.96	16.236	778.7	674.6	598.1	76.8
99	47.52	18.314	870.3	662.4	688.4	79.1
123	47.64	21.72	1034.7	644.1	830.8	80.3
157	47.41	25.106	1190.3	590.7	968.9	81.4
200	47.26	28.121	1328.9	529.6	1111	83.6
247	47.54	30.483	1449.2	478.3	1234.7	85.2
275	47.48	31.704	1505.3	431.9	1244.8	82.7
320	48.01	32.302	1548.7	375.3	1257.5	81.2
336	47.23	31.4	1507.1	332.4	1169.5	77.6
356	47.35	30.581	1478	305.7	1139.5	77.1
382	47.19	27.1	1304.8	290.2	916.5	70.2
426	47.42	25.932	1203.8	270.6	840.3	69.8
453	47.19	24.356	1149.4	240.7	743.9	64.7
484	47.16	23.782	1121.6	220.6	654.8	58.4
511	47.14	23.453	1105.6	201.1	610.9	55.3
542	47.26	22.892	1081.8	160.6	550.7	50.9
581	47.37	24.55	1162.9	111.3	452.8	38.9
605	47.51	25.068	1190.9	70.2	359.4	30.1
639	47.2	26.514	1251.5	43.5	276.6	22.1

3 RESULTS AND DISCUSSION

3.1 Trial Framework Design

The results of the framework design analysis is shown in Table 2.

Table 2: Framework design analysis

Name	Minimum	Maximum
Equivalent Stress	3.086e-003 MPa	42.96 MPa
Maximum Principal Stress	-33.68 MPa	29.72 MPa
Minimum Principal Stress	-80.81 MPa	7.48 MPa
Deformation	0.0 mm	0.5398 mm
Safety Factor	4.816	N/A

Considered from the critical stress the design is safe, because the maximum stress acting on the construction is smaller than the material tensile stress (42.98 <345). Based on the results of the analysis above, the material used for the framework is a low carbon steel pipe with the diameter of 3/4 ”and 1/2” and thickness of 2 mm, this specification is safe

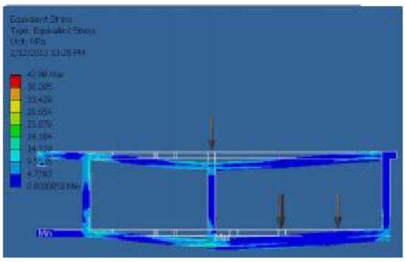

Figure 3: Load Analysis Low

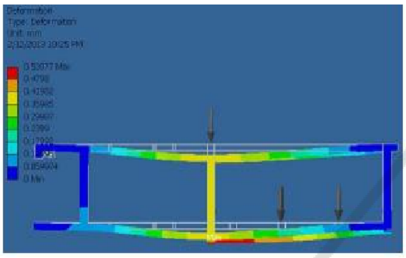

Figure 4: Load Analysis Medium

3.2 Steering Design Test

The steering mechanism used in this mode was the type of ackerman with rack and pinion. When the steering wheel was rotated, the swivel force will forwarded to the pinion by the steering wheel shaft. Then the rotational motion was changed to horizontal with a straight gear rack-gear mechanism. Furthermore, this horizontal movement was forwarded to knuckle arm/ackerman by tie-rod. Ackerman which is connected to knuckle will bend the wheel.

The Ackerman type steering system mechanism shows that the knuckle is angled to form a trapezoid. In this construction, there is a joint point on Ackerman and the tie-rod tip so that a different turning angle occurs between the left wheel and the right wheel

3.3 Test Result for Electric Car

The results of the electric car performance test is shown in Table 3 using the fabricated car shown in Figure 9.

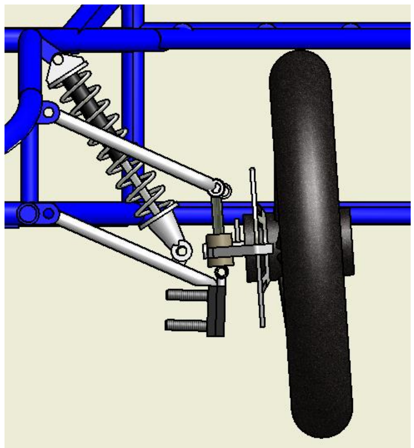

Figure 5: Adjustable wheel tilt model

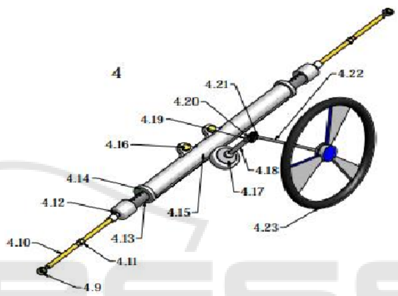

Figure 6: Gear and pinion rake system

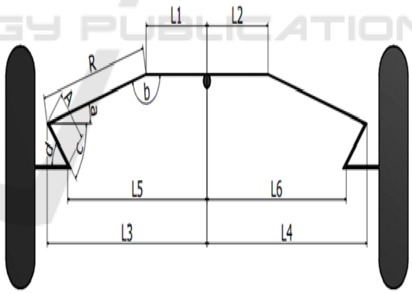

Figure 7: The ackerman

Figure 8: Full body design

Figure 9: Fabricated electric car.

Table 3: Framework design analysis

Category	Information	Result
Average speed	Distance of 8 km, time 12.52 minutes = 751.2 seconds	38.34 km/hour
Climbing Power	Tested at a distance of 10 meters with a slope of 25°	Climb Power was 1387,266 watts (read on display measuring instruments)
Acceleration & Deceleration	Tested at a distance of 100 meters then braked and the stopping distance after braking is 5.3	Readable acceleration on the display devicemeasure was 2.49 m / s2 and result deceleration takes 8.643 seconds
Energy Consumption	Total Energy used in 8 km	587,782 Wh

4 CONCLUSIONS

The test results of acceleration, deceleration, gradeability, show very good data results. However the average speed efficiency shows relatively good results, this is influenced by the transmission system that has not been suppressed by the development of a combination of gears automatically. Model 4 BLDC motors with 1 motor each of 500 watts, this is suitable for large torque speeds, but vehicle speed was still lower than it required.

ACKNOWLEDGEMENTS

The author would like to send the gratitude to the Chancellor, Dean, Lecturer and TEAM of Yogyakarta State University for providing good support for the development of this electric car research.

REFERENCES

Bambang, K., Soebagio, M., and Hery, P. (2011). Design and development of small electric vehicle using matlam/simulink. *Institute of Technology, Indonesia*.

Benitez, J. (1993). *Process engineering and design for air pollution control*. Prentice-Hall.

(BPS), B. P. S. (2010). Bps statistical review of world energy.

Bruce, E. N. and Bruce, M. C. (2003). A multicompartment model of carboxyhemoglobin and carboxymyoglobin responses to inhalation of carbon monoxide. *Journal of Applied Physiology*, 95(3):1235–1247.

Champion, R. C. and Arnold, E. C. (1954). *Motor vehicle calculations and science*, volume 2. E. Arnold.

Curtis, W. and Loren, J. Mastering autodesk inventor 2010 copyright© 2009 by wiley publishing. *Inc., Indianapolis, Indiana ISBN*, pages 978–0.

Grant, M. J. C. and Clay, B. (2002). Accidental carbon monoxide poisoning with severe cardiorespiratory compromise in 2 children. *American Journal of Critical Care*, 11(2):128–131.

Mott, R. L. (2009). Elemen-elemen mesin dalam perancangan mekanis. *Penerbit ANDI, Yogyakarta*.

of Energy, M. and of Indonesia (MEMRI), M. R. (2019). Data konsumsi energi indonesia.

Syamsiro, M., Dwicahyo, M., Sulistiawati, Y., Ridwan, M., and Citrasari, N. (2019a). Development of a rotary kiln reactor for pyrolytic oil production from waste tire in indonesia. In *IOP Conference Series: Earth and Environmental Science*, volume 245, page 012044. IOP Publishing.

Syamsiro, M., Mathias, D. Y., Saptoadi, H., Sawitri, D. R., Nizami, A.-S., and Rehan, M. (2018). Pyrolysis of compact disc (cd) case wastes to produce liquid fuel as a renewable source of electricity generation. *Energy Procedia*, 145:484–489.

Syamsiro, M., Saptoadi, H., Kismurtono, M., Mufrodi, Z., and Yoshikawa, K. (2019b). Utilization of waste polyethylene pyrolysis oil as partial substitute for diesel fuel in a di diesel engine. *International Journal of Smart Grid and Clean Energy*, 8(1):38–47.

Wark, K., Warner, C. F., et al. (1998). *Air pollution: its origin and control*. Addison-Wesley.