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Design Steering System with Independent Front Wheel Drive of The Hybrid Vehicle-Air Pressure and Electrical

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Abstract. The development of alternative vehicle were continued by designing hybrid vehicle that using compressed air and electrical propulsion. This compressed air propulsion on the rear wheels and two electric motor as a front wheel drive (FWD) were installed independently, where left and right can rotate with different speeds and direction. Independent FWD could be a problem when two wheels has a different rotation. The first experiment was tested by measuring the rotation per minute (RPM) on each wheel. Measurement were performed by varying the position of the throttle pedal. The result of measurements on both wheels rotating speed showed a difference of 1 %. The second test was to compare the space requirement, which derived from the function of cornering radius. Space requirement for inactive vehicle cornering system is 4.52 meters and 3.39 meters when system is active.

1. Introduction

Environmental issue is an important factor in the development of automotive technology. In decades, specific attention were given to vehicles that utilize fossil fuels, because these vehicles produce carbon dioxide (CO_2). CO_2 is also considered as major greenhouse gas which has contributing to global warming and climate change [1].

There are about six types of gases that cause the greenhouse effect. Carbon dioxide (CO_2) and methane (CH_4) most cause the greenhouse effect [2] and both are produced from the combustion of fossil fuel vehicles.

Environmentally friendly vehicles began developed by automotive companies and academia. Hybrid, electric and hydrogen propulsions are the type of vehicle propulsion which is commonly produced and developed. Hybrid car driven by wood-gas and electric were first manufactured in 1916 [3].

This paper discusses the steering system on hybrid vehicle which is driven by pressurized air and electrical propulsion. Compressed air is used as the rear wheel drive (RWD) whilst electric motor is used as front wheel drive (FWD). This vehicle can be seen in Figure 1.

Steering system made to solve two (2) major issues. The first issue is synchronization on both front wheels when vehicle is running straight. The second issue is minimizing space requirements when the vehicle is turning. The rotation speed on the wheels can be adjusted by Traction Control System



(TCS), so as to minimize slip on the vehicle [4]. TCS developed for steering system used on this vehicle, so the vehicle is able to regulate the rotation of the front wheel as desired.

Front wheel drive (FWD) and rear wheel drive (RWD) has advantages and disadvantages. Test was conducted to determine the advantages and disadvantages of FWD and RWD. There are three variables of test performed: horizontal, sloping and low friction road. On horizontal road, both layout showed understeering behavior's up to the limit lateral accelerations. On sloping roads, RWD vehicle tended oversteer and FWD still understeer [5]. From this study, both RWD and FWD was not affecting the horizontal road conditions.



Figure 1. Hybrid vehicle-pressure air and electric

Safety is an important issue in the vehicle, so it needs to be developed, even for prototype. In electric vehicle when an unexpected sudden stop occurs due to failure, there is a possibility a serious traffic accident may be caused [6]. This vehicle two DC motors mounted on the wheel, so it needs to be taken into account when the wheels to propulsion systems fail.

2. Design of Steering System

This vehicle has three wheels where there is a rear wheel drive using pressurized air. At the front using two wheels with each mounted brushless DC motor. If the compressed air does not generate thrust, the propulsion function is replaced by electric drive.

Brushless DC Motor mounted in wheel on the front wheels of the vehicle. Motor mounted on both front wheels and each motor is capable of rotating independently. Independent designs DC motor system has the advantage of distribution of torque evenly so that the vehicle is able to accelerate faster and more efficiently if you use 1 DC motor with the same power. However independent DC motor system also has the disadvantage that synchronization of the rotation of the wheel, because the left and right wheels has an independent system so that both wheels have a tendency different rotational speed.

The steering system is an issue on this vehicle. Results obtained manually steering turning radius a fairly wide, therefore it is necessary to design a new steering system with TCS. Overview of the steering system can use Ackerman Geometry.

The necessary steering angle of front wheels can be constructed via given momentary pivot pole O , can be seen in Figure 2. Ackermann geometry can only be analysed by vehicle moving in low lateral acceleration range. This hybrid vehicles moving in the low lateral acceleration. Then, the following relations apply:

$$\tan\delta_i = \frac{l}{R_1} \text{ and } \tan\delta_o = \frac{l}{R+S} \quad (1)$$

where w label the track width and l denotes the wheel base. Eliminating the curve radius R_1 we get:

$$\tan\delta_o = \frac{l}{\frac{l}{\tan\delta_i} + w} \text{ or } \tan\delta_o = \frac{l \tan \delta_i}{l+S \tan\delta_i} \quad (2)$$

The deviation $\Delta\delta_o = \delta_o^a - \delta_o^A$ obtained from δ_o^a as the actual steering angle and δ_o^A is Ackermann steering angle. Result δ_o^a can be obtained from equation (2), Differences $\Delta\delta_o$ is used to judge the quality of the steering system.

Ackermann approaches can also be used to calculate the space requirement of a vehicle during cornering. The hybrid vehicle uses two front wheels in accordance with Ackermann geometry, outer point on the front of the vehicle used as a maximum radius R_{max} . Inner side of the vehicle at location of the rear axle will run on the minimum radius R_{min} , the equation can we get:

$$R_{max}^2 = (R_{min} + w)^2 + (l)^2 \quad (3)$$

where l, w adalah wheel base dan width of the vehicle. Then, space requirement $\Delta R = R_{max} - R_{min}$. More specifically can be described as follows:

$$\Delta R = \sqrt{(R_{min} + W)^2 + (l)^2} - R_{min} \quad (4)$$

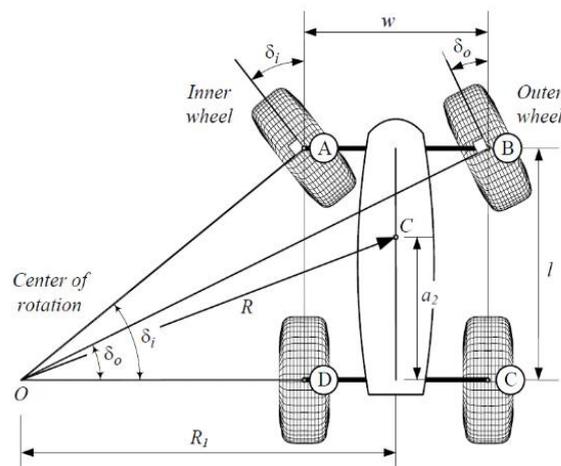


Figure 2. Calculate space requirement [11]

Turning radius calculation with the Ackermann cannot be done when the vehicle is on the move at high speeds, so the testing is done at low speed. Problems can also occur because the two front wheels are fitted independent motors. The problem is the left and right wheels can produce different rotational speeds. However, when turning this could be an advantage.

Rotation on FWD can be set by placing a controller in each motor, so that rotation of the left and right wheels can be set independently. Figure 3 can be seen wiring diagram FWD.

From Figure-3 it can be seen that each motor has its own controller. The direction and speed of rotation of the wheel can be made different by adding a relay on steering. This steering system work when the vehicle is turning right, the controller gives a signal for the motor right wheel had no electricity, so that the left wheel is still working and the right wheel only follow. It also happens conversely.

The steering system is expected to shorten the cornering radius in this hybrid vehicle. Initial testing of synchronization between the left and right wheels to get the same RPM.

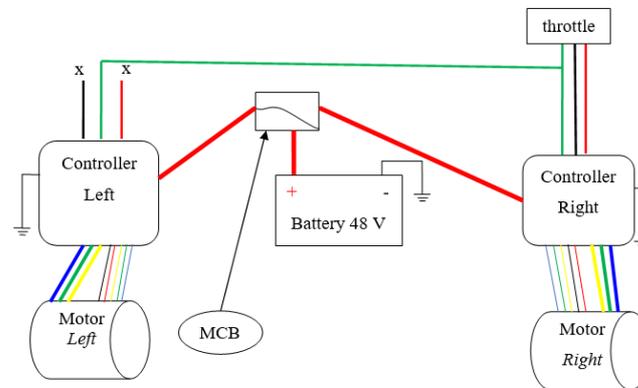


Figure 3. Wiring diagram FWD

From Figure-3 it can be seen that each motor has its own controller. The direction and speed of rotation of the wheel can be made different by adding a relay on steering. This steering system work when the vehicle is turning right, the controller gives a signal for the motor right wheel had no electricity, so that the left wheel is still working and the right wheel only follow. It also happens conversely.

The steering system is expected to shorten the cornering radius in this hybrid vehicle. Initial testing of synchronization between the left and right wheels to get the same RPM.

3. Experiment Result

The first test is done by observing the rotation of the two front wheels. This test was conducted to determine the RPM of the two wheels, in case of the rotation speed difference between left and right wheels may lead to accidents. Testing is done by pressing the throttle pedal in position 1/4, 1/2, 3/4 and full throttle. RPM measurement results on the left and right wheels can be seen at table 1.

Tabel 1. RPM left and right wheel.

Throttle Position	RPM on Left Wheel	RPM on Right Wheel
¼	213,4	215,7
½	298.8	300.2
¾	455.5	457.5
Full	588.1	589.5

From Table 1 it can be seen there is little difference in RPM on the left and right wheels of vehicles. However, the overall results showed there only 1% difference between left wheels with wheel RPM right, it can still be tolerated.

Results from Table-1 showed no significant difference, so it does not need special control or using traction control to synchronize the RPM on the front wheels. The next test is the effect of adding mass to the space requirement. Mass of vehicle is 250 kg. Figure 4 shows the effect of adding mass to the space requirement. The effect of adding mass to the space requirement is because there is a displacement of the centre of gravity of the vehicle. Data taken at a speed of 20 km / h.

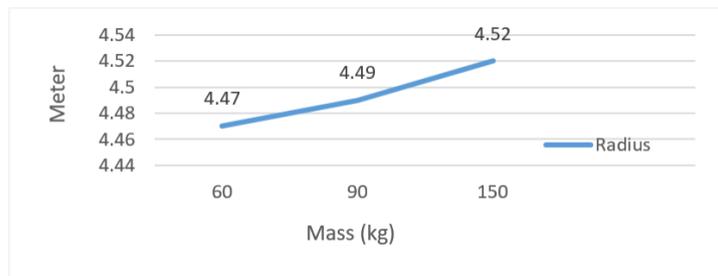


Figure 4. The effect of adding mass to the space requirement when steering system off

The next test was to determine the effect of speed on the space requirement. In this test done when the steering system is powered off, this is done to determine how much space requirement the default condition. The radius of the wheel is 12 inch, the addition of a mass of 90 kg and with RPM obtained in Table-1. The effect of speed on the large turning radius can be seen in Figure 5.

Figure 5 shows that the large space requirement when the vehicle turn is influenced by the speed of the vehicle. The greater space requirement is influenced because of the centrifugal force.

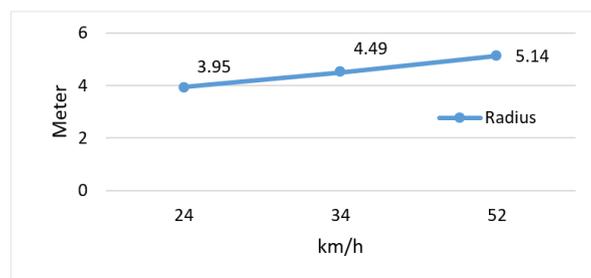


Figure 5. Effect of speed on cornering radius space requirement when system is off

The workings of the steering system can be seen in Figure 6, wherein when the vehicle is moving straight, the both wheel will move with the same rotation. However, when turning the front wheels will have different speeds. When the vehicle is turning right, then the left wheel will spin faster than the right wheel. This also happens conversely. Comparison large space requirement between the systems steering off and on with variable mass can be seen in Figure 7.

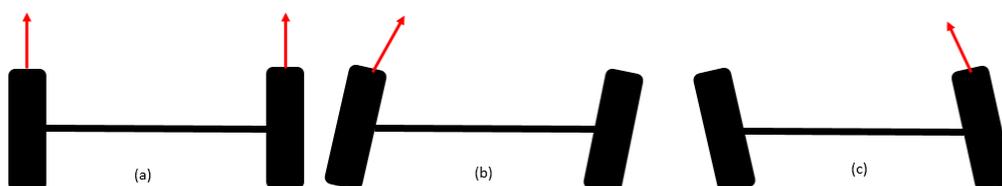


Figure 6. Steering system working (a) when vehicle move straight (b) turn right and (c) turn left

The results in Figure 7 does not significantly affect space requirement. Active steering system is able to reduce the space requirement of about 1 meter compared to when the system is off. Mass variation is not very influential, both when the system off or on.

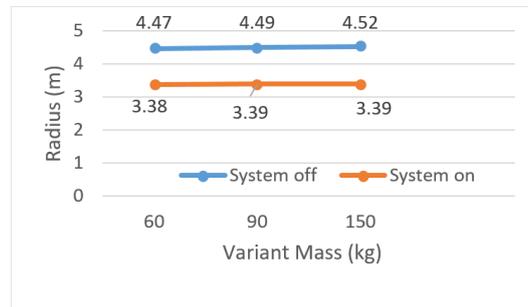


Figure 7. Comparison of space requirement when the system off and on with the mass variations

The next test is to find the effect of variable speed and steering system on the space requirement. Figure-5 shows the change in space requirements by speed variation. Figure 8 shows the comparison of space requirement to variations in speed with the steering system on and off. Steering system in an active condition has a smaller space requirement compared with the steering system on the condition off. Active steering system is able to reduce the space requirement of 1.46 meters when speed of 26 km / h.

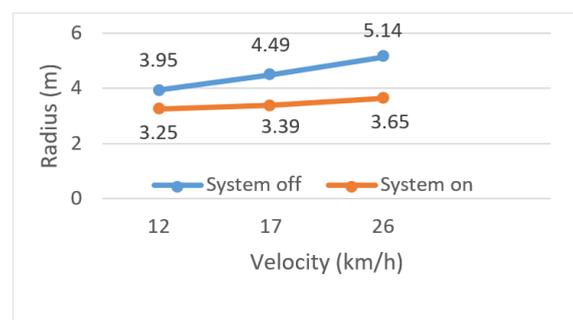


Figure 8. Velocity vs turning radius

4. Conclusion

This study shows that the front wheel drive (FWD) with independent propulsion has some advantages. One of them is in reduce space requirement when the vehicle turns, so the vehicle can turn with more narrow range. FWD with independent motors facilitate vehicle to control the speed and direction of rotation are different on each motor. Different rotation on the left and right wheels can influence space requirement cornering radius. Differences space requirement when the system is activated reaches 1.49 meters shorter than the system off. Space requirement could still be further reduced if the direction of rotation between left and right wheels made differently. However independent propulsion FWD Also there are still weaknesses that synchronization between both wheels. The rotational difference between left and right wheels is only 1%, but this could be a problem when high RPM.

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