PERSONAL ELECTRIC VEHICLE PROTOTYPE DEVELOPMENT

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Abstract- The *Personal Electric Vehicle* (PEV) is not a new thing or new discovery. The truth is this vehicle is already invented since late 1990s. By using electricity as the main source, PEV can transport one person over trip distance up until 10km. The concept in designing a PEV basically is taken from scooters and cycles. Also, the system architecture of PEV is taken from common electrical vehicle. However, the drive mechanism and the performance of a PEV is still one of the major issues where it is still consider as newbie and it limits the development of this technology. Basically, this project is a continuous work from previous research. The aim of this project is to develop a prototype with facility to test PEV drive mechanism and evaluate their performance based on specification given. In order to complete the objective, the detail design for each part involve in building a PEV is developed so that each part can be analyze. It is also important to consider the material selection used since the PEV prototype will involve series of performance evaluation. At the end of this project, a PEV prototype is developed with facility to test its performance and its drive mechanism.

Keyword – Modification; Prototype Development; Drive Mechanism.

1 INTRODUCTION

The emerging light of electric vehicle industry with its *personal electric vehicle* (PEV) is poised to be the next wave in transportation technology. Today's world congestion and pollution problem that has becomes worst from day to day, the well-being people finally realize and considering changing their perception on combustion engine vehicle into electric motor vehicle. Another problem that might be related to the next wave in transportation technology is due to high population in cities that contributes into increasing of vehicle since many people affordable to have their own vehicle or transportation.

However, the full potential of PEV has not been realized to a large extent since people always questioning the ability of a PEV. According to Ulrich (2006), people keep complaining and claiming on PEV mostly about the PEV feature itself such as not light enough, cannot go far and the cost for a PEV is not reasonable compare with its ability. They also questioning the worthy of trade-offs they need to pay across these dimensions of performance with its efficiency [1]. Since the market value of current PEV is almost same as a price of a car, they comparing it and come out with a conclusion that it is much better to pay for a conventional car rather than buy a PEV since a car gives more benefits and much more convenience when compare to a PEV. While some people view PEV as a vehicle of the future, most of them still consider it as unnecessary.

2 DESIGN REQUIREMENT

This project will be focus on the development of PEV prototype. The prototype development will be based on the specification set by Mr Faisal Zainor (2011):

- Total mass (PEV + rider) = 30Kg + 80Kg = 110 Kg
- Maximum speed, V = 30 Km/hr
- Distance travel per full batteries charge = 10 Km
- Maximum full charging time = 4 hours

- Maximum slope angle of ascent = 25^o

At the end of this project, we will develop one PEV prototype with facility to test various electric motors in order to increase PEV's drive mechanism and evaluate their performance.

3 DESIGN PROCESS

i. Tractive Force, $F_{Tractive}$

The movement behavior of a vehicle along its moving direction is completely determined by all the forces acting on it in this direction. There are three major forces at work which resist a vehicle from moving:

- Rolling resistance
- Air resistance
- The force of gravity as a vehicle moves up a hill

The tractive force, F_t in the contact area between the tires of the driven wheels and the road surface propels the vehicle forward. The summation of all three major forces form the tractive force; a force that need to overcome by a vehicle in order to move forward.

$$F_T = Froll + Fair + Fslope \quad [1]$$

Rolling Resistance

The force of the rolling resistance is a function of the weight of the vehicle multiplied by a coefficient of the rolling resistance. This force is mostly independent of car speed.

$$F_{Roll} = C_r M a_{gravity} \quad [2]$$

Where C_r is the rolling resistance coefficient. Typical values for the rolling coefficient (u_{roll}) = $(0.0136)*(0.04 \times 10^{-6})*(3.6v)^2$, where v is the function of speed, M represent Mass of the vehicle (Kg), while $a_{gravity}$ is the force of gravity (taken as 9.81 m/s^2)

Air Resistance

The force of the air resistance is proportional to the square of the speed, the density of the air, the silhouette are of the car, and the drag coefficient for the vehicle. A vehicle travelling at a particular speed in air encounters a force resisting its motion, referred to as aerodynamic drag resulting from two component; shape drag and skin friction

$$F_{air} = ½ \; C_d A_f \rho v^2 \quad [3]$$

Where Cd is the Drag coefficient of the vehicle, A is Frontal surface area of vehicle and rider (m^2), ρ is the Density of air (1.2 Kg/m3 at sea level at normal temperatures) and v is the speed of vehicle (m/s)

The Force of Gravity As a Vehicle Moves Up a Hill

The force required to lift a vehicle uphill is a function of the angle of the hill and the force of gravity

$$Fslope = mg \sin \Theta \quad [4]$$

Where M is the mass of the vehicle (kg) while g is the force of gravity (9.81 m/s^2)

ii. Power Required for Forward Motion

Power is a measurement of work per unit time. Work is a measurement of a force moved at some distance. Therefore, to determine the power required to move a vehicle at a certain speed, it is simply the total of all forces to overcome multiplied by the speed.

$$\text{Power, } P = (Froll + Fair + Fslope)\, v$$

From equation [1], Thus

$$\text{Power, } P = (F_T)\, v \quad [5]$$

iii. Power Required for Acceleration

The Personal Electric Vehicle is set to accelerate at the rate of 1 m/s^2. To calculate the power required to accelerate a vehicle, first determine the amount of energy required to accelerate a vehicle from 0 to a speed of v:

$$\text{Kinetic Energy, } KE = ½\, m v^2 \quad [6]$$

Then, to calculate the power, divide the energy required by time it takes to acceerate the vehicle:

$$\text{Power, } P = KE/t \quad [7]$$

iv. Rotational Speed and Torque at Wheel

Since the torque has been calculated, the rotational speed of the wheel needed in order to move the PEV prototype to the required speed is:

$$\text{Velocity, } v = \omega r \quad [8]$$

Where ω is the Rotational speed of the PEV prototype while r is the radius of the driven wheel.

From definition of torque itself, the torque applied at the wheel, Tw is:

$$Tw = F_T\, r \qquad [9]$$

Where F_T is the Total Traction Forces acting on wheel and r is Radius of the driven wheel

4 RESULT AND DISCUSSION

i. Conceptual Design

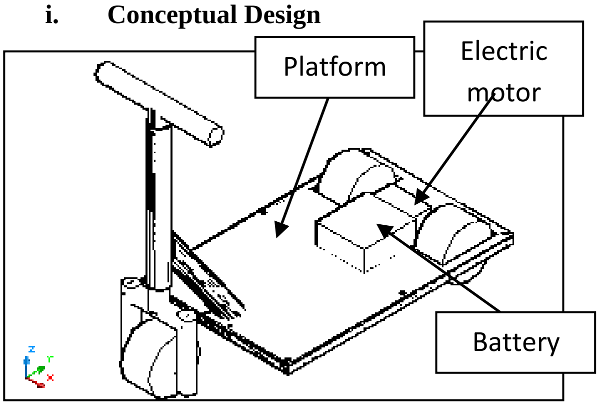

Figure 2: Conceptual Design 1

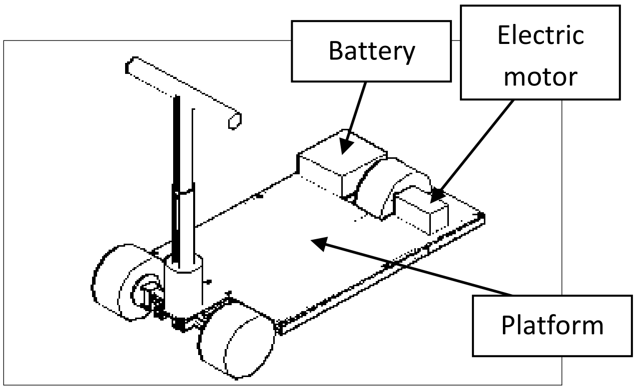

Figure 3: Conceptual Design 2

ii. Conceptual Design Analysis

The conceptual design 1 (Figure 2) used three wheels where one wheel been installed at the front and the other 2 wheels are installed at the platform. The prototype maneuvering is done by the front wheel like typical motorbike and bicycle based steering. By installing two wheels at the rear side of the prototype, it will give more stability to the prototype especially during standby phase and during the user drive the prototype.

While for conceptual design 2 (Figure 2), like conceptual design 1, this design also used three wheels. The different is just there will be only one wheel being install to the platform and another two wheels will be installed to the steering. The two wheels being installed at the steering mean that the maneuvering and the power drive will be carried out by the same two wheels.

iii. Decision Matrix

To ensure that the final design chosen meet it requirement and all design criteria set earlier, it is decided to employ decision matrix to compare between both of the conceptual design. This step is important since there are many consideration and studies need to be done before finalizing the design.

This criterion is important to be considering since it will affect the performance and the drive mechanism of the prototype.

Option	Decision Making Criteria					
	Selection	Cost	Design Complexity	Maintainability	Overall Stability	Total
	Conceptual Design 1	9	9	7	8	33
	Conceptual Design 2	9	7	8	6	30

Table 1: Decision matrix to choose the best conceptual design

Note: The rating is in the range 1 – 10 where 10 represent the best and 1 represents the worst

From the decision matrix analysis above, the conceptual design 1 is the best in term of serving and may fulfill the objectives of this project. Although both of the design has same cost for development, but in term of design complexity and overall stability, conceptual design 1 is much more better when compare with conceptual design 2. Despite this design has the disadvantage of being maintainability, it still serves the other design criteria perfectly. In this project, the development of the PEV prototype is based on the conceptual design 1.

iv. Material Selection

There are many type of materials can be chosen and used in developing the PEV prototype. The material available has been divided into two categories; metal and non-metal material. In this project, it is preferable to use material with metal basis, based on the objective of this project.

However, since each of the material has its own physical and mechanical properties, it is decided on which one of the material is the best to be selected. Based on research and analysis done, the best material selection that can be used to develop the PEV prototype is Aluminum.

	Modulus of Elasticity, E (GPa)	Ultimate Tensile Strength (MPa)	0.2% proof stress at Yield (MPa)	Elongation at Failure (%)	Fatigue Limit/ UTS (5x10 cycles)	Density (Mg/m - specific energy
Steels						
Medium Carbon	200	520	310	26	0.5	7.85
CrMo (AISI 4130)	200	1425	1240	12	0.5	7.85
Aluminum Alloys						
2024-T4	73.1	470	325	20	0.29	2.8
6061-T6	68.9	310	276	12	0.31	2.8
7075-T6	71.7	570	503	11	0.265	2.8
Magnesium	44	248	200	5 to 8	0.37	1.79
Titanium Alloys						
IMI 125	105 to 120	390 to 540	340	20 to 29	0.5	4.51
IMI 318	105 to 120	1000	900	8	0.55	4.42
Composites						
"S" glass-epoxy	90	3750	3450	3.5	0.16	2.63
HT graphite-epoxy	221	3600	2000	1.25	0.25	1.75
Boron-epoxy	250	1200	?	?	0.8	1.9
Boron-Aluminum	165	1025	?	0.65	0.7	2.4
Kevlar-49-resin	75	1380	?	2.75	0.7	1.45
Glass-nylon	2.3	59.9	59.9	14	?	1.18
Woods	12	100	60	?	?	0.67

Figure 4: Some of possible material can be used for the prototype development.

v. Battery Selection

Based on calculation done in Chapter 3 – Design Process, a 24 V 500 W DC electric motor has been selected.

To have a source of power that can move the motor, a 24 V 13 Ah NimH battery pack is selected. This type of battery is widely used for hi-power E-bike and robots. It consist of 20 pieces of F-sized 13 AH NimH cell in a plastic container. The battery need to be charged using the Smart Charger (1.8A) with 3-pin connector which is installed to the home plug.

Nominal Voltage	24 V
Nominal Capacity	13 Ah
Maximum Charging Time	160 minutes
Weight	5.4 Kg

Table 3: Specification of suggestion battery selection

vi. Electric Motor Selection

Based on calculation done in Chapter 3 – Design Process, a 24 V 500 W DC electric motor has been chosen to run the PEV prototype. The required torque for the PEV prototype. Table2 below show the specification of the chosen electric motor.

Model	MY1020
Type	Brush Motor
Voltage	24V DC
Rated Speed	2500 RPM
Rated Current	27.4 mp
Sprocket	8mm, 13 tooth pinion gear
Outpur Power	500 W

Table 2: Specification of suggestion electric motor selection

vii. Prototype Development

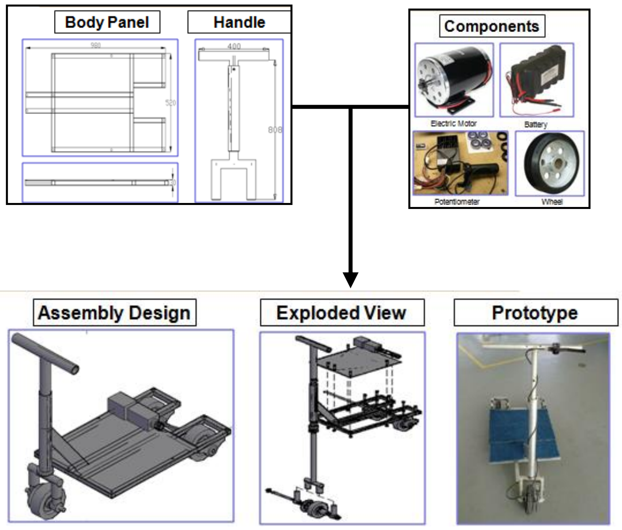

Figure 5: Steps and activities performed during prototype development

5 CONCLUSION AND RECOMMENDATION

A PEV prototype is managed to develop with facility to test its performance and drive mechanism. We also manage to produce and developed the prototype with low cost, easy to maintain, simple mechanism and provides effective turning which may lead into one of the new design of PEV in future. If the overall project is a success, it will not be long before citizens in developing country such as Malaysia are affordable to buy one PEV as their most needed personal vehicle.

Below is the finished prototype managed to be developed by the author.

Figure 5: Steps and activities performed during prototype development

It is also hope that by the improvement made into existing PEV using data gather by this prototype, it will lead into solution of the world congestion and pollution problems that become worsen especially is metropolitan cities.

Besides, in order to improve the design as well as its performance, the author would like to recommend that the successor of this project will do the following items:

- Conduct simulation using ADAMS or ANSY to get more accurate data on material selection
- Do experiments that involve various type of electric motor using this prototype to evaluate its performance so that the optimum electric motor can be find resulting from the experiment.
- The test is recommended to be done on the road surface rather than at the lab
- All data gathered and obtained from each testing or experiment should be fully utilized so that it will become benefits for future researcher and designer.

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