DESIGN AND FABRICATION OF PERSONAL ELECTRIC VEHICLE DRIVEN BY BRUSHLESS HUB MOTOR

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Robotic and Automation) (Hons.)

by

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Tajuk: **DESIGN AND FABRICATION OF PERSONAL ELECTRIC VEHICLE DRIVEN BY BRUSHLESS HUB MOTOR**

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I hereby, declared this report entitled "Design And Fabrication of Personal Electric Vehicle Driven by Brushless Hub Motor" is the result of my own research except as cited in references.

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Date : 21 Jun 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Robotic and Automation) (Hons). The member of the supervisory committee are as follow:

…….....

(Pn Silah Hayati Binti Kamsani)

…….....

(En Mahasan Bin Mat ali)

ABSTRAK

Tujuan kajian ini adalah untuk mereka bentuk, mencantum dan mengkaji PEV tiga roda dipacu oleh hab motor tanpa carbon. PEV tiga roda adalah lebih stabil berbanding PEV dua roda kerana penambahan titik sentuhan pada permukaan tanah. Penggunaan PEV adalah untuk perjalanan jarak dekat yang boleh ditunggang satu orang pada satu masa. PEV ini mengandungi tiga bahagian asas yg utama iaitu penyimpanan tenaga, sistem pacuan dan kerangka. Kaedah yang digunakan untuk mencapai matlamat kajian ini adalah dengan melakukan eksperimen untuk menguji prestasi PEV yang direka. Eksperimen yang telah dijalankan adalah pengurusan bateri, prestasi brek, ujian cara menggerakkan dan ujian sentakan pergerakan. Dari eksperimen, semakin bertambah beban semakin berkurang kemampuan PEV yang direka. Oleh itu, kelemahan yang dikesan perlu ditambah baik untuk kerja-kerja masa depan.

ABSTRACT

The aims of this study are to design, fabricate, and analyze a three-wheeled PEV driven by brushless hub motor. The three-wheeled PEV is more stable compared to two-wheeled PEV due to extra point of contact to the ground. The use of PEV is for short distance travel that can occupy one person at a time. The PEV consists of three basic function which are energy storage, drive system and chassis. The methods that were used to achieve the aim of this study is by doing an experiments to test the performance of the fabricated PEV. The experiments that has been carried out is battery management, braking performance, manoeuvrability test and moose test. From the experiments, it shows that as the load increase the performance of PEV deteriorate. Therefore, these weaknesses need to be improvise for future work.

DEDICATION

Only

My beloved father, Tengku Abdul Jalil Bin Tengku Osman

My appreciated mother, Raimah Bt Endut

My adored sisters and brothers, Tengku Naziihah, Tengku Sakinah, Tengku Ahmad Alif, Tengku Ahmad Naji and Tengku Ahmad Afif for giving me moral support, money, cooperation, encouragement and also understandings

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LIST OF ABBREVIATIONS

PEV	-	Personal Electric Vehicle
LRT	-	Light Rail Transit
EV	-	Electric Vehicle
DC	-	Direct Current
SLA	-	Sealed-Lead Acid
NiMH	-	Nickel-metal Hydride
AH	-	Amp Hour
WH	-	Watt Hour
PSM	-	Projek Sarjana Muda
FYP	-	Final Year Project
RPM	-	Revolution per minutes
COG	-	Centre of gravity
RM	-	Ringgit Malaysia
PCS	-	Pieces

LIST OF SYMBOLS

km/h	-	kilometre per hour
mm	-	milimeter
W/kg	-	Watt per Kg
Kj/kg	-	Kilo joules per kilogram
Amps	-	Amperes
V	-	Volts
m	-	meter
s	-	second
cm	-	centimeter

CHAPTER 1
INTRODUCTION

This chapter presents the project background, problem statement, objective of the project and scope of the project.

1.1 Project Background

People with a partial or total walking disability normally use wheelchair to help them become more mobile. Nonetheless, wheelchair can only be used where there is access to door with larger frame and inclined ramp which are not commonly available in private homes and/or work places. In order to overcome this problem, a paired rear wheel and steerable front wheel are powered with a downsized of golf cart (Kramer, 1986). Thus, the design of wheelchair is change from normal wheelchair to a three wheeled with steerable front to make it less bulky and easily steered.

Personal electric vehicle (PEV) or also known as electric bicycle or scooter is one of latest technology to help the elderly and disable people to move around. It is easy to store due to its slimmer structure. Recently, normal people who work in big metropolitan city also use PEV to commute to work if they are using public transportation such as train or LRT. Instead of using car which will need parking space, PEV is used for travelling to and fro home to the train station, and the train station to the work place. This also led to a lesser carbon foot print.

In general, PEV has a frame or chassis with a platform for the rider to stand, a front wheel mounted for steering control, and rear wheel which rotatable at rear section (Sauve, 2002). Figure 1.1 shows a commercially available PEV. Normally, a scooter is built with a steerable front wheel and a fixed rear wheel. To move it, the rider stands on one foot on the scooter with the other foot pushes the ground. The rider needs to balance the body while riding. Otherwise, the scooter becomes unstable which could cause the rider to fall.

PEV uses motorized wheel, thus a power supply, i.e. battery is used to power the motor. Typically, battery uses for PEV is lithium ion-type such as lithium iron phosphate ($LiFePO_4$). This is also the type of battery commonly used as one of the major positive electrode materials of lithium ion battery in electric vehicles (EV) (Cheng-Hua *et* al., 2011).

Figure 3.1: Example of PEV available in the market (Freegotech, 2016)

1.2 Problem Statement

In big cities such as Kuala Lumpur, traffic congestion occurs during peak hours which are between 7.30 a.m. to 9.30 a.m., and 5.00 p.m. to 7.00 p.m. These are the time when people travel from their home to the work place and vice versa. Thus, many people opted for using public transportation such as RapidKL or LRT (Light Rail Transit). Still, they normally have to walk to reach their destinations as the stations of this public transport are situated a little far from their offices. Thus, by using PEV, the commuters can reduced the time spend to reach their workplace.

When scooter was first introduced in the market as a recreational tool, it has to be manually pushed by leg to move it. As the time flies and the technology become more advanced, an electric scooter is invented. Now, motorized wheel is used instead. Nevertheless, most electric scooter is two-wheeled. This causes the rider the need to balance their body while riding PEV. Therefore, a three-wheeled vehicle is suggested to overcome this problem. In addition, as train station or LRT station are normally crowded with people, the size of PEV also need to be considered so as not to block other people as well as easy to move.

1.3 Objectives

The objectives of this project are:

i. To design three-wheeled personal electric vehicle for short distance travel
ii. To fabricate the designed three-wheeled personal electric vehicle
iii. To analyse the performance of three-wheeled personal electric vehicle

1.4 Scope of Project

The scopes of this project are:

i. The limits weight for a rider is up to 70 kg.
ii. The travel speed is up to 20 km/h for 10 km distance travel.
iii. PEV is designed so that it is suitable for outdoor and indoor use.

1.5 Report Outline

The remainder of the report is organised as follows:

Chapter 2 is the literature review. This chapter presents the literatures that relevant to particular topic of this research, demonstrating the information of any previous work and awareness of related theories and discussions. The literature review consists of general system of PEV, drive system and chassis, as well as power management.

Chapter 3 is the methodology of the report. This chapter discusses the methodology carried out in order to produce the desired result or outcome of the project which include design, analysis project and fabrication.

Chapter 4 is the result and discussion. This chapter consists of results of analysis and experiments done in this project.

Chapter 5 is a conclusion for this research. Sustainability element and suggestion for future work are also provided in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Personal Electric Vehicle

Personal electric vehicle (PEV) emerged as a new category of transportation device in the late 1990s. PEV offers several potential benefits to consumer that is reduction of automobile use in congested urban environment. Usage of automobiles can cause air pollution, noise, and consumption of non-renewable resources, congestion, parking, and traffic accidents. These costs are especially high in dense urban environments, rising to as much as US$1 per km (Ozabay *et* al., 2001). PEV offers a services more efficiently in short distance travel.

Besides that, PEV is a quiet and clean transportation. This is because PEV operates in near silence and without noxious fumes, high temperature exhaust components, or dripping fluids. There are a few segments exist in the current market that is (1) stand-on scooters, (2) sit-on cycles and (3) mobility scooters. Normally, mobility scooters are being used by the old people or as mobility aid devices. Table 2.1 shows the characteristics comparisons between these three segments as done by Ulrich (2005).

Table 4.1: Assumed properties for three vehicle segments. (Ulrich, 2005)

	Units	Stand-on scooter	Sit-on cycles	Mobility scooters
Top speed	km/h	30	42	8
Cruising range	km	20	40	8
Cruising speed	km/h	25	35	6
Minimum wheel diameter	mm	200	250	180
Maximum hill angle	percent	10	10	10
Riding position	-	Standing straight ahead	Seated, feet in front of body or stranding vehicle	Seated as in a chair
Terrain	-	Urban pavement	Urban pavement	Indoors, shopping mall
Existing product	-	Xootr eX3, Badsey Hot Scoot	Voloci, eGo II	Easy travel, Scootie

2.2 General System of Personal Electric Vehicle

In general, there are three basic functions in PEV; energy storage, drive system, and chassis. Basically, the energy storage device is modulated through controller that implemented as an electronic device. Meanwhile, the drive system controls how the PEV moves. On the other hand, the chassis can be thought as rider interface, wheels, braking system and structure that supports other elements of the vehicle. Figure 2.1 below shows the general system of PEV.

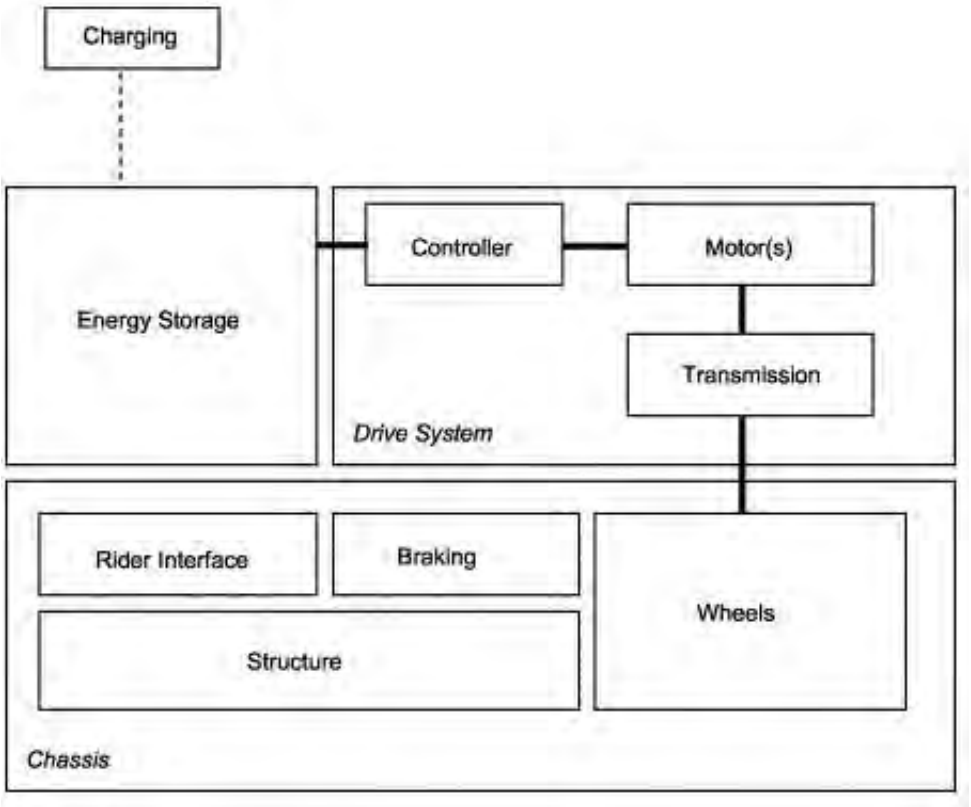

Figure 2.1: General system for PEV

2.3 Energy Storage Technology

There are three categories of energy storage that have been used in electric vehicle that is batteries, combustion-powered generators (as in hybrid vehicles), and fuel cells. Unfortunately, combustion-powered generator and fuel cells are currently not viable to be used in personal electric vehicle. So, the focus will be on batteries for energy storage.

Lithium-ion (LiIon) batteries are currently the lightest high-power batteries available commercially and are used widely in electronic devices such as portable computer and mobile electronic devices. Lithium ions cells are likely to improve 10-20 percent in energy and power density (Vyas *et* al. 2000). It is also been used for electric bicycle/vehicle due to its excellent performance. Among the materials in Li-ion battery is Cobalt (Co) and Manganese (Mn). The limited amount of Cobalt, (Co) storage in the earth leads to a small market potential as power battery cathode material for EVs, although $LiCoO^2$had good properties and became a leading player in small size Li-ion battery. The amount of

Manganese, (Mn) storage was abundant and the price of Mn was much cheaper than Co, which could be the main material of cathode material of Li-ion battery (Dai *et* al. 2005).

Besides that, other type of battery is sealed-lead acid (SLA). This battery is commonly used in motor vehicles such as forklifts and golf cart. This battery is rechargeable and reliable for everyday use. Unfortunately, one of its advantages is that it can be heavy. This is because a lead-acid battery is made up of several lead and lead oxide electrode plates immersed in an acidic electrolyte. The battery can weigh between 1 kg to 3 kg. Besides that, the electrolyte of the batteries can evaporate through battery vent per cell. The evaporate process occurs while the battery is being recharged but if the electrolyte level is below the minimum required level, distilled water is added to the affected battery cell to reach its normal level back (David, 2010).

Another type of battery is Nickel metal-hydride (NiMH) that is lighter than SLA batteries but the cost of the batteries is more. Nickel metal-hydride also requires a more complex charging process. However, NiMH batteries are standardly used for most cordless power tools and portable computers.

Table 2.2: Properties of three battery technologies for PEV (Ulrich, 2005)

Properties	**Units**	**Lithium ions**	**Sealed Lead Acid**	**Nickel metal hydride**
Energy density @ 1C discharge rate	kJ/kg	448	87	207
Power density (continuous)	W/kg	500	200	200
Cost per unit mass	US$/kg	90.00	2.50	30.00
Cost per unit energy	US$/MJ	201	29	145
Number of charge-discharge cycles possible (unit only 80 percent of original capacity is available)	Cycles	500+	150-200	200-400
Maturity of technology	Years use in transportation applications	2	80+	5