

DESIGN AND ANALYSIS OF FOLDABLE HUMAN POWERED VEHICLE

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**A report submitted
in fulfilment of the requirements for the
Degree of Bachelor of Mechanical Engineering (Automotive)**

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive).


Signature :.....

Name of supervisor :.....

Date :.....

DECLARATION

I declare that this project report entitled “Design and Analysis of Foldable Human Powered Vehicle” is the result of my own work except as cited in the references.

| | |
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DEDICATION

To my beloved family especially my mother, Fatimah Binti Muda and my father, Ahmad Bin Sulaiman

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In the name of Allah, the most Gracious and Most Merciful

All praise to God for His blessings and guidance. Thanks for giving me strength to complete this project report. I am really grateful as I have completed this Projek Sarjana Muda with the help and support, encouragement and inspirations by various parties. All the knowledge and information that they give are really helpful.

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ABSTRACT

Human powered vehicle (HPV) is the eco-friendly vehicle that can help people achieve the green technology concept. Human powered vehicle was powered by muscular strength to move on road. In addition, HPV is more comfortable to use compared to bicycle due to stability and seating position. HPV is more safe to ride in term of stability because it uses three or four wheel. But, HPV is difficult to store or parking due to its size. HPV is bigger than bicycle. This study is to solve the size of HPV by reduce the size of HPV with design a foldable HPV. The frame of HPV will be design to be foldable to make the HPV is easier to store or parking. This invention will help people to save their space to parking after riding a HPV. Therefore, the foldable chassis of HPV will be analysed to find the size reduction and be tested with stress analysis to ensure the design is safe to use.

ABSTRAK

Kenderaan berkuasa manusia adalah kenderaan mesra alam yang boleh membantu orang ramai untuk mencapai konsep teknologi hijau. Kenderaan berkuasa manusia ini digerakkan oleh kekuatan otot manusia untuk bergerak di jalan raya. Di samping itu, HPV adalah lebih selesa untuk digunakan berbanding basikal kerana faktor kestabilan dan posisi kedudukan ketika menunggangnya. HPV lebih selamat digunakan atas faktor kestabilan kerana HPV menggunakan tiga atau empat roda. Tetapi HPV lebih sukar untuk meletakkan kenderaan kerana saiz HPV adalah lebih besar daripada basikal. Oleh itu, kajian ini dijalankan untuk menyelesaikan masalah saiz HPV dengan mencipta reka bentuk HPV yang boleh dilipat. Kerangka HPV yang boleh di lipat boleh memudahkan HPV untuk di simpan atau diletakan di tempat meletak kenderaan. Ciptaan ini akan dapat membantu orang ramai untuk menjimatkan ruang untuk meletakkan HPV selepas digunakan. Oleh itu, kerangka HPV yang boleh dilipat akan dianalisis untuk mencari pengurangan saiz dan diuji dengan analisis tekanan untuk memastikan reka bentuk lebih selamat untuk digunakan.

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LIST OF ABBREVIATIONS

| | |
|-----|------------------------------|
| CAD | Computer Aided Design |
| FEA | Finite Element Analysis |
| HPV | Human Powered Vehicle |
| PDS | Product Design Specification |
| USS | Under Seat Steering |

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Human powered vehicle is an environmentally friendly and affordable vehicle that can help people to achieve the green technology concept. Human powered vehicle is a one type of vehicle that powered only by muscular strength to move on the road. This HPV is a land vehicle with seat position that is inclined backwards and the bottom bracket and the pedals are attached front. The current HPV that has not foldable may be difficult to carry and stored for future use. This type of design is chosen for ergonomic factor cause this HPV also can be fordable and detachable. This HPV is designed in foldable and detachable by using fasteners at the joint. This type of design also to propose a compact foldable HPV this is reduce the size and overcome all the limitation in the current available HPV (Bohra et al. 2016).

Generally, the current HPV that shown in Figure 1.1 are not easy to carry to everywhere because due to the space that people can't store this HPV in the car. As we know, HPV may be bigger in size compare to the bicycle. This type of HPV design is to overcome this problem by reducing the insufficient space after this HPV is folded. With all the problem in current HPV, the next possible solution is the usage of foldable and detachable HPV since this HPV can be folded and carried around to the work place or everywhere it can be used.

Since this HPV is being folded and detachable, it may be use less space and can be easy to store because it doesn't require any special parking space (Bohra et al. 2016).

There is a part of this HPV is to be folding. The main body of this HPV can be folding and wheel and other component is to be fitted. This design of HPV also uses a compact joint which can provide on the main body so that the rear and front body can be overlap after this HPV is folded. Then, the seat of this HPV also can be folded and adjustable according to comfortable of user. The main reason to reduce the height and space of this HPV is folded the main chassis. This seat position is the most common design use today for a good reason which is for rider comfort and easy of riding.



Figure 1.1: Example of HPV (Source: Iniguez et al. 2012)

Besides, this type of HPV uses a three wheel which is two wheel in the front and one wheel at the rear. The transmission of this HPV which transfer the power from the pedal to the rear wheel. HPV use a roller chain that pass the power from the pedals to the drive-wheel and drive it. This HPV also have a suspension system that isolates users body from road vibration. Then, this mechanism will make this HPV increase the safety as control and road grip will be improved. Besides that, if the HPV has no any suspension system, it will change a certain amount of user's propulsion into movement of bike in a vertical direction. The HPV

suspension system will show up only when riding heavily loaded or climbing steep hill (HP velotechnik, 2012).

The frame of HPV is the important part in the system. This is because the frame or body will support the load and also can be folded after using it. There are several options in term of frame geometry in the design space defined by the conventional, forward facing and recumbent rider position. The proper design and analysis is very crucial. Then, the material use in the frame for HPV also can affect the result and analysis in this report.

1.2 PROBLEM STATEMENT

Nowadays transportation has been important in society for many reasons. Transportation also has changed the life style and the way people travel. Transportation become important to people since everybody need a transport to travel or do some activity. Transportation also use a lot of resources like time, fuel, and material. But transportation also has a weakness in term of stability, safety, fatal accidents, and aerodynamic resistance while using a bicycle. Then, green house emission and cost actually the major weakness of transportation.

Human powered vehicle is the one of green technology vehicle that can keep our environment clean. As we know HPV is powered by human power to move it and not involves with any burning fossil fuels. HPV also not create a noise to the environment. But HPV also have some limitation which is the current available HPV is a bigger in size that can make it difficult to store and to carry anywhere. HPV is bigger than bicycle but these two vehicles has same problem which is both are difficult to bring anywhere and stored. It's mean that HPV require a more space to parking. This issue may give a minor impact in usage of HPV to the users. The unfordable HPV is difficult to take it with users when they go. HPV required a lot of space to place in car to bring it anywhere.

1.3 OBJECTIVES

The objectives of this project are as follows:

1. To design an eco-friendly vehicle that not harm the environment.
2. To design and analysis, the fordable human powered vehicle.
3. To design a compact human powered vehicle to reduce size and space.
4. To find the percentage of space reduction before and after foldable.

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. Only result of design and analysis for foldable human powered vehicle are presented in this report.
2. The stress analysis is tested only at the frame of HPV.
3. The design and analysis is using a CAD drawing which is CATIA.

CHAPTER 2

LITERATURE REVIEW

2.1 Concept of Foldable Human Power Vehicle

Foldable Human Powered vehicle (HPV) are apply the concept of aerodynamic, which is the seating position of this foldable HPV are lower. The seating height can affect the drag force of HPV. The more increase the seating position from the ground, the highest value of drag force of HPV. The value of drag force will be increase directly proportional with the distance of the seat position from the ground. As we know, the principle of aerodynamic can be understood that wind flow must be smooth in order to reduce drag force. Therefore, with the low reclined position a smooth airflow can be produce a less drag force. The frontal area of this HPV also play the important role because it is the important part that can also affect the concept of aerodynamic (Alam et al. 2012).

This HPV was design to be foldable because it will reduce space and lighter. HPV are suitable to use for short distance but it also can be used for long routes. This concept of foldable HPV is same with bicycle, but it more easy to ride and more stable because the seat position of this foldable HPV is inclined backwards and the bottom bracket and the pedals are attached at the front. The foldable HPV are easy to bring anywhere because it uses less space. Other than that, the main chassis of this foldable HPV can be folded to reduce space

when store it. The concept of foldable that was apply in this HPV are very easy to use and very friendly.

Type of material use for chassis also plays a major role in strength and safety of the foldable HPV. The design of foldable chassis for HPV more ergonomic by applying the best material on it. Analysis process can be done to find the best material that can be apply on the chassis of the HPV. The chassis of the foldable HPV was designed to improve the design of the existing HPV to be foldable with an igniting idea from the concept of existing foldable bicycle. Besides that, the foldable chassis of HPV is an aerodynamic natural structure that can make the HPV stable and strong (Raghuvanshi & Srivastav, 2015).

2.1.1 Design Consideration

The vehicle must free from the sharp edges that can harm the user in term of safety. The stability of vehicle due to the low center of gravity. Therefore, the material will be selected to applied on the foldable HPV. The total front and rear wheel of the HPV also be calculated. Then, this study will focus on the main point that can affect the comfortable of the rider which is elbow and knee of the rider. Hence, the basic need requirement for the ergonomic feature will be consider in this study. Lastly, this study focus on dimension of length for wheel base, height and track width.

2.2 Folding Chassis for Human Powered Vehicle

The ability of this HPV is it can be folded and easy to stored. Foldable HPV has three main part of the chassis that can make this HPV can be fold. The part of the chassis for HPV was joint by using a shaft, bolt and nut. The chassis may present separable assemblies which is a front part and rear part.

Therefore, the wheelbase can be folded to reduce space during parking or store it and can be extended when the user wants to ride it. The potential of foldable HPV is when the wheelbase can be shortening and lengthen with the design of chassis that can be folded. The foldable chassis play the important role cause the chassis must have the ability to hold the force by the rider and also can be folded. In the same way, the joint for the chassis is very important to link the main part of the chassis so that it can be folded (Lark, 2014).

The mechanism of joint for HPV can present the ability of chassis to keep maneuverability in the HPV's folded and unfolded state. However, the design of HPV still same with the existing HPV but transformable chassis. The improvement on the chassis of the HPV has many practical advantages such as the HPV can be folded to reduce it wheelbase. Then, the HPV can keep the maneuverability during unfolded without changing the chassis' geometry. In addition, the ability of the foldable chassis to perform as a rigid body in zero power failure situation is the objective in this project (Lark, 2014).

The foldable chassis of HPV also has a suitable center of gravity that can present the stability during ride on the road. As a result, the chassis also fulfil the basic need requirement for ergonomic needed in term of comfort. Besides, the position mechanical system of the HPV is maintaining after folded (Lark, 2014). For information, the transformable chassis can be lock after unfolded and also give a stability to the HPV. The foldable chassis are not affect the handling of this type of HPV due to the steering are place both side of driver. In addition, the foldable chassis was design based on the igniting idea of a Y shape (Raghuvanshi & Srivastav, 2015).

In addition, the front chassis includes a pair of wheel fork that can be folded to reduce the width of HPV while the rear chassis can be folded to reduce the length of wheelbase of the HPV. Besides, the wheel fork may be mounted at the front part of the chassis.

2.3 Drive Mechanism for Human Powered Vehicle

The drive and steering mechanism is the important parts to control the HPV during on the road. The HPV allow a rider to drive forward by moving the power from upper and lower body muscle group that present a motion similar to running or walking. Thus, the rider can transfer muscle-generated power by the movement of the both legs and arms to the drive mechanism (Yunaska, 2004).

This type of HPV is constructed of a foldable chassis, a drive means comprised of a leg powered. The crank set is placed at the front part of HPV that act as a drive sprocket and the middle and rear sprocket as a driven sprocket. Then, the crank set that is connected by a continuous chain to middle sprocket and continue to the rear sprocket communicating with rear wheel of the HPV. The crank set for this HPV apply the conventional bicycle crank set. In addition, the middle sprocket is link with rear sprocket that attached to the rear wheel of HPV by a continuous chain. Besides, the chain connected to the crank set to the rear sprocket through the middle sprocket. Furthermore, the steering mechanism are attached to the chassis at the middle part of the HPV. The steering mechanism control the steerable front wheel and the movement of the steering mechanism by the rider's arms produces an additional propelling force. In addition, the drive mechanism convert the steering motion into forward motion of HPV (Yunaska, 2004).

However, the performance of drive mechanism can be affected by the force required to apply on pedal and the number of rotation of the wheel. The best performance is by increasing the number of rotation of wheel and reduce the force required to use on the pedal to move the HPV. In addition, by increasing the diameter of drive sprocket it may result the higher drive mechanism efficiency. The value of velocity ratio also increases when increasing the diameter of drive sprocket (Urunkar & Deshpande, 2014).

Then, the value of efficiency for the drive sprocket transferring power to the rear sprocket can be state through the efficiency's test for the derailleur-type chain drive. But, there are some factors that can affecting the value of efficiency such as the sizes of the sprocket and the tension in the chain. Thus, the larger size of diameter sprocket present more efficient transfer of power while the small size of diameter sprocket may be less efficiency. Additionally, the higher chain tensions more efficiency than the lowest chain tension proved to be less efficiency. It was found that the normal chain drive use for HPV depends on the chain operation as it transferred from the drive sprocket on the high tension part of the drive sprocket. (Urunkar & Deshpande, 2014).

The drive mechanism element of HPV depends on it design and the way it being driven. In the same way, the configuration of the linkage joining the foot-powered section to the arm-powered section in this HPV almost same with the existing HPV. But, the difference is this type of HPV has a transformable chassis that can reduce the length of wheelbase. The position of drive mechanism can influence the comfort of the rider during on the road. In other hand, the steering mechanism also play the important role in term of comfort where the steering must give an equal angle or produce more angle than the steering to make the tire turn left or right with smoothly (Teja et al, 2016). The steering mechanism use for this type of HPV is suitable to use because it allows rider to control or steer the HPV easily while making a tight turning.

A steering mechanism for HPV is receiving the movement of the steering control from a rider commonly includes a handlebar that mounted to the middle of the chassis and connected to the foldable steering pivot. Besides that, the steering arm are mounted to each wheel fork and can be detach when the HPV is folded (Wilcox & Knapp, 2005). But, the handle bar is no need to disconnect from the main chassis in order to fold the HPV.

The foldable HPV also equipped with the disc brake and the absorber system to avoid the vehicle from safety failure. The absorber is placed under the seat area of the HPV to reduce the vibration and prevent the damage on the structure of the chassis. It also gives a comfortable and smoother ride to the rider during travelling on the road. Then, the disc brake is installed at the rear wheel while the brake lever is mounted at the handle bars to make the rider easy to apply the braking. In the other hand, the braking system was design to apply on the vehicle for the reason to have a better stability during braking (Gulati et al, 2012).

2.4 Ability of Recumbent Vehicle

Human powered vehicle than shown in Figure 2.1 is a vehicle that use four wheels and provides a low center of gravity. HPV can be categorised as a recumbent vehicle due to rider sit in a recumbent or semi recumbent position. Furthermore, the front part of the chassis is interconnected to rear part of chassis and can be folded. The chassis relatively close to ground and can maintaining the low center of gravity (Wilcox & Knapp, 2005). The recumbent vehicle also gives the more comfortable to the rider due to the basic need requirement for ergonomic.



Figure 2.1: Example of prototype for HPV (Source:Abdullah et al. 2016)