ANALYSIS OF BATTERY PERFORMANCE ON ELECTRIC BICYCLE REAR WHEEL

MUHAMAD BAKRI BIN ABDUL HAMID

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Alamat Tetap:

KG. KEDUNDONG MUKIM DERANG
O6400 POKOK SENA KEDAH

DR. TUAN MUHAMMAD YUSOFF SHAH BIN TUAN YA.

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Signature :

Name of examiner : Mr. Muhammad Ammar Nik Mu’tasim

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Date :

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Name of Supervisor : Dr. Tuan Muhammad Yusoff Shah bin Tuan Ya

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ABSTRACT

Bicycle basically is a form of simplest transportation method that can be use by us to move from one point to another. In conventional way, the bicycle needs the human who operates it use their own energy to force the bicycle so it can move. So an invention has been created and it was electric bicycle, basically using an electric motor and battery powered to replace the human energy and force. Compare to the normal bicycle, a battery powered electric bicycle delivers the travel distance at lowest possible cost compared to the one who pedals a bicycle and derived muscle energy from food. The main focus for this project is to analyze of battery performance on electric bicycle motor so that that it can achieve all the objective set. The performances of electric bicycles are basis for the data needed from electric motor and the battery. The task included is the fabrication of tire test rig to test the performances of electric motor besides testing the battery. Due to limited sources like the bicycle frame, all the testing is done at the tire test rig for the whole project. The result shows that relationship between voltage and current really significant in the power and speed produce by the electric motor that are really helpful in development of motor controller later. For the future development, there is a hope for fully functioning electric bicycle with a motor controller that have a selective mode for different riding profile.

ABSTRAK

Basikal pada asasnya merupakan sejenis alat pengangkutan ringkas yang boleh digunakan bagi tujuan pergerakan dari satu titik ke satu titik yang lain. Secara tradisionalnya, basikal memerlukan manusia untuk mengendalikannya menggunakan tenaga mereka sendiri untuk membuatkannya bergerak. Jadi satu ciptaan telah dihasilkan iaitu basikal elektrik, dimana ianya menggunakan motor elektrik yang dijana oleh kuasa bateri bagi menggantikan tenaga manusia. Jika dibandingkan dengan basikal biasa, basikal berkuasa elektrik menawarkan jarak perjalaanan dengan kos yang rendah berbanding dengan mereka yang menggunakan tenaga yang dihasilkan manusia melalui makanan. Fokus utama bagi projek ini adalah untuk menganalisa prestasi sel kering terhadap motor basikal elektrik agar dapat mencapai objektif seperti mana yang telah ditetapkan. Proses kerja yang terlibat ialah fabrikasi sebuah pelantar bagi roda basikal untuk menguji kemampuan motor elektrik selain menguji kemampuan bateri. Disebabkan kekurangan sumber seperti rangka basikal, kesemua ujian dilakukan pada pelantar roda bagi keseluruhan projek. Hasil dari projek ini menunjukkan hubung kait di antara voltan dan arus elektrik memainkan peranan penting di dalam penghasilan kuasa dan kelajuan terhadap motor elektrik dimana ianya amat membantu di dalam pembangunan alat kawalan elektik motor pada masa hadapan. Harapan agar pembangunan secara menyeluruh dapat diteruskan bagi merekabentuk basikal elektrik yang dapat berfungsi secara penuh termasuk mempunyai alat kawalan motor yang terdapat mod pilihan bagi penyesuaian semua jenis profil tunggangan yang berbeza.

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C_d	Drag coefficient
P	Density
h	Elevation above sea level
G	Elevation change over distance traveled
A	Frontal area
M	Total mass

LIST OF ABBREVATIONS

MIG	Metal Inert Gas
BLDC	Brushless Direct Current
DC	Direct Current
AC	Alternate Current
CAD	Computer Aided Design

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Bicycles are widely used after it was introduced in Europe somewhere in 19th century and the main purpose for it was to provide a form of recreation. The developments of bicycle still continue until today due to the practicality and ease of use. Bicycle can be categorized into many types for function and purpose such as road bicycle, touring bicycle, downhill bike, mountain bike and electric bike. All the design and development was designated to match with it purpose to function well in that particular situation. The basic component for a bicycle consists of front and rear wheel, frame, handlebar, seat and fork.

A traditional bicycle is a two-wheel vehicle that is propelled by the rider who delivers muscle power through pedals that rotate one of the vehicle's two wheels. The rider keeps the bicycle upright by steering the front wheel to create a force that restores the vehicle's center if gravity to its stable zone whenever necessary to prevent tipping. Today's motorcycle is a two-wheel vehicle that is propelled by a fuel-burning engine. An electric bicycle carries batteries or fuel cells that deliver electric power to a motor that is coupled to either wheel. In most electric bicycles the rider can chose to use muscle power to deliver all, part, or none of the propulsion power required to maintain his or her adopted travel speed. Some models even sense your pedal pressure and command the motor to deliver more power whenever you pedal hard.

The innovation of bicycles brings on the creative way to improvise the use of bicycle by invention of electric bicycle or e-bike. The e-bike is basically a bicycle with

an electric motor used to power the vehicle. Components for this bicycle still majorly consist of what are required to build a bicycle but with some addition like electric motor, controller and battery. Electric bicycle now are rapidly increase in term of usage since 1998 and China was the leading country for most users of electric bicycle and followed by others European country.

1.2 PROBLEM STATEMENT

Bicycle is use as an alternative for transportation and for leisure such as sport and recreation. For the sport and recreation purpose like adventure cycling, of course the users need to use extra energy and force to control the bicycle. The main point is to reduce the users' effort to control the bicycle without sacrifice the fun of riding. To overcome this problem, the bicycle needs to assist with electric motor and it is also offers a cleaner alternative to travel short-to-moderate distance rather than driving a gasoline powered vehicle.

To comprehend this problem, development of electric bicycle is essential to study and analyze the need of electric motor, battery and speed controller for designing the electric bicycle that can be programmable.

Furthermore, the design of electric bicycle only focuses on development of electric motor and battery. Thus by developing an electric bicycle, the problem can be analyzed theoretically and practically.

1.3 OBJECTIVES

i) Analysis on electric motor and battery for performance evaluation
ii) Fabrication model of tire test rig

1.4 SCOPES OF WORK

The following studies are including in the analysis of battery and electric motor.

i) Lithium ion 48V 12Ah
ii) Brushless direct current electric motor 48V 1000W
iii) Testing the electric motor on test rig
iv) 23 inch in diameter wheel hub drive

1.5 HYPOTHESIS

By the end of the project, it was expected the analysis on electric bicycle motor and battery is completed and ready for testing.

CHAPTER 2

LITERATURE REVIEW

2.1 ELECTRIC BICYCLE BACKGROUND

Electric power bicycles start to develop since late 1890s when on December 31, 1895 Ogden Bolton, Jr., was granted U.S Patent 552271 for a battery-powered bicycle with a 6 pole brush and commutator direct current hub motor mounted in the rear wheel are shown in Figure 2.1. For back then, the design of the motor contained no internal gears and only draws 100 amperes (A) from a 10-V battery. There are some others design that contributed in the development of electric bicycle such as bicycle that was propelled by double electric motor where the motor was installed in the hub of the crankshaft axle (Coate, 1994).

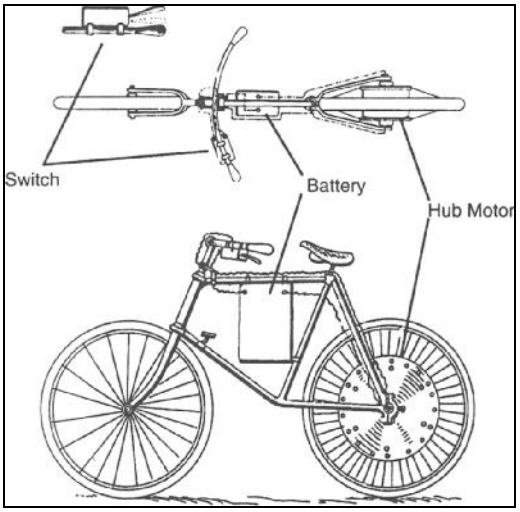

Figure 2.1: Rear wheel hub mounted motor

Source: Coate (1994)

Electric bicycle are just like an ordinary bicycle but only assisted by electric motor that can make the users feel less fatigue during cycling. The uses of electric bicycle are possible for the purpose such as recreation, commuting to work, delivery of goods and services, and establishing communication with remote villages in developing nations (Ulrich, 2006). The uses of electric bicycle can be fully utilized by increasing the distance that a physically weak person travel on normal bicycle and they can be motivated by the challenge of achieving an unusual goal like charity ride or sponsored ride. For the police and army applications, it helps for mobility in silent and quickly patrol in urban areas that are quite important for some reason and situation.

Distance capability of electric bicycles are varies as function of travel speed. It shows that at some speed the distance that can be covered for a fully charged for assuming 100 percent system efficiency and 100 percent depth of discharge for batteries. The detail is explained in Figure 2.2.

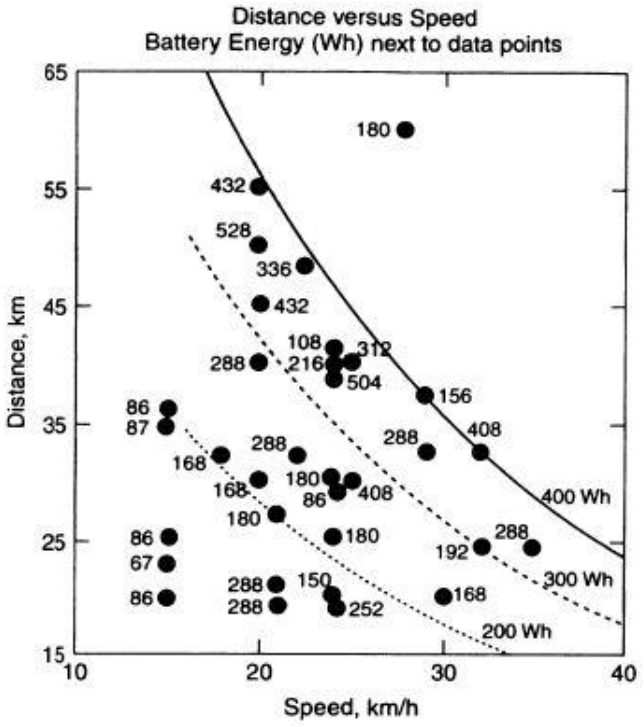

Figure 2.2: Distance capabilities

Source: Ulrich, (2006)

The history of electric bicycle was start a long time ago and the future of electric bicycle are depends on economics, the cost of fuel and air pollution in general. The entire factor really affecting the motorized vehicle and that will trigger the alternative way for transportation if the motor vehicles in cities are prohibited in risky pollution zones. Again bicycles and especially electric bicycle can be the common vehicles for commuting in the urban area, as we can see in the Shanghai over a million people bicycle to work and this situation can create an opportunity for cyclist to get a better facility like freeway lane for bicycle that maybe more comfortable with rain covers over the bicycle ways and recharging stations at workplace (Jamerson, 1997). The future for electric bicycle should be significant and continuing improvements in travel range, battery life, reliability, riding comfort and many others features. As a leading country in gaining widespread acceptance of electric bicycle, the two-wheelers types most commonly used in China include bicycles, gasoline powered motorcycles, and E2Ws. These types are classified in Table 2.1 according to key attributes (Weinert et al, 2008)

Table 2.1: Classification of two wheelers

Classification	**Types**	**Power**	**Top speed (km/hr)**	**Fuel consumption (l/100km)**	**Range (km)**
Bicycle	-	-	10-15	n/a	n/a
Electric two wheeler (E2W)	Electric bicycle	0.25-0.35 kW	20-30	1.2-1.5 kWh	30-40
	Electric scooter	0.3-0.5 kW	30-40	1.5 kWh	300-40
Motorcycle	Scooter	3-5 kW	50-80	2-3 L	120-200
	Gasoline motor cycle	4-6 kW	60-80	2-3 L	120-200

Source: Weinert et al , (2008)

Generally there are regulations and laws that keep evolving in every aspect to make sure it is updated with the current situation and electric bicycle are not excluded. The regulations will affect in term of design and use of electric bicycle, the design and limitations are summarized in Table 2.2 (Gardner, 2002). Other regulations are deal with insurance, helmets, operator age, license, and it may be applied strictly to electric bicycle riders as soon as their presence on streets becomes significant.

Table 2.2: Design and limitation in various countries

Location	**Motor power limit (W)**	**Speed limit (km/h)**	**Weight limit (kg)**	**Other limitations**
European union	250	25	No	Pedal assist
United Kingdom	200	25	40	Must have pedals and on/off switch
Canada	500	32	No	Must have pedals less than 4 wheels and on/off switch
Taiwan	No	30	40	-
Japan	No	24	No	-
China	240	20	No	Must have pedals
United States	750	32.2	No	Must have pedals and less than 4 wheels

Source: Gardner, (2002)

2.2 EVALUATION OF MATHEMATICAL MODEL

An electric bicycle have it own mathematical model that can predict the power consume for it to operates like rolling resistance and required power motor.

2.2.1 Rolling Resistance

Low speed riding will come with mainly rolling resistance and that resistance depends on bicycle weight, type of bearings used and the type of tires. To calculate the rolling resistance, an experiment was conducted (Morchin, 2009) and the data are as follows.

$$Cr=A+B/W \quad (2.1)$$

Table 2.3: Rolling resistance experiment

		A	**B**
Electric bicycle	35 psi	0.0031	0.75
Three wheel	15 psi	0.0031	0.53
recumbent	35 psi	0.002	0.455
	50 psi	0.0019	0.423

Source: Morchin, (2009)

2.2.2 Required Power Motor

Analytical expressions are needed to illustrate the power necessary when designing an electric bike. All the parameters should be considered to develop the wheel torque that needed for travelling at indicated speed, based on their purpose of use. Those values also should have enough force to overcome resistance like wind, rolling, and the gravity when climbing uphill. The constant variable has been set up like frontal area is $0.4m^2$, weight is 75kg, drag coefficient is 1, rolling coefficient is 0.007 and the elevation

is 15 m (Gross, et al , 2004). The Table 2.4 below shows the data obtain about the torque needed to move the vehicles.

Table 2.4: Torque needed to move the vehicles

	Head wind speed				
Km/h	0	10	25	40	
Bicycle speed	Road power required				Road grade (%)
19.3	86	145	279	468	0
	259	318	452	641	3
	431	491	625	814	6
25.7	161	261	472	755	0
	392	492	702	985	3
	622	722	932	1216	6
32.2	277	428	730	1124	0
	565	716	1018	1412	3
	853	1004	1306	1700	6

Source: Gross et al, (2004)

2.3 ELECTRIC BICYCLE SOURCES OF POWER

If we look at the normal human powered bicycle back then until nowadays, we just can concluded that the bicycle sources of power are come from the cyclist itself, by pedaling using their legs and really dependent on their health. But since the innovation of bicycle there are alternative source of power to move the bicycle like battery that can be used to generate the electric motor for the purpose of assist the cyclist. The batteries itself have been proven are used to stored energy for decades. By analyzed the suitable battery that can be used, it can give advantages when it comes time to decide which power sources are suitable to use with the electric bicycle depends on the purpose of cycling.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discusses the method used to fabricate, conduct and analysis in the research. Other than that, methodology is an important element where it specifically describes the method to achieve the objective of this research to run smoothly.

3.1.1 PROJECT FLOW CHART

The flow chart shown in figure shows step by step the planning for this project

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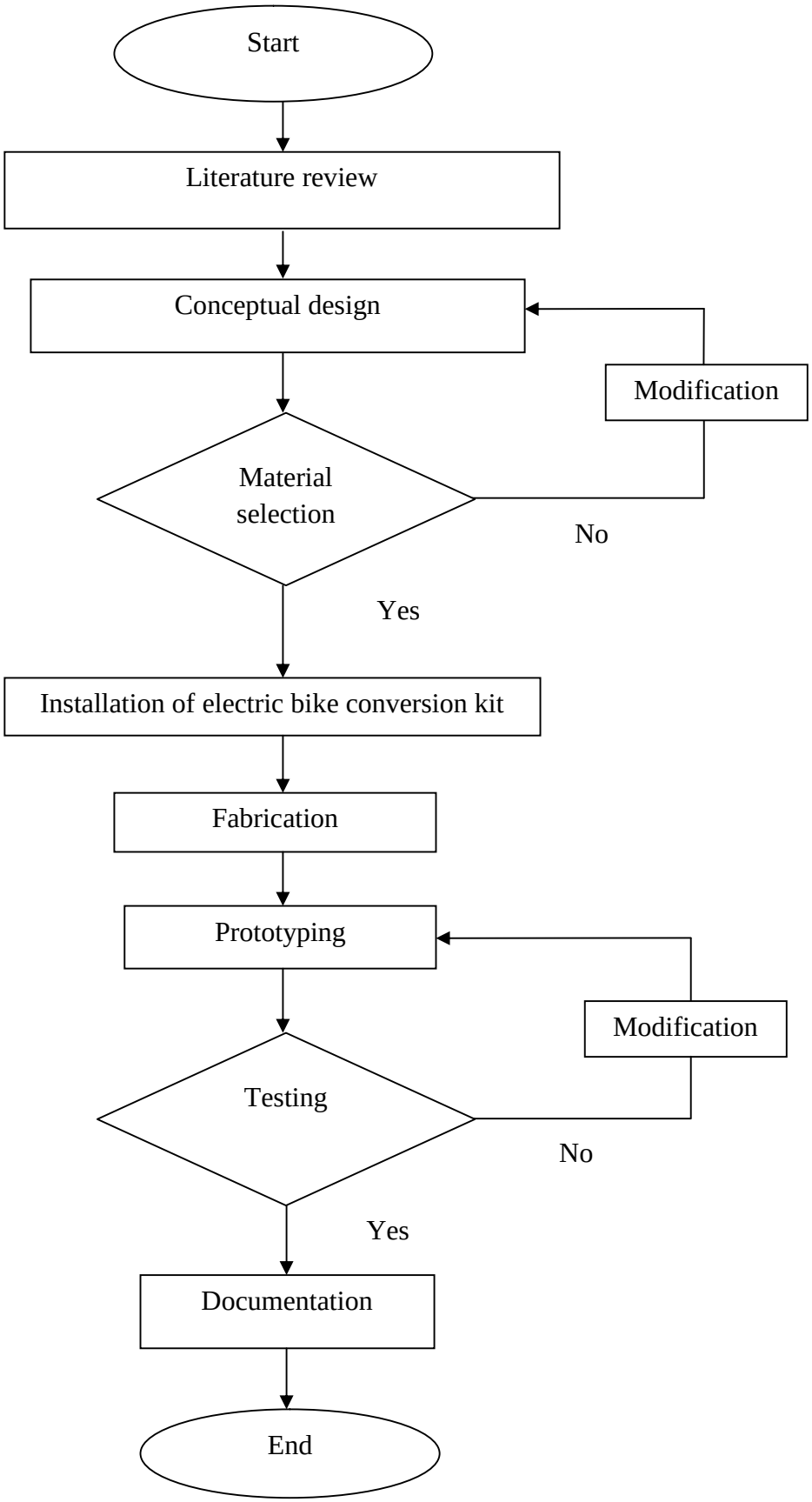


Figure 3.1: Project flow chart

3.2 LITERATURE SUMMARY

From the previous study about bicycle and electric bicycle, consideration and decision have been made for the development of the electric bicycle and some parameters have been set up as follows

3.2.1 Design Concept and Criteria

i) Electric motor type: in wheel hub motor because it is more efficient and produce more torque than mounted electric motor.
ii) Drive train: one wheel drive electric motor due to the purpose for transportation
iii) Batteries: lithium ion for the lightness and have more energy
iv) Ergonomic: disk brake added for safety.

3.2.2 Design Benchmarking

There are some comparison in designing electric bicycle such as type of electric motor and type of battery used just to be refine to compatible the development. The advantages and disadvantages of the selection are shown in Table 3.2 below.

Table 3.2: Comparison between various electric motor

Electric motors	Advantages	Disadvantages
DC motor	• Provide excellent speed control for acceleration and deceleration • Simple and cheap drive design	• Brush wear • RF noise from the brushes may interfere with electronic devices.
AC motor	• Low cost • Speed variation	• Inability to operate at low speed • Poor positioning control
Brushless DC motor	• Higher torque to size ratio • No commutator or brushes to wear out	• High initial cost • Affect electronically sensitive equipment.

After all the considerations are taken in selecting the most suitable electric motor, brushless dc motor has the matching requirement. It has selected because:

i) Project objective: the design need to develop an electric bicycle and for this project was to analyze the electric motor that already have been attached on the wheel.
ii) Time constraint: the project duration is about 7 month and in that time all the fabricating of tire test rig should be completely done.
iii) Machining limitation: electric motor that has been selected already attached on the wheel and the wheel needs to test on the tire test rig. The test rig will be fabricating using MIG welding machine and the materials should be strong enough to hold the wheel.

3.2.3 CAE Analysis

Stress and strain analysis is chosen to be analyzing on the tire test rig design and the materials used to fabricate it. The analyses are done by AUTODESK and SOLIDWORKS software.

3.2.4 Fabrication

The fabrication need to be done by choosing the suitable material and method for the tire test rig are as follows:

i) Main process - MIG welding
ii) Material preparation – Band saw, milling machine, hand drill
iii) Finishing – belt grinder, hand grinder, set of file
iv) Assembly – measuring tools, fastener

3.3 PART INVOLVING IN DESIGNING TIRE TEST RIG

Some of the requirements need process to be taken out including the machining and all the process should follow the objective and scope of design. Some of the steps are as follow:

i) Technical drawing
ii) Material selection
iii) Fabrication process

3.3.1 CAD

One of the important aspects in engineering is engineering drawing where all the details of the product will be considered before the actual product are produced. All the dimensions and tolerances will be stated in the drawing because it can cause failure to the final product if we do not have a proper view of what we actually fabricated. The methods in engineering drawing are as follow:

i. Drawing block

It have all the information such as part name, tolerance, title and it also served as an identity for the drafter of the drawing.

ii. Part dimension

The component to be drawn is subjected to the dimensions to make sure the precision of the final product. The important aspect considered in engineering drawing of the project is:

i) The dimension should not interfere with another dimension
ii) Same dimension on other view is avoided
iii) All angle in the drawing should be clearly stated

3.3.2 Material selection

After all the drawing is finish, material selection will be the next step. When selecting the material, it should follow some of the requirement including material availability, machining capability and the function of the part.

If the material selected can be used in hard or extreme condition, so the function of the product should be in extreme condition, or otherwise. For the fabrication of tire test rig, the main part was to select a material that capable to hold the stress and strain from the wheel itself when it was rotating.

The tire test rig basically only using a metal that have heavy base to withstand the vibration due to the rotation of the wheel. Summarized of material selection and justification is shown in Table 3.2

Table 3.2: Material selection for tire test rig

Types of material	Application	Justification
Solid steel bar	Test rig base	• Firm and solid • Easy to machine
Hollow steel bar	Wheel holder	• Easy to machine • Soft metal to fabricate

3.3.3 Fabrication process selection

For the process of fabrication, some tools from the laboratory are used to complete the part. The summary of the laboratory equipments was listed in Table 3.3.

Table 3.3: The summary of the laboratory equipments

Equipment	Fabrication part	Justification
Horizontal bend saw	Raw material cutting	• Fast clean cutting • accurate
Cutting and grinding tools	Part finishing	• Obtain surface finish
Conventional milling machine	Hole maker	• Accurate surface finish
MIG welding machine	Making joint	• Joining the part
Belt grinder	Surface finishing	• Smooth and accurate surface
Pillar drill	Making hole	• Simple operation

3.4 ANALYSIS

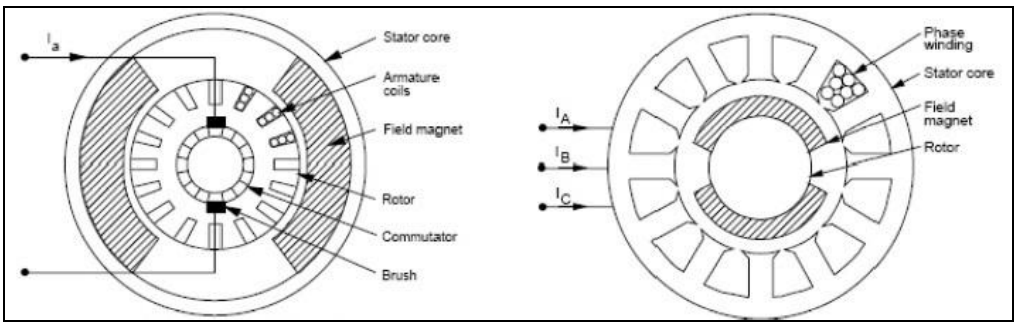
3.4.1 Brushless Direct Current Motor

For the electric motor, it has been decided to choose over brushless direct current motor over the conventional direct current motor and the specifications are listed in Table 3.2:

Table 3.4: brushless direct current motor specification

Power	48V 1000W
Weight	7 kg
Maximum RPM	450
Diameter of the motor	20.5 cm
Torque	25 N.m

The selection of the motor is based on design requirement of the wheel where the type of motor which is brushless motor is more suitable to be integrating into the wheel hub.



a) Conventional DC motor b) Brushless DC motor

Figure 3.2: Comparison between conventional DC motor and brushless DC motor

As we can see from the figure above, the main different in design construction between both motor are the brush and the magnet, where in conventional DC motor, the stator core are static and in brushless DC motor, the stator core who are the rotated part. This design of motor can be integrated into wheel hub which is easy and can be work perfectly together especially for bicycle design purpose.

As a bicycle that can be used for different purpose or mode of riding under various conditions of speed, road condition and wind resistance, the gear ratio could be determined to make sure the efficiency are obtain at maximum value.

3.4.2 Stress and Strain Analysis

The analyses part of the tire test rig model is done with stress and strain and followed by displacement analysis. The parts that will be analyzed are the wheel holder because that is the important part and the result of analysis may vary if the part has failure.

The tire test rig model will be analyzed using AUTODESK software and the engineering drawing is done using SOLIDWORKS software. To make the analysis, correct parameter is set to get a good result such as the fixed point, boundary condition and the type of the materials. The following are the method in analyzed the part.

i. Drawing the model

The drawing is done by SOLIDWORKS software where later the drawing will transfer into AUTODESK software for analysis. The drawing can be referring to Figure 3.2.

Figure 3.3: Drawing of tire test rig

ii. Analysis using AUTODESK

In analysis part, there are some analysis that can be done, including the stress, strain and displacement. The result from the analysis is important because from the analysis we can see whether what we are fabricating next will be success or failure in term of design and application.

For the stress analysis is shown in Figure 3.4, strain analysis is shown in Figure 3.5 and displacement analysis is shown in Figure 3.6.

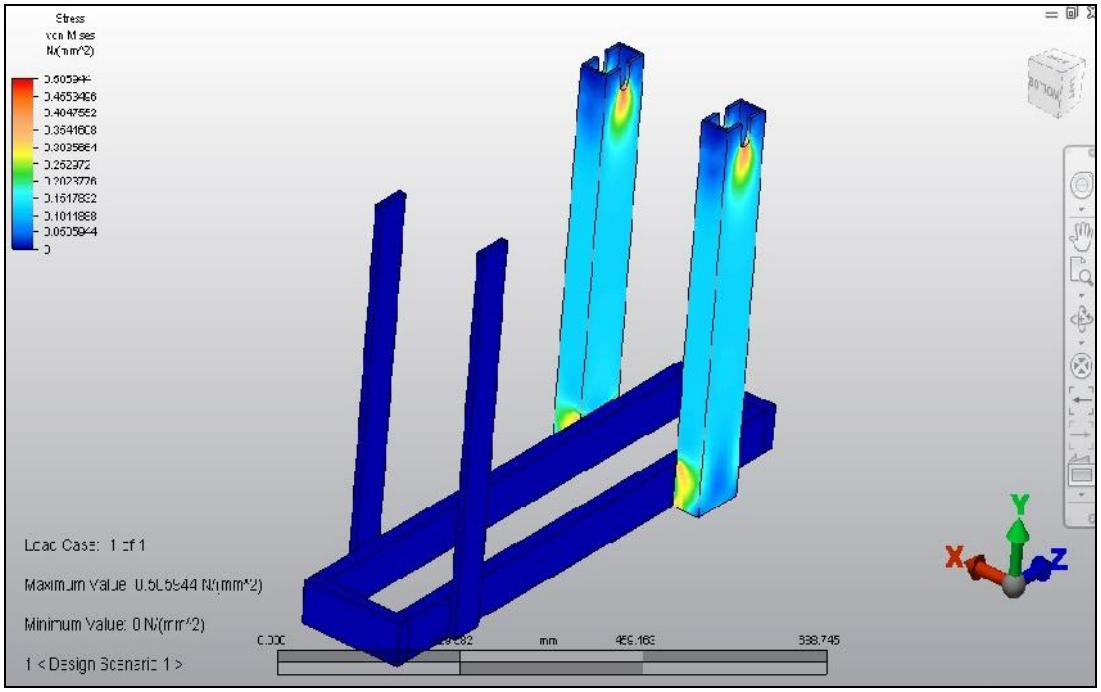


Figure 3.4: Stress analysis

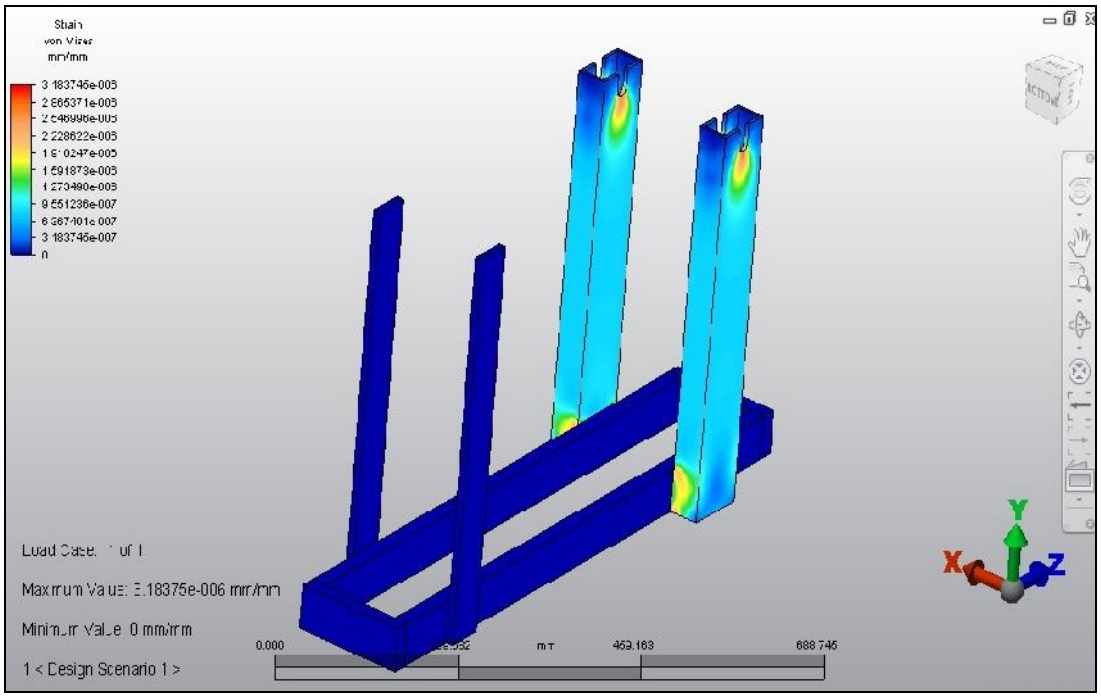


Figure 3.5: Strain analysis

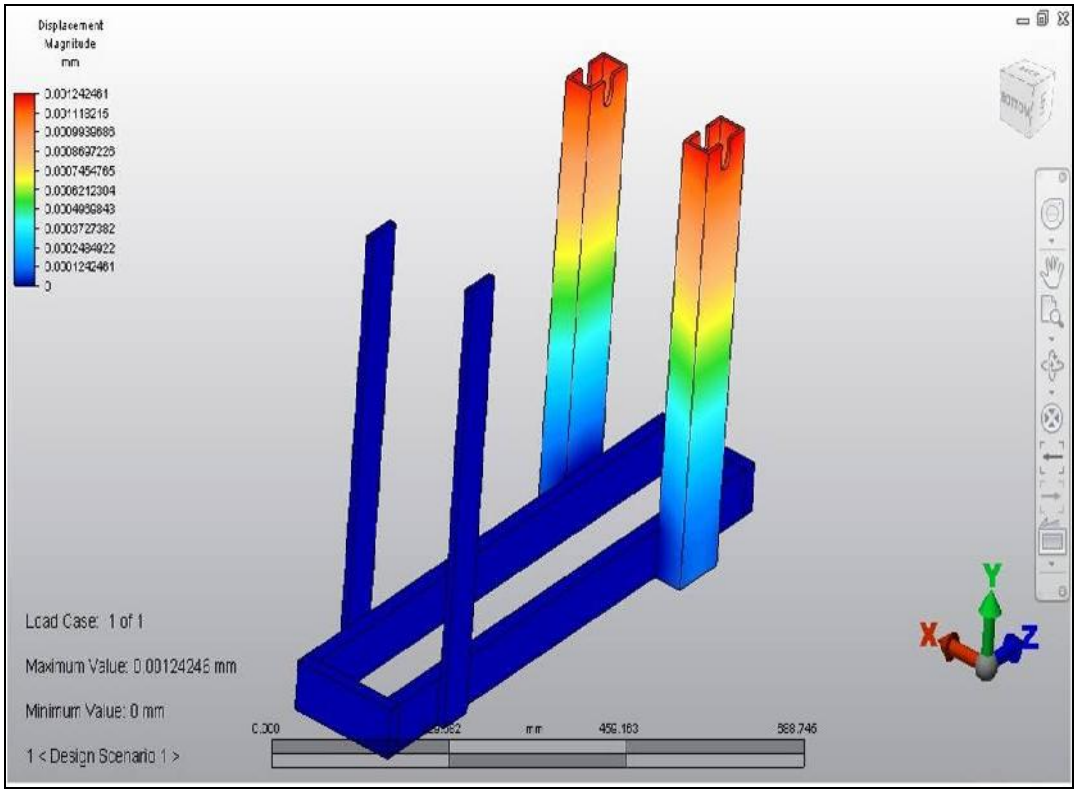


Figure 3.6: Displacement analysis

Result and discussion of this analysis will be discussed in chapter 4.

3.5 FABRICATION PROCESS

After analysis is complete, fabrication of tire test rig is started. The fabrication process is divided into 3 categories which is work piece preparation, main process, and finishing.

3.5.1 Work piece preparation

i. Material

Cutting machine is used to cut the material into desired dimensions and it included the band saw, grinder and drilling machine. Work piece that have already cut are shown in Figure 3.7.

Figure 3.7: work piece

ii. Cutting machine

The machine is used to cut the material into smaller piece for ease of work. The machine are shown in Figure 3.8.

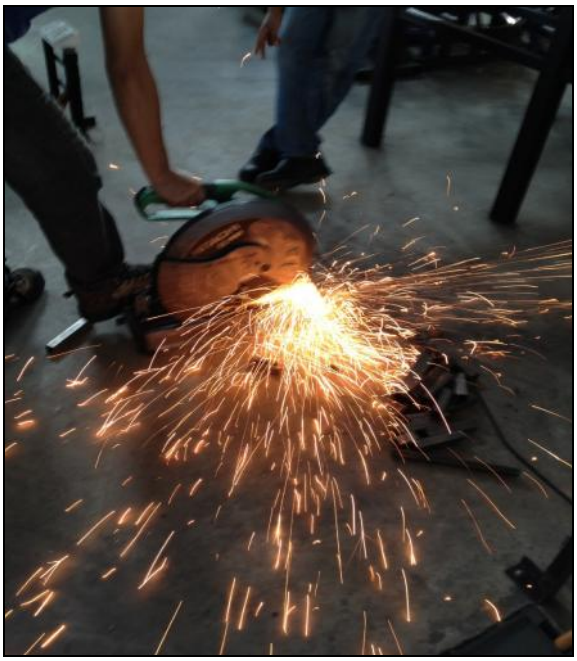


Figure 3.8: cutting machine

3.5.2 Main Process

For the assembly and joining process, the main process is using the welding machine and for this project is used MIG welding machine. The joining should be strong enough to prevent failure to the work piece. The process of welding is shown on Figure 3.9.

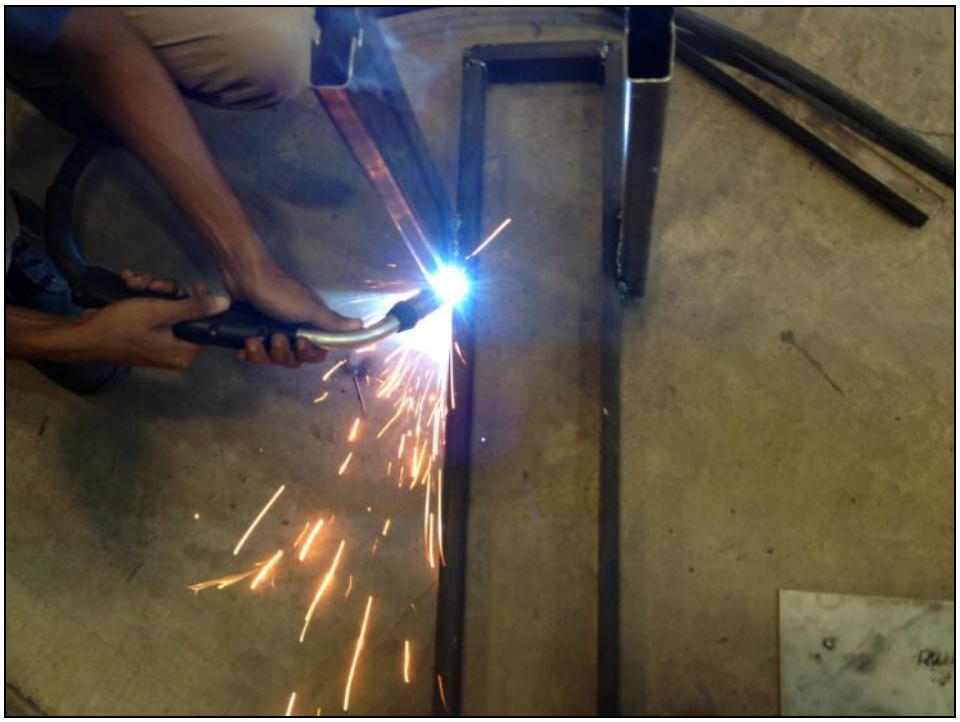


Figure 3.9: welding process

3.5.3 Finishing

Finishing process mainly focus on the surface finish, dimensions accuracies, tolerance and fit of each component. This is because the main process is not accurate enough and need some finishing touch on it. For finishing process in this project is use bench grinder, set of file and hand grinder machine. It is shown in Figure 3.10 for bench grinder and the finish product in Figure 3.11.

Figure 3.10: Bench grinder

Figure 3.11: Finish product

3.6 FINAL REPORT WRITING

3.6.1 Proposal

There must be proposal before all the final report is officially done and the process will be taking place in Final Year Project 1. The proposal includes the basic understanding about the project such as problem statement, objectives and scope of work.

3.6.2 Presentation

Each semester there is presentation that needs to be presented by student to summarize the work done and shows the progress during the project is executed. The presentation is to identify the problem encountered and how to solve it.

3.6.3 Thesis preparation

In thesis preparation, all the work done during Final Year Project 1 and 2 should be documented and the contents including introduction, literature review, methodology, result and discussion.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

After all the set up are prepared, the data can be taken from the electric motor and the battery. The design requirement for the electric bicycle design is concluded in Figure 4.1.

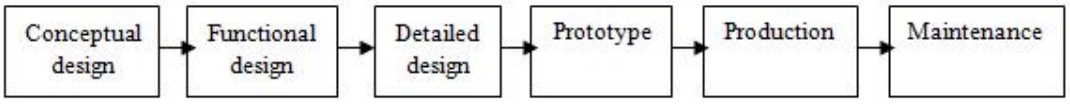


Figure 4.1: System component in design

4.1.1 Motor Speed Sensing

The speed of motor can be measured using tachometer where the result would be influenced by force measurement, the motor input voltage and current measurements. Magnetic sensors can be use to measured speed by providing signal output changes from rotating magnets that have been attached to the wheel. Variable reluctance sensing uses pickup coils that produce changes in coil output voltage for rotating magnetic field.

As we can see from the constant parameter was a voltage supplied where it come from the battery power sources which is 52.9 kV in average and the speed of the electric

motor are dependent on the current supplied which is can be manipulated by changing the value of resistance to the electric motor.

4.1.2 Battery Performance

Battery that are powered this brushless electric motor are lithium ion battery which is proven has a better life cycles and can load a higher voltage. Battery basically discharge when the negative plate deliver electrons through a conductor to the positive plate. One of the challenges toward battery charging was temperature rising during the recharging process and it will affect the chemical reactivity inside the battery itself. For the battery test performance, a set of data has been taken and the result are shown in Table 4.1

Table 4.1: Battery test performance

Electric motor RPM	Time to discharge (min)
100	61
200	65
300	68
400	62
500	50

Data shown that when the electric motor load with high RPM, the battery usage are increase due to the high current draw from the battery to support the power needed and the for the low RPM, the battery usage also not so efficient because at that condition, the electric motor need a high torque to move the electric motor and it will also result in large battery consumption. The graph for battery performance is shown in Figure 4.2.

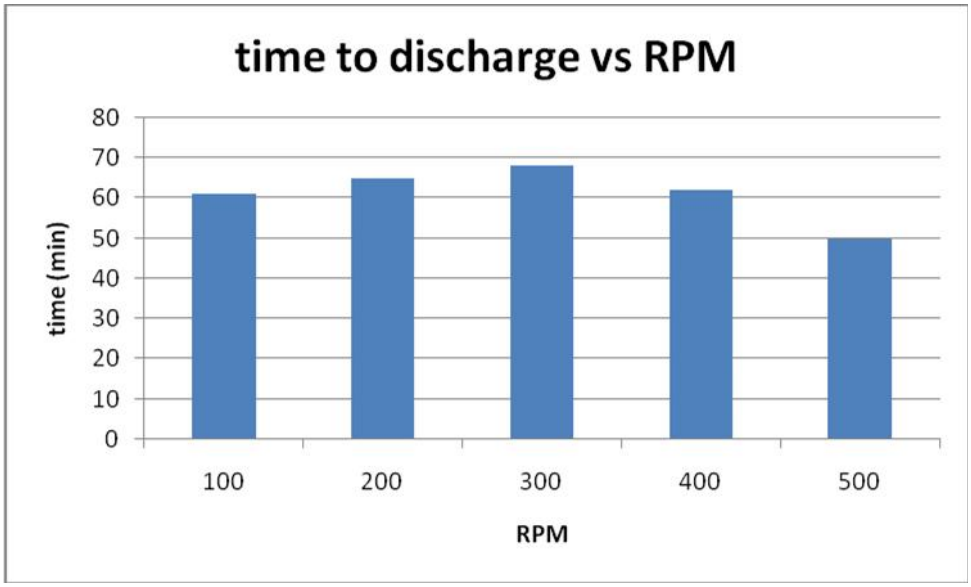


Figure 4.2: Time to discharge versus RPM

4.1.3 Voltage and Current Relationship

Voltage is the product between current and resistance that occur in the Ohm's Law where the variable for this electric motor is resistance since the voltage are constant that supplied from the battery. To know how voltage and current react toward the speed of the electric motor, a set of data has been taken that shown in Table 4.2.

Table 4.2: voltage and current toward electric motor speed

RPM	Voltage	Current
100	52.9	42.866
200	51.7	31.358
300	52	23.485
400	52.9	10.756
500	52.7	1.274

The graph for relationship between voltage and current toward electric motor are shown in Figure 4.3.

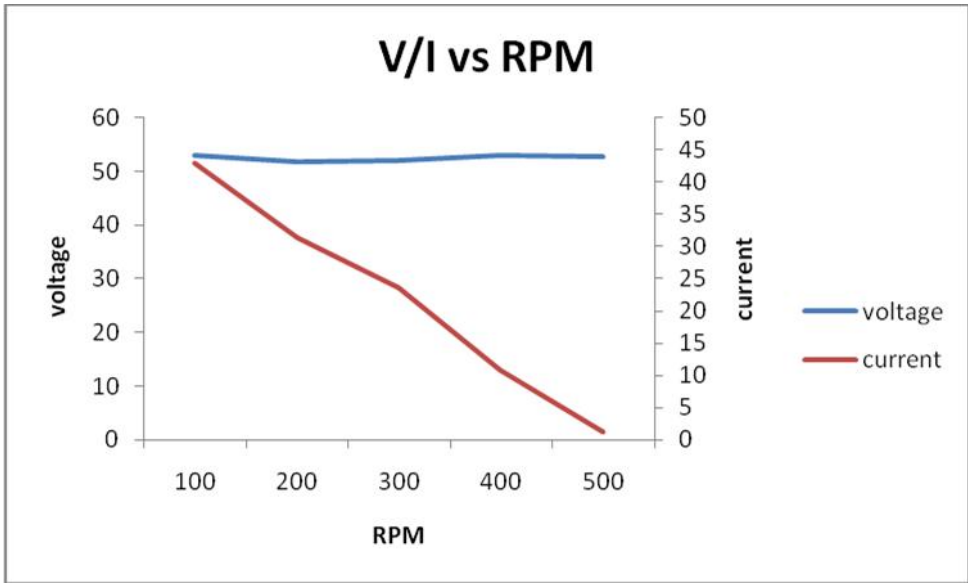


Figure 4.3: Relationship between voltage and current toward electric motor

4.1.4 Electric Motor Power

Power for electrical part can be calculated by the product of voltage and current. For the electric motor, the power also can influence by the speed due to the demand for torque when it comes to certain condition that need more torque. Usually when it comes to the low speed, the torque for that electric motor is high and the data are shown in Table 4.3.

Table 4.3: Power produced from electric motor speed

RPM	Power (watt)
100	1811.922
200	1418.118
300	1179.003
400	556.4
500	156.425

The graph for relationship between power produce by the electric motor speed are shown in Figure 4.4.

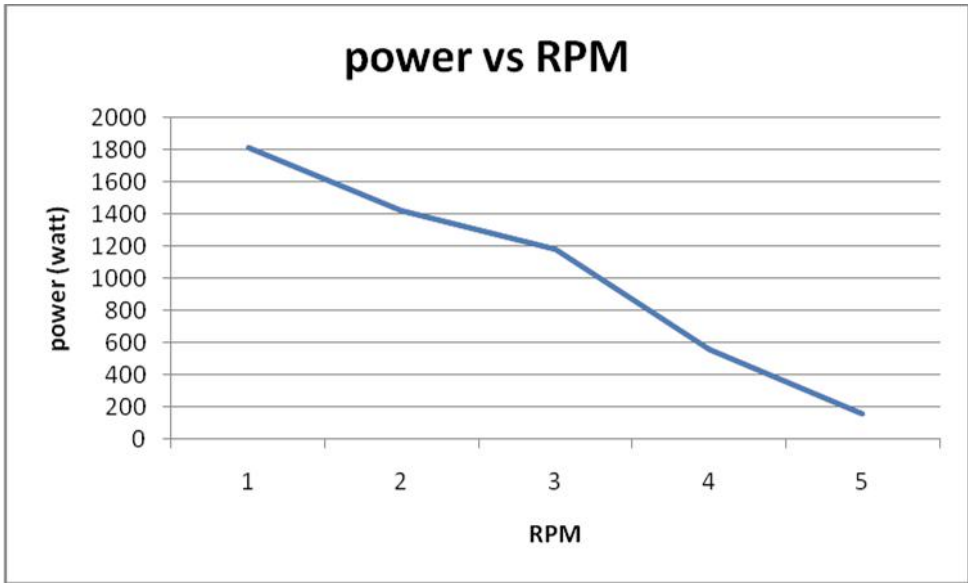


Figure 4.4: Power versus RPM

4.1.5 Experimental modeling

The experiment are conduct on a smaller scale model by using a direct current motor and ARDUINO software that act as a controller to show the relationship between current and voltage supplier toward the speed of the electric motor.

From the result, a slightly changes in voltage can increase the speed on the motor and the development of electric bicycle can be improve by study the connection and by knows how its work. The coding for ARDUINO software in controlling the speed of direct current motor can be refer in Appendix A.

CAHPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This electric bicycle system is design and develops to achieve understanding in principle of designing the whole system and its requirement. As the project progress conclusion can be made in several aspect of fabrication. This is including:

i) Design refinement conclusion – by a set of goals, the design set up to serve several purpose such as fabrication to meet the objective
ii) Analysis conclusion – simple analysis on the test rig to show the selected material and design is correct
iii) Fabrication conclusion – all part have been fabricate using various type of machine
iv) Assembly conclusion – all part have been assemble according to the engineering drawing and reference of tolerance.

5.2 RECOMMENDATION

For future development of this project, some recommendation can be share in this thesis. This project should be continued by other student for further research and development in many areas such as development of the motor controller and the minimization of battery usage also for more advances application like two wheel drive electric bicycle for more extreme purpose or application in various road conditions.

5.2.1 Testing

In this project the testing process that involving the installation of electric motor to the bicycle is not done because of time limitation and constraint. Several methods are suggested for the testing and that is including:

i) Testing the battery performance on covered distance by one wheel drive and two wheel drives.
ii) Design a motor controller that has a several power mode can that controlled the voltage and current supplied.
iii) Testing on various type of road condition such as off road and asphalt road.

5.2.2 Future recommendation

In the future that we can sure is about decreasing in fuel supply and it will affect the automotive industries where alternative energy is required for sustainability of transportation. One of the most developed alternative energy is electric energy that slowly replaces the usage of fossil fuel to drive a vehicle. It shows that development of electric bicycle can help in essential the transportation methods and it will someday become one of the most important vehicles that drive the people.
Other future modification ideas for improving the design are:

i) Solar powered electric motor
ii) Regenerative braking system
iii) High speed lightweight electric motor

The idea of electric bicycle has very big potential to be more develop extensively for the application mainly in transportation methods and the research much continue in how can we design a much efficient energy usage that can bring the benefits to the consumer.

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APPENDIX A

CODING FOR ARDUINO SOFTWARE ON SPEED CONTROL

```
/*
 Stepper Motor Control - speed control
 This program drives a unipolar or bipolar stepper motor.
 The motor is attached to digital pins 8 - 11 of the Arduino.
 A potentiometer is connected to analog input 0.

 The motor will rotate in a clockwise direction. The higher the potentiometer value, the faster the motor speed. Because setSpeed() sets the delay between steps, you may notice the motor is less responsive to changes in the sensor value a low speeds.

*/

#include <Stepper.h>

const int stepsPerRevolution = 200;  // change this to fit the number of steps per revolution
// for your motor
// initialize the stepper library on pins 8 through 11:
Stepper myStepper(stepsPerRevolution, 8,9,10,11);
```

```
int stepCount = 0;  // number of steps the motor has taken

void setup() {

  // nothing to do inside the setup

}

void loop() {

  // read the sensor value:

  int sensorReading = analogRead(A0);

  // map it to a range from 0 to 100:

  int motorSpeed = map(sensorReading, 0, 1023, 0, 100);

  // set the motor speed:

  if (motorSpeed > 0) {

    myStepper.setSpeed(motorSpeed);

    // step 1/100 of a revolution:

    myStepper.step(stepsPerRevolution/100);

  }

}
```