Faculty of Engineering Technology

INCORPORATING FLYWHEEL HYBRID MODULE IN MOTORCYCLE: SIMULATION AND ANALYSIS APPROACH

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DECLARATION

I declare that this thesis entitled "Incorporating Flywheel Hybrid Module In Motorcycle Simulation And Analysis Approach" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality as a partial fulfillment of Bachelor of Mechanical Engineering Technology (Automotive Technology) (Hons.).

Signature :…….....…….

Supervisor Name :…….....…

Date :…….....

DEDICATION

I would like to thanks to everyone who involved in finishing my final year project.

First of all I would like to say thank you to my project supervisor En. Muhammad Zaidan Bin Abdul Manaf for the guidance and teaching while finishing this project. All of those teaching and effort were priceless to me.

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Specials thanks to my friend that has help me in completing this final year project and several UTeM staff that giving the support and help.

Finally, I would like to thanks to the researcher who publish their research paper which is my main source in completing this final year project.

ABSTRACT

This study investigates the simulation and analysis the structure and material of Flywheel Hybrid Module (FHM) in order to get good performance during the operation. Simulation and Analysis Phase is done to reduce the time and cost consume to run a prototype if using experimental method. Besides, this phase is also to show and demonstrate the eventual real effects and condition of the FHM over time. The simulation and analysis of the FHM is done by Hyper Work Inspire Solid Thinking 2016. The design of the FHM is divided into two main parts which are flywheel and rim. The design of the FHM is follow the correct parameters suggest by the embodiment design phase. In the simulation, angular velocity is applied based on the safety factor consideration and the speed limit of FHM in the real life. The simulation start with initial velocity of 1000 rpm until the maximum velocity of 9000 rpm which is considered the standard speed of a motorcycle in real life. Two material are be tested in this phase which are medium carbon steel and aluminum. As result, Von Mises stress and displacement for every material is analyzed. For aluminum flywheel, the maximum stress and displacement are 154.5 MPa and 0.395 mm while for aluminum rim, the maximum stress and displacement are 1176.0 MPa and 0.699 mm. Centrifugal force also be determined and analyzed for each of velocity applied in the simulation. For aluminum flywheel and rim, the maximum centrifugal force are 94.67 rad m kg/s^2 and 258.05 rad m kg/s^2. The stress and displacement data can be used to determine the high stress concentration. From the high stress concentration, the fatigue area can be determine and fatigue of the FHM can be predict well. Lastly, the structure and material of the FHM is determined and the best material for FHM is aluminum in order to achieve good performance.

ABSTRAK

Kajian ini menyiasat simulasi dan analisis struktur dan bahan "Flywheel Hybrid Modul (FHM)" untuk mendapatkan prestasi yang baik semasa operasi. Simulasi dan fasa analisis dilakukan untuk mengurangkan masa dan kos untuk menjalankan sebuah prototaip jika menggunakan kaedah eksperimen. Selain itu, fasa ini juga adalah untuk memaparkan dan menunjukkan kesan sebenar dan keadaan FHM itu dari semasa ke semasa. Simulasi dan analisis FHM itu dilakukan dengan "Hyper Work Solid Thinking 2016". Reka bentuk FHM itu terbahagi kepada dua bahagian utama iaitu flywheel dan rim. Reka bentuk FHM itu adalah parameter yang betul dicadangkan oleh fasa Reka Bentuk. Dalam simulasi, halaju sudut digunakan berdasarkan pertimbangan faktor keselamatan dan had laju FHM dalam kehidupan sebenar. Simulasi di mulakan dengan halaju awal 1000 rpm sehingga halaju maksimum 9000 rpm yang dianggap standard kelajuan motosikal dalam kehidupan sebenar. Dua bahan akan diuji dalam fasa ini iaitu sederhana karbon keluli dan aluminium. Sebagai hasil, Von Mises tekanan dan anjakan untuk setiap bahan dianalisis. Bagi flywheel aluminium, tekanan maksimum dan anjakan adalah 154.5 MPa dan 0.395 mm manakala untuk aluminium rim, tekanan maksimum dan anjakan adalah 1176.0 MPa 0.699 mm. Emparan juga boleh ditentukan dan dianalisa untuk setiap halaju yang digunakan dalam simulasi tersebut. Bagi flywheel aluminium dan rim, emparan yang maksimum adalah 94.67 rad m kg/s^2 dan 258.05 rad m kg/s^2. Data tekanan dan anjakan boleh digunakan untuk menentukan kepekatan tinggi tekanan. Dari kepekatan tinggi tekanan, kawasan keletihan ini boleh menentukan dan keletihan FHM itu boleh diramal dengan baik. Akhir sekali, struktur dan bahan FHM yang ditentukan dan bahan terbaik untuk FHM adalah aluminium untuk mencapai prestasi yang baik.

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CHAPTER 1

INTRODUCTION

1.1 Background

Hybrid system is a power system that use two different types of system that are internal combustion system and electric motor system. Hybrid system is consists of twotype which are hybrid electric system and mechanical hybrid system. In this project, a Flywheel Hybrid Module (FHM) is used in supporting mechanical hybrid system. The ultimate goal of this project is to design and develop the fully functional prototype of FHM incorporating in motorcycle wheel. As a basic, a flywheel is a mechanical device with a significant moment of inertia used as a storage device for rotational energy. Flywheels have become the subject of extensive research as power storage devices for uses in vehicles. The concept of this study is implementing new power system on motorcycle's front rim by integrating the flywheel hybrid module on the motorcycle's rim.

The integration of the flywheel hybrid module on the front rim of motorcycle, gearing system is used and important to deliver and transmit the rotational energy from the flywheel to the motorcycle's front wheel. Besides, the gearing system is used as torque converter and the torque energy will be transfer from the flywheel hybrid module to the motorcycle's front wheel slowly or vice versa. In this case, planetary gear system is used as the gearing and transmission system for the flywheel hybrid module.

Flywheel hybrid module are one of the system that support mechanical hybrid in automotive. The development of this technology is being driven by rising fuel costs and tightening emission legislation. Power-train hybridization or flywheel hybrid system is an attractive option for achieving significant fuel savings. In order to develop this mechanical based hybrid system, our team use 5 stages of mechanical engineering design method as mentioned below.

In this study, there are five design phase incorporate in order to complete this study. The first phase known as Conceptual configuration phase. In this phase, the idea for this study is collect and propose to utilize a PDS. The concept of this project will be evaluate and finalize in this phase. Next, the second phase known as Embodiment design. It is the phase where the design concept is invested with physical form and standards. ASHBEY method will be used in this phase. The third phase is Simulation and Analysis. This phase is to show and demonstrate the eventual real effects and condition of the FHM over time. After that, the next stage is phase four. Phase four is performance optimization. This phase is to optimize and the detail the configuration of the FHM to better performance. This will be enhance by optimizing the shape, material and size. Lastly, the final phase are prototyping and testing. In this phase, the model will be fabricate and testing under actual environment and condition.

In this paper, I be assigned on the third phase which is Simulation and Analysis phase as my selected phase. In this phase, the analysis involves the FHM based on the type of drive cycle, the load predict and suitable type of flywheel that give the optimum performance. The expected outcome of this report are about energy analysis and structural analysis. The analysis also is alternative to study the flywheel hybrid module based on the major effect such as stress distribution, the vibration and fatigue occurs on the flywheel.

1.2 Problem Statement

In mechanical design, actual prototype must be produce and testing to look and analyze the structure performance. As we can see, current research and practices using an experimental method to test the prototype. Current practices usually make a prototype for a test and to run other testing, another prototype is make. This lead to the main problem where the experimental method is consume more time and cost in order to make one prototype for one test. As for that, Computer-Aided Engineering (CAE) is use in this phase to reduce the time and cost consume in testing a prototype.

1.3 Aim and Objectives

The aim of this research project has therefore been to assess the doses and risks associated with the simulation and analysis approach. By using Computer-Aided Engineering (CAE), following are the three objectives that need to be accomplished:

1. To determine load of the flywheel hybrid module under several velocity.
2. To determine the stress and displacement of the flywheel hybrid module using Finite Element Analysis (FEA).
3. To predict the fatigue of the flywheel hybrid module.

1.4 Scope

This study conducted in simulation and analysis for the flywheel hybrid module for motorcycle, which is among the tier. The work scope of this study is divided into three phases as discussed below.

Scopes of phase 1

Predict load of the flywheel hybrid module when under several motorcycle velocity. The load will be predict and determine by using suitable equations.

Scopes of phase 2

In this phase, each of the component for the flywheel hybrid module will be analyze using the Finite Element Analysis to determine the stress and displacement of each component. The component that involves are flywheel and front rim of motorcycle. Each component will simulate by involving it under rotational speed using Hyper Work Solid Thinking Inspire software. At the end, the maximum and minimum stress under several rotational speed for the components will be determine.

Scope of phase 3

This phase will be run to predict the fatigue of the flywheel hybrid module. From the stress and displacement data, the critical part where high stress concentration occur will be determined. High stress concentration will lead to the crack at the critical part and at the end, there will occur failure of the product. This test is simulate and run using Hyper Work Inspire 2016 software. This is due to the conventional way take a long time to run the analysis and need high cost in fabricating other prototype to run other test.

1.5 Structure of the Project

Chapter 1 states the problem and background of the study. This chapter also discussed the objective, hypothesis and scope of the project. So that the reader can get an initial idea about what the project is all about.

Chapter 2 explains in detail about literature review of the study. It consists of the concept of hybrid where hybrid system is the combination of two different types of system which are internal combustion system and electric motor system. Besides, the study of hybrid electric motorcycle. In order to reduce fossil fuel usage in the international market, Electric Vehicles (Evs) and Electric Motorcycles (Ems) have the potential to done the task. To done the simulation and analysis that I be assigned, the study of the simulation and analysis from previous study is needed to achieve the objectives. Drive cycles, stress and displacement and

fatigue life is also study in this phase by previous study and research to support my objectives.

Chapter 3 explains the methodology of this study. There are three phases in this study. Phase 1 is the load prediction of flywheel hybrid module under motorcycle velocity. Phase 2 focus on determining the stress and displacement of the flywheel hybrid module using Finite Element Analysis (FEA). Phase 3 focus on the prediction of fatigue of the flywheel hybrid module.

Chapter 4 is analysis and discussion chapter. The results from the simulation in phase 1 and phase 2 are analyzed here. The prediction results of phase 3 also analyzed here. In experiment result, there are divided by three sections. The first one is focused on centrifugal force of the flywheel hybrid module when there are angular velocity applied. The second one is focused on the maximum and minimum displacement and stress data of the flywheel hybrid module using Finite Element Analysis (FEA). Lastly, the third sections is focused on the fatigue of the flywheel hybrid module.

Chapter 5 is conclusion chapter. It conclude the findings from this study. Generally, the angular velocity affects the centrifugal force. The higher the angular velocity, the higher the centrifugal force. Besides, the best material to fabricate the flywheel hybrid module is aluminum which produce less displacement and stress. This also help to increase the period of material withstand the fatigue and long lasting.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature reviews are all about carried out the information for whole project in order to completing this project. Previous study or project done by researcher and other such as books, journal and article have been used as the sources. This chapter is introduce to explain about the concept and integration of FHM in the previous study. Besides, this chapter also explain about the previous study done by researcher about the advantages of flywheel and hybrid system and also about the 5 stages of mechanical design.

2.2 Concept of Hybrid

Hybrid system is a power system that use two different types of system that are internal combustion system and electric motor system. Hybrid system is consists of twotype which are hybrid electric system and mechanical hybrid system.

In mechanical hybrid system of vehicle, mechanical energy is obtained from internal combustion engine while electric energy is obtained from the energy that stored in the battery to move the vehicle. The mechanical hybrid system recovers kinetic energy from the vehicle during braking to a high-speed, rotating flywheel via a variable drive system (Brockbank, 2010). Electrical energy delivery system also required in this system to convert electrical energy to mechanical energy.

Hybrid electric vehicle is a combination of both conventional internal combustion engine and electric propulsion. The presence of electric power train is intended to achieve the better fuel economy. Modern hybrid electric vehicle system make use efficiency improving technologies such as regenerative braking which converts vehicle's kinetic

energy into electric energy for charging the battery rather than wasting its energy (Reddy & Tharun, 2013).

There are many different of drive train structures for hybrid that are parallel hybrid and series hybrid. In parallel hybrids the ICE and electric motor are both connected to mechanical transmission and can simultaneously transmit power to drive the wheels usually through a conventional transmission. These are also capable of regenerative braking and internal combustion can also act as generator for supple-mental recharging. Parallel hybrids are more efficient than comparable to non-hybrid vehicles especially during urban stop and go conditions and at times during high way operation where electric motor is permitted to contribute. Some of the examples of parallel hybrids are Honda insight, Civic, Accord (Reddy & Tharun, 2013). The configuration of the series hybrid electric vehicle is shown in Figure 2-1 and Figure 2-2. Engine drives the generator to generate power and power is directly transferred to energy shortage unit or drive motor. Drive motor works in electric mode to drive the vehicle or in generating model to transfer mechanical energy to electric energy. The energy of the series hybrid electric vehicle is distributed by the vehicle controller. Vehicle controller distributes the energy between Auxiliary Power Unit (APU) and energy shortage unit according to the power demand of driver and parts condition (Wu, 2013).

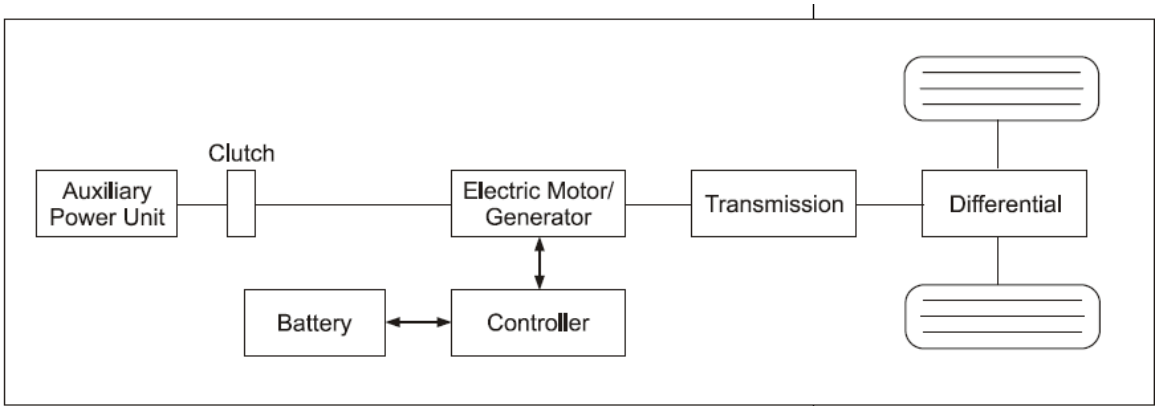

Figure 2-1 : Parallel Hybrids Powertrain (Reddy & Tharun 2013)

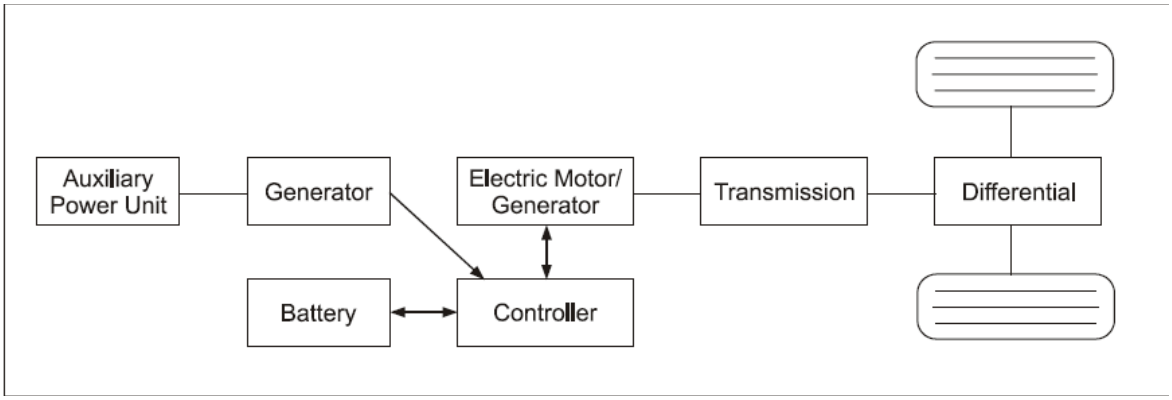

Figure 2-2 Series Hybrids Powertrain (Reddy & Tharun, 2013)

2.3 Hybrid Electric Motorcycle

In this era, governments and automakers in many countries have responded by allocating considerable economic resources to develop renewable fuels and fuel efficient vehicle powertrain technologies. Electric Vehicles (Evs) and Electric Motorcycles (Ems) have the potential to reduce fossil fuel usage in the international market. However, they are facing challenges in consumer acceptance due to range limitations, lack of charging stations, the high cost of batteries and poor battery performance. Currently, both gasoline Spark Ignition (SI) and diesel Compression Ignition (CI) engines have been integrated into hybrid powertrains. CI engines have a higher thermal efficiency than SI engines, due to the higher compression ratios and lean burn ratios used. CI engines the air/fuel charge is not pre-mixed, which leads to incomplete combustion and very high temperatures in the combustion zones. This then results in high levels of NOx and Particulate Matter (PM) emissions (Craig, 2013).

The Motor Driving system is the "heart" of Hybrid Electric Motorcycles, whosemain task is to convert the energy in the batteries into the dynamic energy on wheels with high efficiency, or vice versa. The motors installed in Hybrid Electric Motorcycles must have such features as broad torque and speed spectrum, large outputting torque at low speed and acceleration, low torque at high-speed driving, easiness in manipulation and stabilization, quick dynamic response, high power density, and so on (Ping, 2011).

A schematic diagram for the Hybrid Electric Motorcycle (HEM) is shown in Figure 1. The HCCI engine is used to drive an electrical generator. The electric power from the generator is used to charge the battery pack utilizing a DC/DC converter, which boosts the generator output voltage to a level higher than the battery terminal voltage. The wheel motor is driven by the electric power flow from the battery to propel the vehicle. The engine combustion and all power flow action are monitored and controlled by an integrated controller (Craig, 2013).

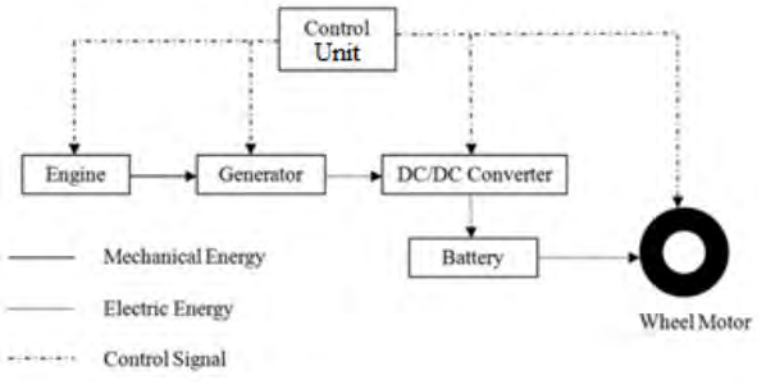

Figure 2-3: Schematic diagram for the Hybrid Electric Motorcycle (Craig, 2013).

2.4 Simulation and Analysis Phase

In this project, I be assigned to complete the third phase which is simulation and analysis phase. Simulation and analysis is important phase to complete a project and this can be shown by previous study. At the same time for complicated geometries, assessment of this factor and total energy remains elusive, therefore proposed finite element based analysis of such geometries could directly help determine the maximum achievable energy density. This approach consists of four steps:

- Step 1, a fully parametric model of the flywheel is created to be inputted to ANSYS (a finite element modelling and analysis software) to form the desired geometry.
- Step 2, model obtained in Step 1 is analyzed using ANSYS/LSDYNA, an explicit code, to obtain the stored kinetic energy and mass of the flywheel.

- Step 3, the same model is also analyzed using ANSYS, an implicit code, and overall stress distribution of the flywheel obtained and critical stresses and regions identified.
- Finally, using kinetic energy, mass and maximum stress of the flywheel obtained in Steps 1–3, an optimization is performed to come up with the maximum obtainable Specific Energy level, meantime making sure that the maximum equivalent stress is less than the maximum (Arslan, 2008).

2.4.1 Drive Cycles

In an automotive technology, the research in using flywheel as a secondary power source begins as in early 70s. Nowadays some automotive manufacturer start to put this technology inside their cars even some of them uses it in high performance car. However, the reliability and performance of the flywheel hybrid is uncertain. Therefore, this technology is still on going further research and refinement. In performance aspect, the major drawback of flywheel hybrid is in the recharging and storing capability. It only can be charge using regenerative braking which exist during deceleration phase of driving cycle (Manaf, 2015).

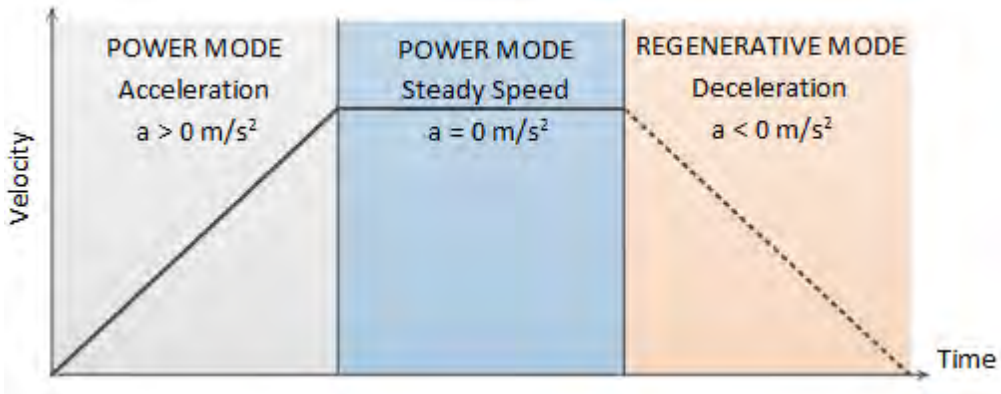

Figure 2-4: Three types of driving drive (Manaf et al. 2015).

2.4.2 Stress and Displacement

In this study, energy output that need to be evaluate is the kinetic energy that can be store by the flywheel. The previous study show that modern technology has enabled a new application for the age old flywheel in advanced flywheel energy storage systems. These systems are often called mechanical batteries since electrical energy is input, stored as rotational mechanical energy, and converted back to electrical energy to provide power on demand. The Flywheel is designed in 3D modelling CATIA (Reddy, 2015).

2.4.3 Fatigue Life

Fatigue life is a function of the magnitude of the fluctuating stress, geometry of the specimen and test conditions. An S-N diagram is a plot of the fatigue life at various levels of fluctuating stress. From previous study stated by Kihyon Kwon and Dan M. Frangopol, under the repeated or fluctuating application of stresses during voyages, ship fatigue life can be assessed by using a fatigue reliability method based on the S-N (stress vs. Number of cycles) approach. Besides, the S-N (stress vs. number of cycles) approach and available sea loading information are used to evaluate the time-dependent fatigue reliability (Kwon & Frangopol, 2013).

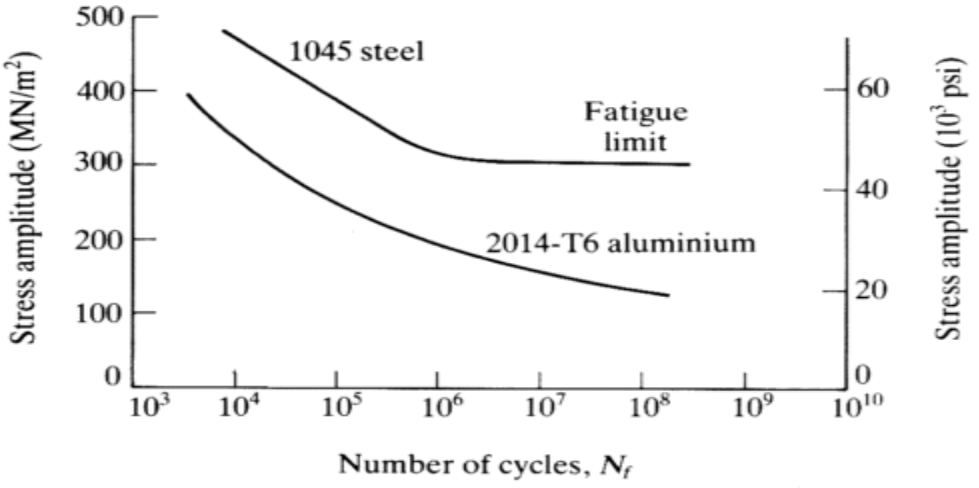

Figure 2-5: S-N curve

(Source: www.efunda.com/formulae/solid_mechanics/fatigue/images/fatigue_SN_01.gif)

CHAPTER 3

METHODOLOGY

3.0 Introduction

The study will be conducted into several phase, where all the details of the simulation and analysis methods will be show in order to identify the project objectives in more details. There are several phase of methodology in incorporating flywheel hybrid module in motorcycle by using simulation and analysis approach.

The phase start with determine the load of the flywheel hybrid module under set up velocity. The flywheel hybrid module will be run and from intial velocity of 1000 rpm until maximum velocity of 9000 rpm where these are the standard velocity of motorcycle. For each set up velocity, the centrifugal force of the FHM will be determined by using an equation of $Fc = I\alpha$.

The method are done by continue to the next phase where the next phase is determine the stress and displacement of the flywheel hybrid module using Finite Element Analysis (FEA). In this phase, two material are selected for the FHM to be analysed which are carbon steel and aluminum. The stress and displacement of the FHM for each material will be determine in order to choose which material can withstand high stress and displacement.

Fatigue prediction of the flywheel hybrid module is the next phase in methodology. After done the simulation under the set up velocity, the area of the high stress concentration on the FHM geometry is identify in order to predict the creep. From the creep, the fatigue area of the FHM where the high stress and displacement can be determine when load is applied.