UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Engineering Technology

INCORPORATING FLYWHEEL HYBRID MODULE IN AUTOMOBILE: SIMULATION AND ANALYSIS APPROACH

Ahmad Faizal Bin Azis

Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours

2016

INCORPORATING FLYWHEEL HYBRID MODULE IN AUTOMOBILE: SIMULATION AND ANALYSIS APPROACH

Ahmad Faizal Bin Azis

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Automotive Technology) (Hons.)

Faculty of Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this thesis entitled "Incoporating Flywheel Hybrid Module in Automobile: 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 reportis sufficient in terms of scope and quality as a partial fulfillment of Bachelor of Mechanical Engineering Technology (Automotive Technology) (Hons.).

Signature :…….....……

SupervisorName :…….....…

Date :…….....

DEDICATION

To my beloved parent, Azis Bin Hassan and Ku Roslida bt Ku Abd Ghani,

My supportive family members,

And friends those give me motivation and encourage me in finishing the task,

Thanks you so much.

ABSTRACT

This study introduced the simulation and analysis the structure of flywheel hybrid module (FHM) in order get the perfect performance during its operation. From the previous research, the author only use the classical method which is simple equation formula to evaluate energy analysis for the flywheel hybrid module. This project must be done in order to improve the method to evaluate the energy output of flywheel hybrid modul by using finite element analysis (FEA) method. The FHM design was conducted by using CAD software namely CATIA V5R21. The design be divide into two part which are the first part is flywheel and the second part is combination of ring and rim. A FHM type is designed in several steps based on the design considerations. A methodical plan must be followed so that all parameters are considered. The design was import to the Inpire SolidThinking software to proceed the simulation. The angular velocity and the load that applied on the model is the parameter that need to be focus during analysis process. The value of angular velocity was applied based on the safety factor consideration and the limit speed of the part FHM in the real life. The maximum angular velocity that be apply is 60000 rpm. The material be apply are Aluminium 6061 and medium carbon steel. Result from the analyses including Von Misses stress and displacement. The result that produce can use to investigated the stress concentration on the both part of FHM. From the location of stress concentration, the fatigue failure was predicted. It can be seen from the result wether material used or load applied need to be considered for a better result for future study.

ABSTRAK

Kajian ini memperkenalkan simulasi dan analisis struktur modul roda tenaga hybrid (FHM) untuk mendapat prestasi yang yang sempurna semasa operasi. Dari penyelidikan sebelum ini, penulis hanya menggunakan kaedah klasik yang merupakan formula persamaan mudah untuk menilai analisis tenaga untuk modul roda tenaga hibrid. Projek ini perlu dilakukan dalam usaha untuk meningkatkan kaedah untuk menilai output tenaga roda tenaga hibrid modul dengan menggunakan kaedah analisis unsur terhingga (FEA). Reka bentuk FHM telah dijalankan dengan menggunakan perisian CAD iaitu CATIA V5R21. Reka bentuk ini dibahagikan kepada dua bahagian iaitu bahagian pertama adalah roda tenaga dan bahagian kedua adalah gabungan cincin dan rim. Jenis FHM direka dalam beberapa langkah berdasarkan pertimbangan reka bentuk. Pelan teratur mesti diikuti supaya semua parameter akan dipertimbangkan. Reka bentuk dimasukkan ke perisian Inspire SolidThinking meneruskan simulasi. Had laju sudut dan beban yang digunakan ke atas model ialah parameter yang perlu difokuskan semasa proses analisis. Nilai had laju sudut dikenakan berdasarkan pertimbangan faaktor keselamatan dan had kelajuan FHM dalam kehidupan sebenar. Had laju sudut maksimum yang dikenakan ialah 60000 rpm. Bahan dikenakan ialah Aluminium 6061 dan keluli karbon sederhana. Hasil daripada analisis termasuk tekanan Von misses dan sesaran. Keputusan hasil itu boleh guna untuk menyiasat penumpuan tekanan terhadap kedua-dua bahagian FHM. Ia boleh dilihat dari keputusan samada bahan yang digunakan atau muatan yang digunakan hendaklah dipertimbangkan untuk satu keputusan yang lebih baik untuk kajian masa depan.

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my final year project supervisor, Mr Muhammad Zaidan Bin Abdul Manaf from the Faculty of Engineering Technology UniversitiTeknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this thesis.

My grateful thanks also go to all lecturers who always give supports and advices for me to work harder and smarter.

I am also thankful to all my friends especially my project team's member who always give support and moral for me to complete my thesis.

Special thanks to my beloved family for their moral support in completing this degree. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

TABLE OF CONTENT

LIST OF FIGURES

FIGURE **TITLE** **PAGE**

LIST OF TABLES

TABLE **TITLE** **PAGE**

CHAPTER 1

INTRODUCTION

1.1 Background

Nowdays there are many cars produced at the road and had been improved to get better in order to achieve optimum performance and convenient to the human and also to the environment. Hybrid vehicle is one of solution to solve the problem. A hybrid vehicle is a vehicle that used two different type of power source. There have the key component of hybrid vehicle which are drive motors, power units, generator, energy storage systems, regenerative braking, and control system. The hybrid system can be classified into three types which are series hybrids, parallel hybrid and series-parallel hybrid. There are many research about hybrid vehicle in order to improve it. The latest hybrid is by using flywheel as secondary source. An alternative to the hybrid powertrain is a mechanical hybrid system utilizing a rotating flywheel as energy storage device and a variable drive to transfer the energy to and from the vehicle driveline. Flywheel serve as kinetic energy storage and retrieval devices with the ability to deliver high output power at high rotational speed as being one of the emerging energy storage technologies available today in various stage of development.

Flywheel hybrid module (FHM) is one of the great innovations in order to increase the performance of hybrid vehicle. Today, many research effort focus on improving energy storage capability to transfer high power at delivery times, long-term longer than convenient battery power innovation. The operation of kid's toys car concept is one of the solution how the concept of FHM is developed. A small metal disk or small flywheel is attact inside the toys is used to store the kinetic energy and transmitted from wheel during push action. When released, the knetic energy store inside flywheel is transfer back to the wheel and pushed the toys forward.

FHM need to assemble to the right part on the system in order to get optimum performance of the vehicle. The transmission is the part also know as torque converter that can trasmitt the rotation energy from the flywheel directly to the wheel. Basically, the flywheel is place in or near the tyres. Figure 1.1.1 shows the potential location for flywheel hybrid system.

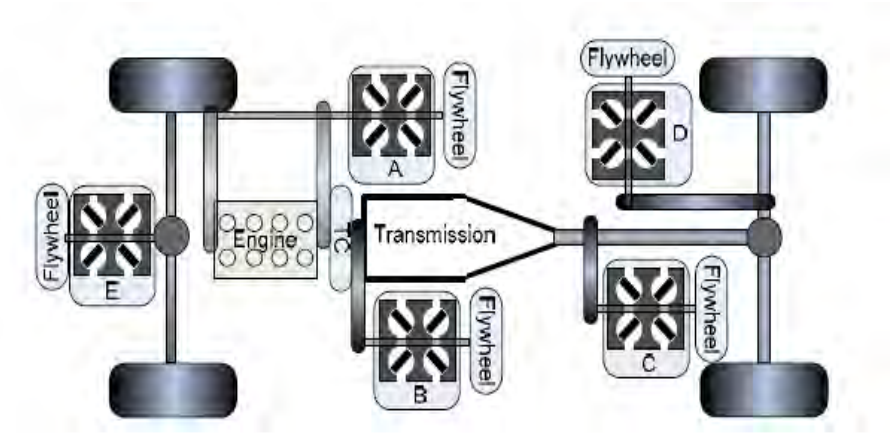

Figure 1.1: The potential location for flywheel hybrid system
(Source: Brockbank 2016)

The rotation of wheel will followed by the flywheel. This time the flywheel can generate and store the kinetic energy. When the brake pedal is push, the rotation of wheel also will stop but not for flywheel. The kinetic energy that had been stored by the flywheel will help and support the tyre to rotate automatically when the vehicle start to move. So, the flywheel not only the product that can store the energy but also can be the second source of energy to vehicle. The kinetic energy produce by rotation flywheel that delivers can save other energy. FHM is the one solution to solve the problem of the fuel consumption.

From the investigation previous studied, there have been highlight the five stages in order to develop new FHM on automobile. The first stage is the Conceptual configuration. This stage is about to collect the idea and finalize the concept which related to the FHM. Next, the second stage know as Embodiment design. Second stage give the detail information about the develoment on physical standards. Third stage is Simulation and Analysis. This stage is about to demonstrate and investigaed the detail parameter of FHM and the critical part under the value load apply. For the next stage is to optimize and detail the configuration. Lastly, the stage is prototyping and testing. The information and analysis from other stage need to combine and finalize in order to get perfect product.

This paper focus on the third stage which is Simulation and Analysis. The performance and development of the flywheel related to the simulation and analysis studies before. The analysis involves the flywheel hybrid module based on type of drive cycle, the output energy produce, and suitable type of flywheel that give the optimum performance. The analysis also is alternative to study the flywheel hybrid module based on the major effect. For example, the stress distribution, the vibration and fatigue occurs on the

flywheel. By using the CATIA software or AutoCAD software, the various analysis can be done such as structure analysis, performance analysis and static analysis.

1.2 Problem Statement

From the previous research, the author only use the classical method which is simple equation formula to evaluate energy analysis for the flywheel hybrid module. The equation is show on Equation 1.1 and Equation 1.2 below (Singal et al.2014).

$$E = \frac{1}{2} I \omega^2 \qquad (1.1)$$

$$E = \frac{1}{2} mv^2 \qquad (1.2)$$

Equation 1.1 & 1.2: Total energy analysis
(Source: Singal et al.2014)

This project must be done in order to improve the method to evaluate the energy output of flywheel hybrid modul by using finite element analysis (FEA) method.

In addition, the other problem is about the stucture of flywheel at higher speed. There are several previous research for flywheel which is runing at higher speed. For example Jaguar and Volve flywheel system. But there is no data about high speed test that is related to the structure of flywheel.

1.3 Aim and Objectives

The aim of this study is to simulate and analyse the structure of flywheel to get perfect performance for hybrid vehicle. In order to achieve the aim, following are the three objectives that need to be accomplished:

1. Determine load of the flywheel hybrid module under several angular velocity
2. Determine the stress and displacement of the FHM using finite element analysis
3. Fatigue prediction of the flywheel hybrid module

1.4 Scope

The scope is to run a heuristic simulation model of flywheel hybrid of automobile. The main consideration for simulation and analysis must therefore focus on the critical part and material selected. The work scope of this study is divided into two phases.

Performance

1. The maximum and minimum energy output over period of time before crack
2. Maximum displacement under the value load apply and without load apply

Structure integrity

1. Select the material with high maximum radial stress
2. Improve the performance of component to overcome the resonance, fatigue and other harmful effects of forced vibrations
3. Life cycle of flywheel on within ten years

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 general problem that this study tries to overcome. It explains about the analysis and operation of rotational flywheel hybrid. The method of diagnosis and preventive are also discussed here.

Capter 3 explains the methodology of this study. There are three phases in this study. Phase 1 is to investigated the load of flywheel hybrid module under several angular velocity. Phase 2 focus on stress and displacement of the FHM using finite element analysis. Final phase is about the fatigue prediction of the flywheel hybrid module

Chapter 4 is the result of the project. The result from the analysis is investigated to know the better structure of flywheel hybrid module. The best material is selected in order to improve the performance of flywheel hybrid module.

Chapter 5 is the conclusion of the project. The outcome of the project will be describe on this chapter. There are also the recommendation in order to improve the future of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss mainly on the last research about these topic which is flywheel hybrid for automobile. It is important in order to get the idea about the simulation and analysis of operation of flywheel hybrid. It also help in advancing these type of technology to give the benefits in todays life.

2.2 Basic concept and proprties of flywheels

A flywheel is a simple device, essentially a disc or drum supported on bearings with an output shaft. Flywheel has a long application history in mechanical industry. Todays, it attracts more and more research as an energy storage method. For example,a fywheel energy storage system (FESS) uses a high speed spining mass (rotor) to store kinetic energy. The FESS can be used in the cases where large power is needed in short time, for example, city bus, frequent light train, braking power regenerating, shipyard crane, as well as for wind power and smart grid energy storage (bai et al.2012). In FESS, a motor drives the flywheel rotor to run at a high rotating speed. The rotor store the energy in

mechanical one. When it is needed, the energy is dicharged by decreasing the rotating speed of rotor. Normally the rotor is supported by mechanical bearings that provide very low frictional losses. By using permanent magnetic levitation, superconducting bearing, or active magnetic bearing it gives the high performance of FESS (bai et al.2012). The flywheel rotor work in a high speed, must be high energy density, high mechanical strength, and dynamic properties (han et al.2012). Therefore the flywheel rotor was the key of FESS research and develop. Figure 2.1 show the example of flywheel rotor.

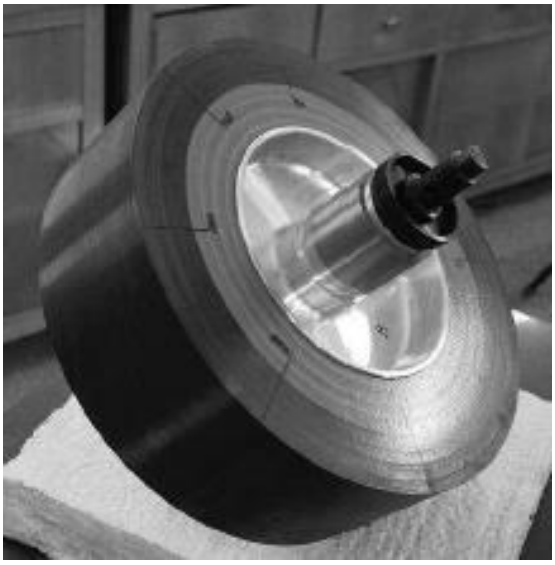

Figure 2.1: Example of flywheel rotor
(Source: Bai, Zhang, and Wang 2012)

For the flywheel hybrid system, the mechanical Kinetic Energy Recovery System (KERS) for the F1 have been develop and consists of a high-speed flywheel comprising a carbon filament wraped round a steel hub and a Torotrak full-toroidal traction drive CVT (brockbank et al.2010). KERS are the new technology that utilization in car vehicle particularly in hybrid car to recovering a moving vehicle motor vitality under braking. In the following years, the F1 team have improve that the KERS framework able to get the

perfect performance for F1 racing car. As a result, the McLaren team has won F1 GP by consuming the KERS framework. Todays, the KERS technology has being inspried by the hybrid common car.

2.3 Integration of flywheel hybrid on the automobile

For the automobile which use the flywheel as an energy storage device, a suitable means to connect the flywheel to driveline is needed that would allow the flywheel to change its speed continuously (Pullen & Dhand et al.2014). The rotational speed influence the energy ouput and energy transfer to the other system. The transmission is need for the flywheel in order to transfer the energy. The use of continuosly variable transmission (CVT) are slightly perfect on the flywheel. The requirements of the CVT used in a flywheel hybrid vehicle is different to that use in a conventional vehicle. The main different is that the CVT in a flywheel hybrid vehicle should be able to transfer energy in the forward as well as the backward direction at high efficiency (Pullen & Dhand et al.2014).

There are many transmission had been mention on previous studied. For example, hydrostatic transmissions, traction cntinuously variable tansmission, electric tansmission, and mechanical transmission. Hydrostic transmission is a system that transmitts energy using hydraulic fluid. For traction CVT, it transfers torque through adhesive friction. The tranction drives usually have a limited ration range which are by using belt drivers and rolling traction drives. Next, electric transmission is about the mechanical energy converted into electrical energy and will reconverted to mechanical energy to other component. Lastly, the mechanical transmission. This transmission use a slipping clutch

in series with a stepped gearbox. The gearbox has distrete ratios at each step the clutch can be slipped to achieve the desired ratio. Besides, CVT though purely mechanical would use the planetary gear set (PGS) as a two degree of freedom device (Pullen & Dhand et al.2014).

Since 2009, the F1 has introduced the KERS in its race cars. The system of Flybrid-Torotrak employs a mechanical flywheel based on KERS. In this system, the flywheel is connected to a double toroidal drive which is connected to the input drive (Dhand & Pullen et al.2013). Figure 2.2 shows a schematic of the system.

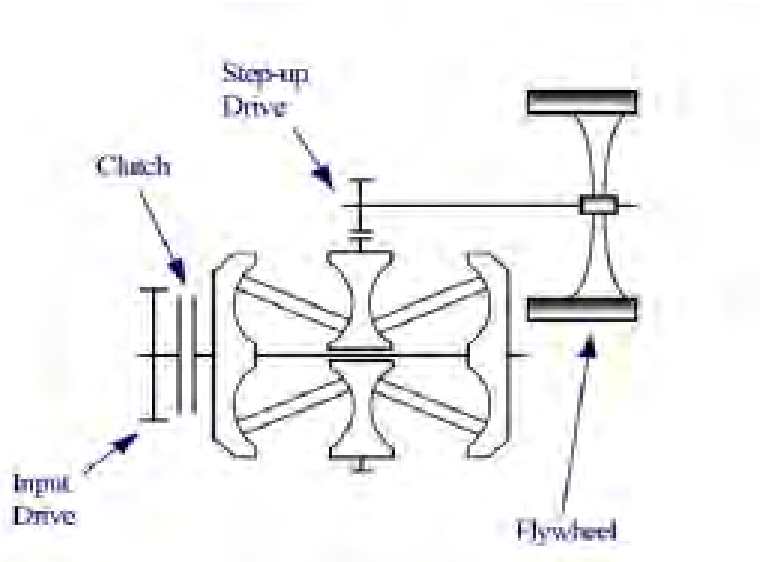

Figure 2.2: Flybrid Torotrak system
(Source: Dhand and Pullen et al.2013)

2.4 Advantages of flywheel system in vehicle

Flywheel are emerging technology with specific characteristics that make them viable energy storage system in comparison to batteries. One of the major advantages of flywheel is the ability to handle power levels. This is a desirable quality in e.g a vehicle, where a large peak power is necessary during acceleration and, if electrical break are used,

a large amount of power is generated for a short while when breaking, which implied a more efficient use of energy, resulting in lower fuel consumption (Bolund et al.,2007). Individual flywheel are capable of storing to 500MJ and peak ranges from kilowatts to gigawatts, with the higher powers aimed at pulsed power applications (Bolund et al., 2007). The fast responstime in flywheels are capable makes them suitable to balance the grid frequency. As the energy contribution from more irregular renewable energy sources increases, this can be an important quality which will grow in importance. From environmental point of view, creation, maintainance and disposing of batteries have dramatic effects on natural environment. Flywheel is a large step toward health environment.

Related to KERS that applied on the F1 racing, the flywheel are able to increase the cycle durability and efficiency which is about 90% in both directions during KERS reference duty cycle (Cibulka et al.2009).

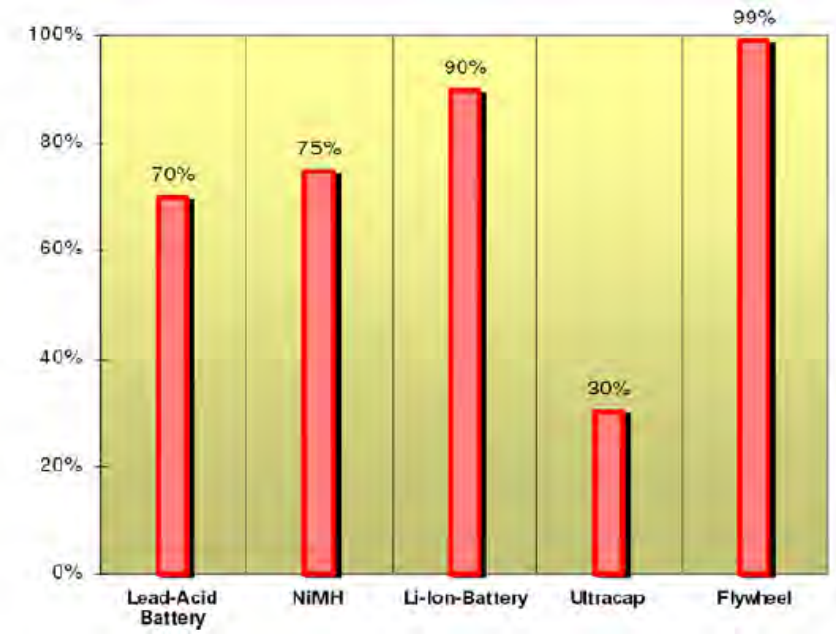

Figure 2.3:Comparative chart in term of voltage stability(full cycle)
(Source: Cibulkaet al.2009)