UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Engineering Technology

INCORPORATING FLYWHEEL HYBRID MODULE IN MOTORCYCLE: PROTOTYPING AND TESTING

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Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours

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

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DEDICATION

To my beloved parents, Abah and Emak;
Ahmad Sibi Bin Sarimin,
Wagiam Binti Samidi,
And also not forgetted to my beloved sibling that always support me;
Mohd Yusri Bin Ahmad Sibi, Mohd Yuzaili Bin Ahmad Sibi,
for the great supports that all of you gave to me,
I love you all.

ABSTRACT

The main function of the flywheel is to store the energy that was transferred to it and release back energy when the system need that energy. This study was conducted to investigates the performance of the fully mechanical hybrid motorcycle by substitute the normal wheel with the wheel that have the flywheel inside. This study is divided into three stages that is fabrication of Flywheel Hybrid Module component, development of low cost Hydraulic Brake dynamometer and dynamometer test. The development of the test rig for low cost dynamometer machine is done in order to get the data performance of the hybrid system. The development of the test rig included initial idea of the test rig by interpreting it into sketching diagram. The detail design with dimension was draw by using CATIA software and the production of the test rig is begun by following the detail design and undergoes several processes. The dyno test of the system is conducted and the result was analysed. From the results, it show that the torque and power output produced by the hybrid system is more high compared to the original system. The maximum torque of orignal motorcycle wheel system is 11.87 Nm and maximum torque of Flywheel Hybrid Module system is 13.63 Nm at 4250 rpm of engine speed. Meanwhile, for the maximum power produced by the original motorcycle wheel system is 8.45 kW and Flywheel Hybrid Module produced 9.7 kW of maximum power at 8500 rpm of engine speed. This shows that the Flywheel Hybrid Module gave significant effect toward the torque and power output of the vehicle.

ABSTRAK

Fungsi utama roda tenaga adalah untuk menyimpan tenaga yang dipindahkan ke ia dan menghantar kembali tenaga tersebut apabila diperlukan oleh sistem. Kajian ini dijalankan untuk mengkaji prestasi motosikal hibrid dengan menggantikan roda asal kepada roda yang mempunyai roda tenaga di dalamnya. Kajian ini telah dibahgikan kepada tiga peringkat iaitu penghasilan komponen 'Flywheel Hybrid Module', penghasilan kos rendah dynamometer hidraulik brek dan ujian dynamometer. Penghasilan pelantar ujian untuk kos rendah mesin dynamometer dibuat untuk mendapatkan data prestasi sistem hibrid. Penghasilan pelantar ujian merangkumi idea awal yang ditafsir kepada lukisan gambar rajah. Rekabentuk terperinci bersama dimensi telah dilukis menggunakan perisian CATIA dan penghasilan pelantar ujian dimulakan dengan merujuk rekabentuk terperinci dan menjalani beberapa proses. Ujian 'dyno' untuk sistem tersebut telah dijalankan dan keputusan telah dianalisis. Dari keptusan tersebut, ia menunjukkan bahawa tork dan had kuasa yang dikeluarkan oleh sistem hibird adalah lagi tinggi jika dibandingkan dengan sistem asal. Tork maksima yang dihasilkan oleh roda motosikal asal adalah 11.87 Nm dan tork maksima bagi sistem *Flywheel Hybrid Module* pula ialah 13.63 Nm pada kelajuan enjin 4250 rpm. Sementara itu, untuk kuasa maksima yang dihasilkan oleh sistem roda motosikal asal ialah 8.45 kW dan sistem *Flywheel Hybrid Module* menghasilkan 9.7 kW kuasa maksima pada kelajuan enjin 8500 rpm. Ini menunjukkan bahawa 'Flywheel Hybrid Module' memberi kesan yang sangat ketara terhadap tork dan had kuasa kenderaan.

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, increasing in petrol price and also the emission causes by the gas combustion from the engine lead to the production of hybrid type of vehicle, mechanical and electrical vehicle. Hybrid vehicle causing in reduction of emission from the product of internal combustion engine. The Flywheel Hybrid Module (FHM) is one of the hybrid systems that assemble into the vehicle. The kinetic energy from the wheel is transfer to the flywheel through the transmission that have planetary gear set system. The energy that stored in the flywheel will slowly transfer back to the wheel when the motorcycle start to moving and make the torque and power of the motorcycle increase.

The components of the FHM are the flywheel, transmission and wheel. The flywheel is connect to the transmission and wheel. The planetary gear set is used as the transmission and it was replaced the transmission and clutch that used in the normal internal combustion engine. The ring of planetary gear set is attached to the motorcycle wheel. All of this FHM system is located at the front tire of the motorcycle, because the front wheel is less complexity compared to the rear wheel that connected to the engine. When the motorcycle is moving, the kinetic energy from the wheel is transfer to the flywheel and then it store the energy. The energy is transferred by using planetary gear set to the flywheel. In stopping condition of the motorcycle, the energy in the flywheel still in there since the energy cannot be destroy nor created but it can be transfer and this make the flywheel to continue rotating. This energy will transfer back to the wheel when motorcycle start to move or when it climb the incline road.

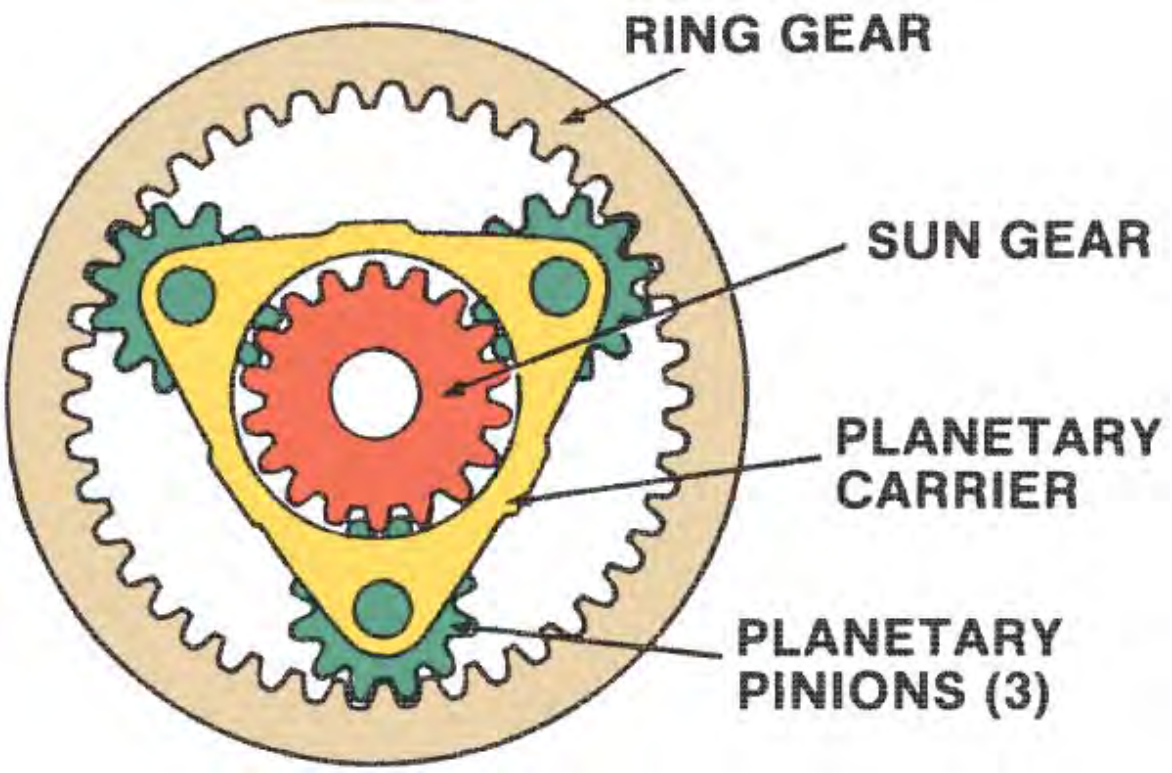

Figure 1-1: Planetary Gear set.

(source: https://wikis.engrade.com/planetarygearsetsoperati)

As the flywheel hybrid module are fully mechanical hybrid drivetrain, it is more simpler system compared to the electric hybrid module because of it does not used any kind of wire to make the system to be function. Besides, it also helped in reducing the fuel consumption and the emission gas that produced in internal combustion engine. Other than that, this hybrid flywheel not wasted the kinetic energy during braking by absorbing it in braking process. The regenerative braking system is used in order to make the energy is absorb by the hybrid flywheel. The increases of power and torque of the motorcycle is another advantages of the flywheel hybrid module especially when the motorcycle starting to move from stop position.

In order to develop this flywheel hybrid module, the stage of engineering design process has been taken. The first and foremost stage that has been taken is problem definition and conceptual design. This is critical stage in developing the product where the criteria of the design is clearly laying out in order to achieve succession of the design. Second stage is embodiment design. This step is used in deciding which of several

components design that has been developed in conceptual design is the best or this step use to decide which of five material selections should be chosen. Thirdly is simulation and analysis. After finished second step, the material or the component design that has been chosen will be analyze by the simulation software for the reliability and durability of the design. Fourth stage is optimization and detail design. At this stage, the selected design and material for the product is optimized and the detail parameter of the design is come out as reference for the next stage of product design. Last stage is prototyping and testing. This is the end of the product design phase where the real design is being come out by fabricate the design and some testing is did to the real product for analyze the performance of the product.

The design of the product will be manufacture to produce real product through the prototyping process. The parts of hybrid flywheel such as flywheel rim has been fabricated in the house by using manual lathe machine in FTK laboratory. The coupling was produced in the FTK laboratory in order to substitute it with planetary gear system. The production of the coupling is done by using manual lathe machine. After that, testing must be done to the flywheel rim and the motorcycle wheel system. The development of the test rig and low cost hydraulic brake dynamometer also has been done for the investigation purpose of motorcycle performance. The dynamometer test is did to the motorcycle wheel before and after hybrid flywheel install on it to analyze the the differences between power and torque produced by motorcycle wheel system.

1.2 Problem Statement

Some issues arises that lead to conduct the study that is in Faculty of Engineering Technology, there is no specific dynamometer machine to evaluate performance of the motorcycle. From that, the low cost dynamometer machine that is Hydraulic Brake dynamometer was proposed to be develop to evaluate and analyse the performance of the motorcycle. Besides, the hydraulic dynamometer needed the specific place for locating the dynamometer machine and operate the system. Each components of the dynamometer machine has it own specific function causes it need to be place at specific arrangement in the system.

1.3 Aim and Objectives

The aim of this study is to fabricate and assemble the Flywheel Hybrid Module to motorcycle and to analyze the performance of the motorcycle after the Flywheel Hybrid Module was installed on it. In order to achieve the aim, following are the three objectives that need to be accomplished:

1. To fabricate the components of Flywheel Hybrid Module using various machining process.
2. To develop test rig of low cost Hydraulic Brake dynamometer and Flywheel Hybrid Module for motorcycle.
3. To setup the low cost Hydraulic Brake dynamometer and investigate the performance of Flywheel Hybrid Module install in motorcycle using Hydraulic Brake dynamometer test.

1.4 Scope

The scope of this study is focus on prototyping and testing of the Flywheel Hybrid Module inserted in motorcycle by using test rig and low cost Hydraulic Brake dynamometer. In order to realize this, three phases of scope has been taken and it is discuss as below:

Scopes of phase #1:

1. Identify the factors for fabrication and assemble the components of Flywheel Hybrid Module by using various machining process.
2. Identify the machine and the machining process that will use to fabricate the component.
3. Identify the step that should be taken for the assembly of the part.

Scopes of phase #2:

1. The scopes of phase #2 focus on development of test rig for FHM system and low cost Hydraulic Brake dynamometer
2. Identify the components of Flywheel Hybrid Module that will be test.
3. Identify the step for developing the test rig.

4. Identify the materials and processes of fabricating the test rig for FHM and Hydraulic Brake dynamometer.

Scopes for phase #3:

1. In this final phase, it was focus on the setup procedure of the test rig system and investigation of the performance of Flywheel Hybrid Module that has been installed in motorcycle by using Hydraulic Brake dynamometer testing.
2. Identify the step for setup the Hydraulic Brake dynamometer.
3. Identify the step for the dynamometer test.
4. Identify the parameter of performance that will be investigate.

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. In this chapter, it consists of the general problem that this study tries to overcome. It explains about the concept of the previous study on Flywheel Hybrid Module, the way Flywheel Hybrid Module integrate with motorcycle and the advantages of the hybrid flywheel. The method of prototyping and testing of the Flywheel Hybrid Module area also discussed here.

Chapter 3 explains the methodology of this study. There are three phases in this study. Phase 1 is focus on the fabrication and assembly the Flywheel Hybrid Module parts by using various machining process. Meanwhile, in phase 2 is the phase where the development of the test rig of low cost Hydraulic Brake dynamometer and FHM components for motorcycle. The last phase in the methodology is phase 3 that focus on the setup procedure of low cost Hydraulic Brake dynamometer test rig and the investigation of performance of the motorcycle when the Flywheel Hybrid Module is install on it by using Hydraulic Brake dynamometer test.

Chapter 4 is analysis and discussion chapter of the study. The results from the fabrication of the Flywheel Hybrid Module components in phase 1 and phase 2, and the experiment in phase 3 are analyzed here. In experiment result, there are divided by two

sections. The first one is focused on developing of test rig for Flywheel Hybrid Module and low cost Hydraulic Brake dynamometer, while the second section is focused on the performance testing of Flywheel Hybrid Module install in motorcycle using dynamometer test.

Chapter 5 is conclusion chapter. It concluded the findings from this study. Generally, the flywheel can store the energy that transfer to it. This is proven from the previous study on the energy stored at the flywheel. The experiment also proven that the flywheel is store the energy that transfer to it from the rotating wheel. Finally, future idea is suggested to improve this Flywheel Hybrid Module system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this literature study, it is focuses about the concept of the FHM in the motorcycle by comparing with the electric motorcycle concept. Other than that, the integration of the FHM with the motorcycle and it advantages is discussed in this chapter. Lastly, the method in all engineering design phase and selected phase is explained in this chapter to give a background to the work covered.

2.2 Concept of Hybrid Flywheel

Hybrid vehicle is vehicle that used more than one types of power sources, such as internal combustion engine and electric motor. The power or energy can be transfer to the flywheel either through mechanical or electrical connection.

A purely mechanical flywheel may have its power transmission unit directly connected to the drive shaft of the vehicle. (Hedlund et al. 2015). The continuously-variable transmission (CVT) is used as a mechanical power transfer device in flywheel hybrid system for transferring the energy and this known as Kinetic Energy Recovery System (KERs). KERS is an energy saving device fitted to the engines to convert some of the waste energy produced during braking into more useful form of energy. The system stores the energy produced under braking in a reservoir and then releases the stored energy under acceleration. (Naveen et al. 2014).

Meanwhile, in electrical hybrid vehicle, the power is transferred to the flywheel through a contact-less manner between motor and stator, and the electric act as power transfer in electric hybrid system. A few common types of electric power transfer that is Permanent Magnet Synchronous Machine, Induction Machine and Reluctance Machine, switched or synchronous. The Permanent Magnet Synchronous Machine energized the rotor with highly coercive magnetic material. From that, the external power for the excitation of the rotor does not necessary in these type of electric power transfer. This leads to the highest charge/discharge efficiencies, but the drawback is that remanent magnetization prolonged, even though the windings are de-energized that is in standby mode, the iron that has been produced losses in the laminated steel. This problem can be solved for the high-speed machine by using a coreless stator. (Hedlund et al. 2015).

In Induction Machines, the inductance motor/generators commonly have less power density and efficiency compared to the permanent magnet motors, but the lack of permanent magnetization significantly reduces the issues with electromagnetically-induced idling losses. The rotor is mechanically quite simple and robust, although a significant portion of the losses are generated there. The rotor losses must be kept low to prevent overheating for the flywheel rotors that suspended on magnetic bearing in a vacuum. The very limited black-body radiation is used as cooling mechanism in the case of overheating. Stationary flywheel with inductance motors/generators have been reported, but higher power density topologies are favored for mobile applications. (Hedlund et al. 2015).

The efficiency of operation of reluctance machine is high at great range of speed. The losses in standby mood is quite low and rare material is not required for it construction. The performance of Permanent magnet motor has been achieved with reluctance motors by using high performance materials. (Hedlund et al. 2015).

Hybrid consists of two type of propulsion system that is Series Hybrid and Parallel Hybrid. An electric vehicle with an onboard source of power for charging the batteries is basically a series hybrid vehicle. Parallel hybrids can give the lowest cost and also give the option of using the existing manufacturing capability for engines, batteries, and motors. However, a parallel hybrid vehicle requires a complex control system. The configurations of parallel hybrid vehicles components is not fixed to one only, it is depending on the roles of the electric motor/generator and the engine. Furthermore, the engine and the electric

motor can be used separately or together to propel a vehicle in a parallel hybrid type of vehicle. Some example of the vehicle that have parallel hybrid system is the Toyota Prius and the Honda Insight, which are commercially available. (Emadi & Rajashekara 2008).

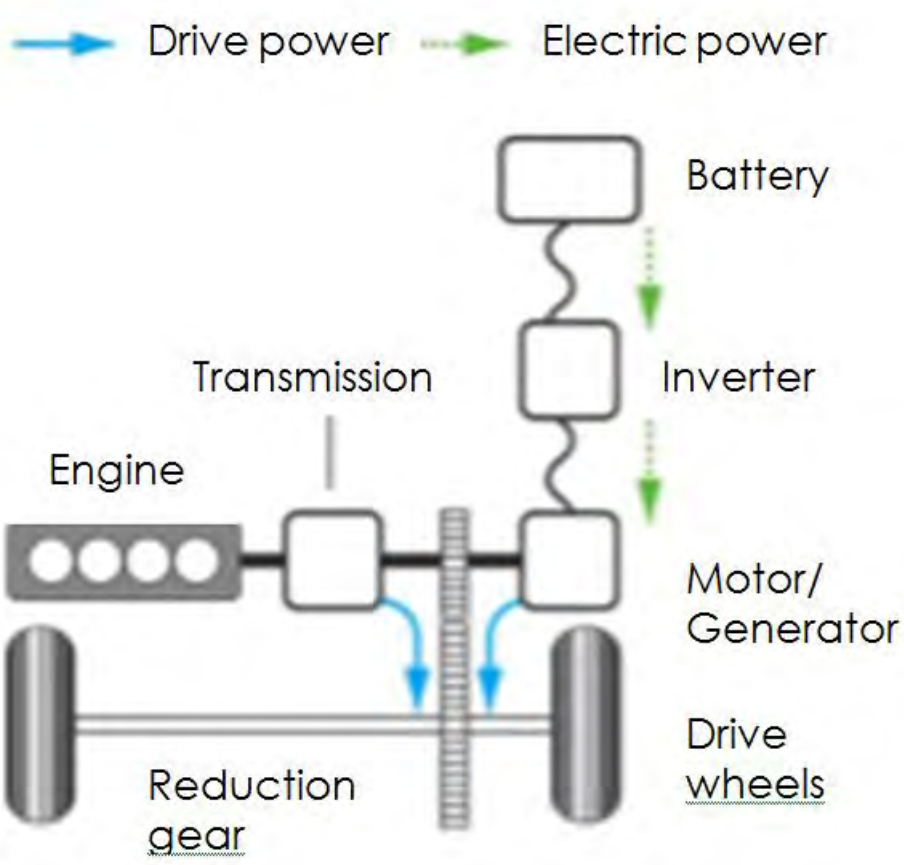

Figure 2-1: Parallel hybrid vehicle propulsion system (Kamper 2008)

2.3 Hybrid Electric Motorcycle

The small in size and cheaper maintenance of the motorcycle make it as the most famous transportation in Asia. For example in Malaysia, until September 2012, the total numbers of vehicles on road reaches 22.3 million with 47.3% from it are motorcycles. The carbon based emission release by motorcycle in Malaysia reached around 900 tons per kilometer. By taking the average daily travel distance of Malaysia bikers is around 25km; the total amount of carbon release by Malaysian bikers is 22,500 tons daily. (Manaf et al.