UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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INCORPORATING FLYWHEEL HYBRID MODULE IN AUTOMOBILE: AN EMBODIMENT DESIGN APPROACH

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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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DECLARATION

I declare that this thesis entitled "Incorporating Flywheel Hybrid Module in Automobile: An Embodiment Design 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 :…………………….................

ABSTRACT

This report introduces the continuity of the previous group phase which is the conceptual design phase in developing and designing a flywheel hybrid module (FHM) in automobile which is more focusing on embodiment design. The main problem for this study is commonly designers most likely to produce the final product from concept idea to computer-aided design (CAD) drawing without consider configuration and parametric design. This report explains about the exact steps in designing flywheel hybrid module. The first step is to get the configuration design and parametric design by using product architecture method. Second, in embodiment design, the material that need to apply on the module also need to determine by using a computer software called CES. Lastly, design need to be improve by using Failure Mode Effects and Analysis (FMEA) method. As the result, the finalize configuration design is draw in 3-dimensional (3-D) drawing by using CATIA V5R20. The design of FHM is suitable for all compact car with rim size R14 which is 356 mm in diameter. From the CES results, the best material that suitable for flywheel hybrid module is aluminium alloy. From the FMEA, some improvement on the current design also is done. For the conclusion, the final design of flywheel hybrid module product is produced with the advantages to reduce fuel consumption and lower the cost of manufacturing since the aluminum alloy is selected. Further study by developing the final design with multiple design by using different software is recommended since it can produces many choices in order to complete the prototype.

ABSTRAK

Report ini memperkenalkan kesinambungan daripada fasa kumpulan sebelumnya iaitu fasa konsep reka bentuk dalam menghasilkan dan mereka bentuk sebuah modul roda tenaga hibrid di dalam kereta yang mana lebih fokus kepada penjelmaan reka bentuk. Masalah utama untuk kajian ini ialah kebanyakan pereka bentuk menghasilkan produk akhir daripada idea konsep kepada lukisan reka bentuk bantuan computer (CAD) tanpa mempertimbangkan konfigurasi dan reka bentuk berparameter. Report ini menerangkan tentang langkah yang betul dalam mereka bentuk modul roda tenaga hibrid. Langkah pertama ialah untuk mendapatkan konfigurasi reka bentuk dan parameternya dengan menggunakan cara seni bina produk. Kedua, dalam penjelmaan reka bentuk, bahan yang perlu diaplikasikan kepada modul juga perlu ditentukan dengan menggunakan perisian komputer dikenali CES. Akhir sekali, reka bentuk juga perlu dibaiki dengan menggunakan kaedah kesan mod kegagalan dan analisis (FMEA). Sebagai keputusan, konfigurasi reka bentuk dilukis dalam bentuk lukisan 3-dimensi (3D) menggunakan CATIA V5R20. Reka bentuk modul roda tenaga hibrid ini sesuai untuk semua kereta kompak dengan rim bersaiz R14 di mana diameternya ialah 356 mm. Hasil keputusan CES, bahan yang paling sesuai untuk module roda tenaga hibrid ialah aloi aluminium. Daripada FMEA, sedikit penambah baikan untuk reka bentuk semasa juga dibuat. Sebagai penutup, reka bentuk akhir modul roda tenaga hibrid dihasilkan dengan kelebihannya untuk mengurangkan penggunaan minyak and mengurangkan harga pembuatan kerana aloi aluminium dipilih. Kajian selanjutnya dengan menghasilakn reka bentuk akhir dengan pelbagai jenis reka bentuk dengan menggunakan perisian computer yang berbeza dicadangkan agar ia dapat menghasilkan pilihan yang banyak untuk menyelesaikan prototaip.

DEDICATION

To my beloved family parents, Mohd Fadzil Bin Jaffar and Saripah Binti Wan Hussain and to all my family members.

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CHAPTER 1

INTRODUCTION

1.1 Background

A flywheel is a mechanical device that is used to store kinetic energy. It also can recycle the kinetic energy. The flywheel is related with the hybrid technologies which are commonly used in automotive industries. The main purpose of the hybrid system which developed by the engineers are to reduce the fuel consumption and give a better performance in a car. In order to increase the performance for the hybrid car, some new technologies had been improved by creating a new system which is called as kinetic energy recovery system or known as KERS. It was first applied in F1 system. In an automotive technology, KERS is a system for recovering a moving vehicle's kinetic energy under braking. KERS is a recent automotive development that enables temporary storage of braking energy by means of a flywheel, batteries or supercapacitor. The stored energy is used for extra acceleration when desired. In this project, the main purpose is to design and develop the flywheel based hybrid drive in vehicle. This system will be called as the flywheel hybrid module (FHM).

The main components for FHM are the flywheel, transmission set and rim. The working principle of FHM is same as the working principle of KERS. In transmission set, it consists of planetary gear, brake pad, brake piston, storage one-way clutch and normally-on clutch. Basically, the KERS working principle involves storing the energy involved with deceleration and using it for acceleration. That is, when a car breaks, it dissipates a lot of kinetic energy as heat. The KERS stores this energy and converts this into power that can be used to boost acceleration. As the car slows for a corner, an actuator unit captures the waste kinetic energy from the rear brakes. This collected kinetic energy is then passed to a Central Processing Unit (CPE) and onto the storage unit. The storage units are positioned centrally to minimize the impact on the balance of the car.As the brake being release, the rotating flywheel will support the tire and this concept will generate more force on tire that helps it to rotating automatically. This system will increase the fuel consumption use for the car and more efficient power which will contribute a better performance in hybrid system. Other advantages of this system are it will produce a high capability for vehicle and it has high efficiency storage and recovery.

Figure 1.1 shows the basic construction of KERS system. The construction of mechanical KERS consists of motor (MGU), continuously variable transmission (CVT), engine and drive wheel. The mechanical KERS use high speed flywheel, kept inside a vacuum sealed container, as the energy storage device. The flywheel in mechanical kinetic energy recovery system is equivalent to the MGU of the electrical KERS. A CVT is connected between the drive train and the flywheel. The CVT is used to control the transfer of energy between KERS flywheel and the drive train. It controlled by an electro-hydraulic control system. The function of the control system is controlling the connection/disconnection of the CVT with drive train and controlling the speed at which the KERS flywheel will rotate.

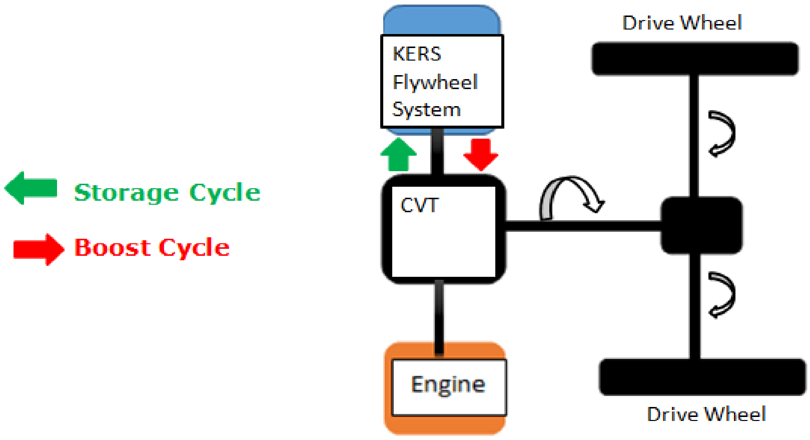

Figure 1.1: The basic construction of KERS system
(Sources: http://blog.mechguru.com/machine-design/kinetic-energy-recovery-system-kers-works)

In automotive technologies, some of the automotive manufacturers start to put this technology in a high performance car. Therefore, this technology is still on going further research and refinement. In performance aspect, the drawback of flywheel hybrid is in the recharging and storing capability. It only can be charge using regenerative braking which exist during deceleration. The purpose of this paper is to create a new flywheel hybrid module (FHM) which will simulate in automobile. In order to develop the flywheel hybrid module, there are many stages or parts in order to complete the designing process. The first stage is the conceptual design stage. In this stage, the general concept of FHM will be discussed. Next phase is the embodiment design phase which is the most important design phase to complete the module. Simulation and analysis phase are the next stage which needs to be done. This phase will do some simulation analysis about the design which taken from embodiment phase. The phase then is following with the optimization and detail design phase. In this phase, the module will be optimizing about their dimension and some details about their material. The last phase for this project is the prototyping and testing phase. The final product of flywheel hybrid module will created and it will be tested to see whether the project successful or not. For this paper, the research will focus on the embodiment design phase approaches in the automobile.

Embodiment design is the part of the design process in which, starting from the principle solution or concept of a technical product, the design is developed in accordance with technical and economic criteria and in the light of further information. Embodiment process is the bridge between the conceptual stage of the design process and the detail design stage. A more detailed analysis of the selected concepts is undertaken in the embodiment stage of the design process.

1.2 Problem Statement

The main problem is commonly designers most likely to produce the final product from concept idea to computer-aided design (CAD) drawing without consideration of configuration and parametric design. They just draw the product in 3D form without sketching in paper first. They missed one of the important phase in engineering design which is the embodiment design phase. This phase will be applied to produce a better product. It is covered in design stage as explained in introduction. Table 1.1 shows the list of research paper that was studied. Only two out of eight research papers used the embodiment design approaches while the others does not applied this method. In order to overcome this problem, an embodiment design approaches will be discussed in this research. It also will cover the exact steps that need to be followed in the design process that will be applied to design the flywheel hybrid module (FHM). In this phase also will explain how to select the preliminary design, configuration, parameter and the dimension of the component in FHM. Besides, the steps how to select the material for the components also will be discussed. Second major problem is the designer also commonly skip the Failure Modes and Effects Analysis (FMEA) method. This method also including in embodiment phase. This method are really important in order to produce a better design. Design for reliability (DFR) must be considered and analyzed based on their risk priority numbers (RPNs). In order to overcome this problem, the FMEA method will be applied in this research to improve the FHM's DFR.

YEAR	AUTHOR	TITLE	EMBODIMENT DESIGN APPROCHES
2006	M. A. Lambert & B. J. Jones	Automotive adsorption air conditioner powered by exhaust heat. Part 1: conceptual and embodiment design.	Yes
2008	Deng et al	Basic design and characteristics study of a double-axial superconducting magnetic bearing system	No
2010	Boon et al.	Design of an in-wheel kinetic energy recovery system for a kart.	No
2012	Manaf et al.	Design project: Ergo stroller	Yes

2012	Buchroitner A et al	Optimal system design and ideal application of energy storage systems for vehicles.	No
2012	Junfeng Wu	Design of a miniature axial flux flywheel motor with PCB winding for Nanosatellites.	No
2014	Song et al.	Design and analysis of a dual mass flywheel with continuously variable stiffness based on compensation principle.	No
2014	Kim et al	Design and fabrication of hybrid composite hubs for a multi-rim flywheel energy storage system.	No

Table 1.1: List of research papers.

1.3 Aim and Objectives

The aim of this study is to establish concept development to refine concept sketches as a distinct stage in the design process by identifying the steps and rules employed. In order to achieve the aim, following are the three objectives that need to be accomplished:

1. To determine the configuration of flywheel hybrid module (FHM) with its parametric design.
2. To select the preliminary materials for the components using Ashby method.
3. To improve the design using failure modes and effects analysis (FMEA) method.

1.4 Scope

The working scope of this project is to study and develop flywheel hybrid module in automobile by approaching the embodiment design. The scope were divided into four phase to ensure the project is conducted within its intended boundary and heading in the right direction to achieve its objective. Scopes of these projects were to study the steps for an embodiment design stage in order to develop the flywheel hybrid module.The work scope of this study is divided into three phases as discuss below.

Scopes of phase #1:

1. Identify and configure the preliminary design and components of flywheel hybrid module by using product architecture method.
2. Identify the arrangement of physical elements in the module.
3. Identify the parametric design of the flywheel hybrid module.
4. Identify the steps take place in parametric design

Scopes of phase #2:

1. Suggest list of materials that maybe used in develop the flywheel hybrid module.
2. Identify the preliminary materials for each components used.

Scopes for phase #3:

1. Identify the design for reliability (DFR) of the module.
2. List the details about the module after using FMEA method.

1.5 Structure of the Project

This project is the continuity of the previous group phase which is the conceptual design phase which is lead by Mohd Nazreen Izuan Bin Mustapha. Producing a flywheel hybrid module (FHM) in automobile is the main outcome of our group project. As a leader for embodiment design's phase, I am played an important role in conducting the members to achieve the group's outcomes. My personal objective in this phase is to design a flywheel hybrid module (FHM) in automobile.

For this report, it was divided into a few chapters that need to be done. 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 basic principle of flywheel and its uses along with the advantages. It also consists if the general problem that this study tries to overcome. It explains about the main important tasks which need to be considered in embodiment design stage. The methods of completing the embodiment design phase are also discussed here.

Chapter 3 explains the configuration design and parametric design. This chapter is the combination of methodology, results and discussions for this section. The configuration design is an important roles in designing a product. For this chapter, it consists of on how the components in FHM located in automobile. It also consists of the parameter and dimension of the components that involved in FHM product.

Chapter 4 is the material selection chapter. In this chapter, it will explain the method on how to select a preliminary material for a product. It focused on the ways or method in selecting material. Some analysis also be done in this chapter. This chapter also the combination of methodology, results and discussions for this section.

Chapter 5 explains about the design for reliability of FHM. Some of the designs need to be repair in order to fulfill the customer requirement based on product. A simple analysis called failure modes and effects analysis (FMEA) was done in this chapter in order to improve the design of the FHM. Same as previous chapter, this chapter also the combination of methodology, results and discussions for this section.

Chapter 6 is conclusion chapter. It concludes the findings from this study. Generally, there are energy store in hybrid flywheel. This is proven through the past review on research and past paper. Finally future preventive method is suggested to make some improvement for the hybrid flywheel module focus on more unique design in the future.

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. The sources that been used was from previous projects done by scientist and other such as books, journal and article where we obtained from SciVerse Science Direct. This chapter is to introduce about the projects about the steps in completing the embodiment design phase according to the past studies as the reference.

The main concept of FHM is as same as the concept of KERS. The components needed are flywheel, transmissions and rim.

2.2 Flywheel hybrid technology to store energy in vehicle

All vehicles act as energy storage systems by virtue of stored kinetic energy which increases with speed. It is therefore not surprising that flywheels have been considered as suitable energy storage devices from an earlier time. Kinetic energy is stored in a similar way to the vehicle and if energy is toggled between the two, the power needed for acceleration can be eliminated in theory, creating the effect of zero inertia vehicles. Similarly, energy normally lost in braking can be captured and regenerated back into the vehicle. Given that the form of energy in the flywheel is mechanical kinetic, the same as that of the moving vehicle, the energy can be transmitted from one to the other and not transformed, maximising potential for high efficiency (Pullen & Dhand, 2014).

From the previous research, it had been concluded that the flywheel is used to store the kinetic energy and reuse it again when it needed. Normally, it is working inside a car after stopping at a traffic light. When the driver press the accelerate pedal, the flywheel will doing its job to rotate the wheel of the car without using any petrol. From this acceleration, it can increase the fuel consumption of the vehicle.

2.2.1 Possible Transmissions for flywheel

Basically, there is much type of the transmissions for flywheel. In order to make the flywheel give its function to the system, the transmissions for flywheel need to be consider. There are three types of transmissions for flywheel which are hydrostatic transmission, traction continuously variable transmission (CVT) and mechanical transmission.

The hydrostatic transmission transmits energy using hydraulic fluid. The usual transmission has two hydraulic devices; one working as a variable displacement pump and the other working as a motor connected by hydraulic lines. The pump converts mechanical energy into pressure and the motor reconverts the pressure energy to mechanical energy. By varying the displacement of the pump a continuous ratio from zero to the maximum value can be obtained thereby forming an infinitely variable transmission (IVT). As a result the hydrostatic transmission does not require any starting clutch. The torque direction is reversed by the pump acting as the motor and the motor acting as the pump (Pullen & Dhand, 2014). Figure 2.1 shows a typical hydrostatic transmission.

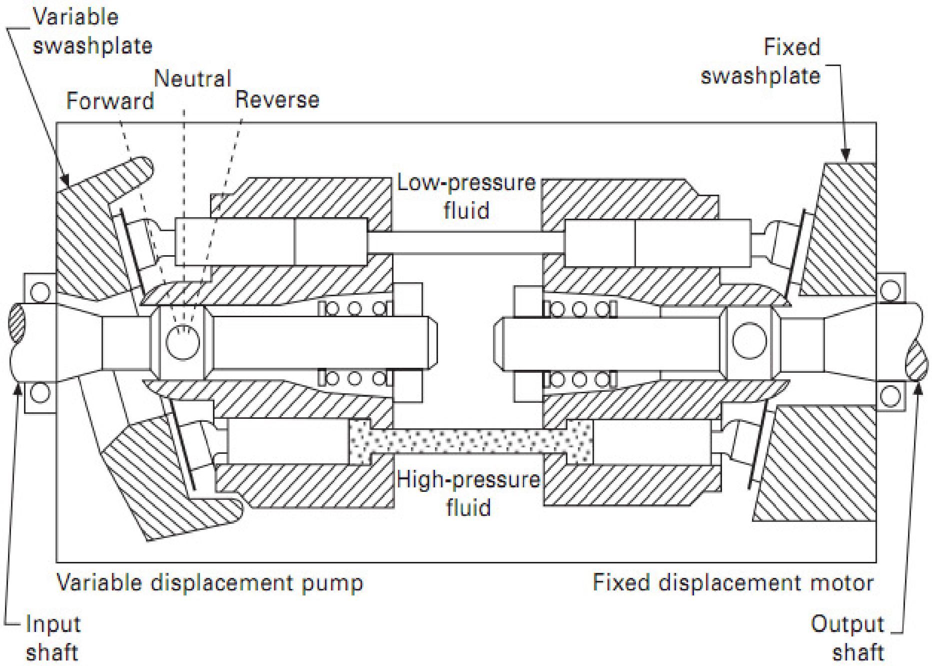

Figure 2.1: The hydrostatic transmission (Beachley and Frank, 1979).

Traction CVT transfers torque between two objects through adhesive friction. The transmission ratio is varied by changing the radius of the point of action of forces. The traction drives usually have a limited ratio range. There are predominantly two types of traction drives: the belt drives and the rolling traction drives (Pullen & Dhand, 2014). The types of traction drives are the belt drives and the rolling traction drives.

The transmission takes place over belts which are placed between two pulleys. By varying the diameter of the pulleys the ratio change is achieved continuously. These belts are usually made of rubber or steel. Rubber v-belt CVTs have been used for many years. Van Doorne of Holland developed a v-belt made up of steel blocks linked by steel bands which was a significant improvement over the rubber belt drives (Walton, 1959). It is a compression belt, where the driver pushes the driven pulley. Figure 2.2 shows the schematics of this type of CVT. A similar type of belt was developed by Battelle Columbus Laboratories (Swain, 1980). Another popular CVT developed by Kumm Industries is the flat rubber belt design shown in Figure 2.3. In this case the belt is positioned radially by drive elements