Regenerative Braking System (RBS): Energy Measurement

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This report submitted in partial fulfillment of the requirements for the award of a Bachelor Degree in Mechanical Engineering (Automotive)

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SUPERVISORS DECLARATION

I hereby declare that I have read this report and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive)

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Date :

DECLARATION

I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged.

Signature :
Author : LOI WEI CHEONG
Date :

DEDICATION

To my parents, who have never failed to give me financial and moral support, for fulfilling my need during the time of developing myself and for teaching me that even the largest task can be accomplished if it is done one step at a time.

To my brother, sisters and friends whose indirectly contribute to this thesis.

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Besides, I would like to thank University Technical Malaysia Melaka (UTeM) for providing me a good environment and great facilities to conduct my PSM 1. Addition, I would like to thank to the Faculty of Mechanical Engineering (FKM) for their guidance, starting from PSM 1 subject registration until the final presentation of my PSM. A special thank to my presentation panels, Dr. Noreffendy and En. Faizul for their attending and judging, and provide me some important information regarding to this project.

Finally, an honourable mention goes to our families and friends for their understandings and supports on me in completing this project.

ABSTRACT

Regenerative Braking System (RBS) is an efficient system to reduce vehicle emission and fuel consumption. RBS is a system which converts mechanical energy to electrical energy during braking action. It will become an important system for future vehicle such as hybrid and electric car. This study will start with literature review about the Regenerative Braking System (RBS). The basic design and components used in the regenerative braking for current vehicles will also be reviewed. Through the study, a RBS model can be design or develop for future study. The working mechanism was studied to understand how the RBS could convert mechanical energy to electrical energy. The important components used in RBS will be determined such as electric motor, motor controller and battery. To produce a RBS model, an e-bike conversion kit has been bought from Hong Kong and an alternator was selected to be installed in the bicycle. The results and calculations show that both devices can function properly, that means both devices can form recovery energy to charge battery during braking. During the recovery energy working, brake effects are formed to decelerate the bike. The recovery energy during braking for both devices are taken and compared to found out which one can produce high recovery energy during braking. In addition this RBS model can be used for future study.

ABSTRAK

Regenerative Braking System (RBS) adalah satu sistem yang berkesan untuk mengurangkan pencemaran kenderaan dan penggunaan bahan api. RBS sistem menukar tenaga mekanikal kepada tenaga elektrik semasa tindakan brek. Ia akan menjadi satu sistem yang penting bagi kenderaan masa depan seperti kereta hibrid dan elektrik. Kajian ini akan bermula dengan kajian literatur mengenai Regenerative Braking System (RBS). Reka bentuk asas dan komponen-komponen yang digunakan dalam regenerative brek bagi kenderaan semasa juga akan dikaji semula. Melalui kajian ini, model RBS boleh direka bentuk atau dibangunkan untuk kajian masa depan. Mekanisme kerja telah dikaji untuk memahami bagaimana RBS boleh menukar tenaga mekanikal kepada tenaga elektrik. Komponen penting yang digunakan dalam RBS ditentukan seperti motor elektrik, motor controller dan bateri. Untuk menghasilkan model RBS, kit penukaran e-basikal telah dibeli dari Hong Kong dan satu alternator dipilih untuk memasang ke atas basikal. Keputusan dan pengiraan menunjukkan bahawa kedua-dua peranti boleh berfungsi dengan baik, ini bermakna kedua-dua peranti boleh membentuk pemulihan tenaga untuk mengecas bateri semasa brek. Semasa kerja pemulihan tenaga, kesan brek dihasilkan dan menyahpecutkan basikal. Tenaga pemulihan semasa brek untuk kedua-dua peranti diambil dan membandingkan untuk mendapat tahu yang mana satu boleh menghasilkan tenaga pemulihan yang tinggi semasa brek. Model RBS ini boleh digunakan untuk kajian pada masa akan datang.

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LIST OF SYMBOLS

F_{reg}	=	Regenerative braking Force
T_{EM_reg}	=	EM available regenerative braking torque
T_{EM_max}	=	EM maximum generation
T_{UC_max}	=	Capacitor charging capacities
η_t	=	Transmission efficiency
r	=	Wheel radius
ω_b	=	Weight factor
ω_1	=	Weight factor of ultracapacitor
ω_2	=	Weight factor of vehicle velocity
ω_3	=	Weight factor of Electric motor state
P_{Ge_max}	=	EM maximum generation power
P_{Ch_max}	=	Ultracapacitor maximum charging power
n_2	=	Motor rotational speed
i	=	Gear ratio
i_0	=	Final reduction gear ratio
P	=	Power
I	=	Current

LIST OF ABBREVIATION

AC	=	Alternating current
BCU	=	Brake control unit
CAD	=	Computer aided design
DC	=	Direct current
DOF	=	Degree of freedom
EECB	=	Emulated Engine Compression Braking
EHB	=	Electro hydraulic braking
EM	=	Electric motor
EPA	=	Environmental Protection Agencies
EV	=	Electric vehicle
FLC	=	Fuzzy logic control
HEV	=	Hybrid electric vehicle
ICE	=	Internal combustion engine
IM	=	Inductive motor
KERS	=	Kinetic Energy Recovery System
PHEV	=	Parallel hybrid electric vehicle
PM	=	Permanent magnet motor
RBS	=	Regenerative Braking System
RESS	=	Rechargeable Energy Storage System
RTD	=	Regenerative Torque Distribution
RTO	=	Regenerative Torque Optimization
SHEV	=	Series hybrid electric vehicle
SOC	=	State of charge
SRM	=	Switched reluctant motor

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CHAPTER I

INTRODUCTION

1.1 Project Introduction

The subject of Final Year Project (PSM), BMCU 4973 and BMCU 4983 are a research and related scientific fields of study at the Faculty of Mechanical Engineering (FKM) that must be provided by final year students to fulfill the requirement of award of degree. Under this subject, every student will be supervised by a lecturer and doing research regarded to the topic he or she has chosen. At the end of the semester/year, students have to carry out a presentation regarded to this project, and showing out all the result and findings of his research.

The purposes of this PSM are to train and improve a student's ability to use knowledge and experience in related field of engineering. Students must able to carry out research through scientific methods such as scientific research, collect and analyze data and produce a design or product. Students must able to handle work with minimal supervision and independently in this final year project. Students must able to present their project work through seminars and written reports properly.

1.2 Background

Regenerative Braking System (RBS) in vehicle is my PSM title. My supervisor is Dr. Musthafah bin Mohd Tahir. As we know, RBS is not new technologies that exist at present. RBS was first used in the locomotive industry. Due to the lack of sophisticated technological knowledge on suitable battery power storage, therefore RBS attracted less interest and further study of this system is also suspended. Nowadays, pollution problems and the limited fuel resources for vehicles have made the RBS back to become an important system for future vehicles. RBS can reduce air pollution and fuel consumption. After understanding the importance of this RBS, which is the purpose of my PSM project will produce an RBS model for future studies. In general, RBS is a system that can recuperate mechanical energy to electrical energy during braking action. This system allows the vehicle kinetic energy to be converted into electrical energy and be storage in the power storage system. This saved energy will be used again to move the vehicle.

My final objective is to compare between DC motor and alternator which can recuperate highest energy during braking action. So, a DC motor and alternator will be assembled in the front tire of bicycle. The DC motor type is already been done by the previous student. Hence, this project will start by collecting information from literature review and then the installation of the alternator in the front tire of the bicycle. Figure 1.1 and 1.2 show the previous work and current work.

Figure 1.1: 24V generator (previous work)

Figure 1.2: 12V alternator (current work)

1.3 Objective

The objectives of this PSM are:

1. To study the basic design of some regenerative braking system used in the vehicles.
2. To measure the regenerative braking energy for 24V DC motor.
3. To measure the regenerative braking energy for 12V alternator.
4. To compare the results of regenerative braking energy for 24V DC motor and 12V alternator.
5. To evaluate an efficient system for future study.

1.4 Scope

The scopes of this PSM are covering:

1. Literature review and existing design information gathering.
2. Model making using 12V vehicle alternator.
3. Build a regenerative braking circuit for 12V alternator.
4. Draw the regenerative braking components using CATIA.
5. Do off road test to the 24V generator and 12V alternator.

1.5 Problem Statement

At the 21th century, the automotive industry has post a great challenge in order to reduce the vehicle fuel consumption and emission, these is due to the shortage of fuel resources and worsen air pollution problem. According to figures released by the US Environmental Protection Agency (EPA), conventional ICE vehicles currently contribute 40-50% of ozone, 80-90% of carbon monoxide, and 50-60% of air toxins found in urban areas.

A study shows that, one third (21 to 24%) energy is consumed during brake. The invention of Regenerative Braking System is viewed as a solution to these

problems, as it recovered wasted energy and restored to become another form of useful energy. Although we realize the beneficial and positive effect bring by Regenerative Braking System, but it still has its issue or problem to be solved; one of the major problems is regarded as the suitable battery to be used in this type of vehicle. Today, most Hybrid car batteries are one of these two types:

1. Nickel metal hydride
2. Lithium ion

Both are regarded as more environmentally friendly than lead-based batteries, but both battery are very expensive and still can cause environmental damage due to the toxic content.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction of Regenerative Braking System (RBS)

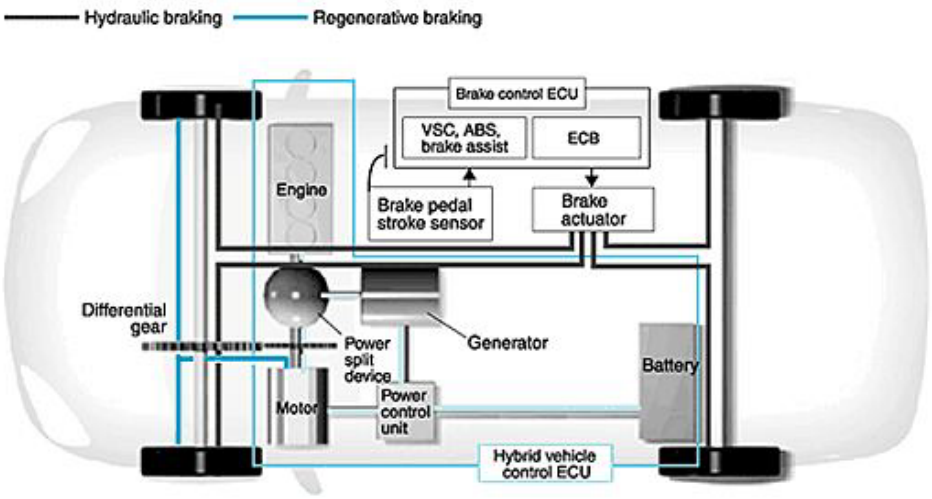

Figure 2.1: Regenerative Braking System (RBS)

(Source: www.brighthub.com)

The Figure 2.1 above show the basic design for RBS. RBS is an important and useful system to reduce the environment pollution and shortage of the fuel resources problem. According to the conservation of energy, energy cannot be created or destroyed but it can change the type of energy. RBS is a system which can convert mechanical energy to electrical energy. This system is used in a vehicle to recuperate the waste energy during braking and converting it to a useful energy for conventional hydraulic brake vehicle. The waste energy was produced when

conventional brake is applied. The recuperate energy is then been saved in a power storage for future usage.

In RBS, the DC motor is used as a generator to recover kinetic energy from the wheel of the vehicle into electrical energy. The conventional hydraulic brake will continue to be used as an emergency brake. Because the RBS is only able to stop the vehicle in a relatively long distance and time. This situation would cause accident to occur. The RBS efficiently reduces the waste energy and regenerate energy during braking as shown in Figure 2.2.

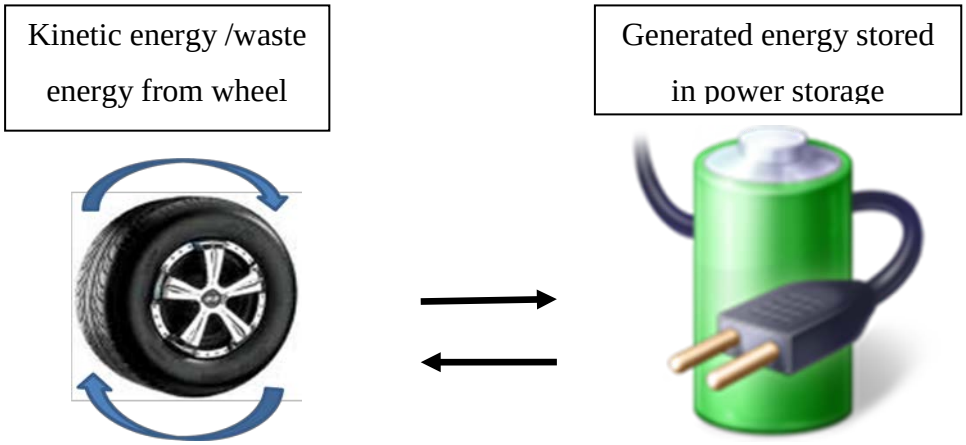

Figure 2.2: Energy conversion in RBS

Nowadays, many modern hybrid and electric vehicles use this Regenerative Braking System (RBS). Examples include the hybrids such as Toyota Prius (Figure 2.3) Honda Insight (Figure 2.4), and the Vectrix electric maxi-scooter.

Figure 2.3: Toyota Prius

(Source: www.fastmotoring.com)

Figure 2.4: Honda Insight

(Source: www.en.automobile.de)

2.2 RBS as Future Solution

The need to increase environmental protection and energy conservation has brought a big challenge for the automotive industry to reduce vehicle emissions and. fuel consumption. For this purpose, extensive solutions for alternative power train has been proposed, including hybrid technology is regarded as the best. Government regulations around the world have become more stringent, requiring lower production for the car (Especially U.S. EPA Tier 2 Bin 5, followed by a Euro 5).

In 2003, a research has been done by V. Dawood and A. Emadi in order to compare between fuel cell, parallel & series hybrid electric and conventional transit bus. ADVISOR software was used to simulate the various heavy-duty buses. Results show a magnificent (as indicated in Table 2.1) improvement in the fuel economy especially in the parallel configuration. [9]

Table 2.1: Comparison between conventional, series hybrid, parallel hybrid and fuel cell vehicle.

(Source: V. Dawood. 2003)

	Conventional	**Series**	**Fuel cell**	**Parallel**
Fuel Converter(kW)	350	100	200	150
Energy storage(kW)	-	300	300	250

Motor(kW)	-	300	250	200
Total propulsion power(kW)	350	300	250	350
Fuel Economy(mpg)/ (km/kg)	5.1 / 0.0082	7.4 / 0.0119	7.5 / 0.0121	9.3 / 0.0149
0-60 mph (s) or 0-96.6 km/h	25.7	18.2	19.1	18.0
Grade Ability (%)	6.0	2.5	2.3	2.5
Max. speed (km/h)	138.4	138.9	138.7	138.1

2.3 Energy Efficiency for RBS

Demirdven, N. and Deutch, J. (2003) compare the energy efficiency of conventional internal combustion engines, fuel cell and hybrid vehicles. In their analysis (as indicated in Figure 2.5 and Table 2.2) indicates that fuel cell vehicles using hydrogen from fossil fuels offer no significant energy efficiency advantage over hybrid vehicles operating in an urban drive cycle. They conclude that priority should be placed on hybrid vehicles by industry and government.[32]

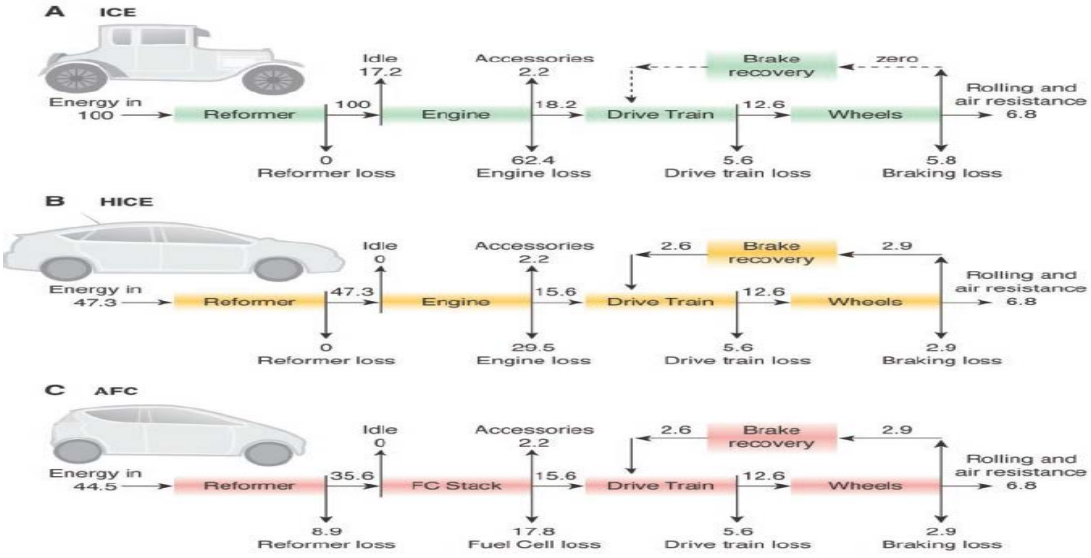

Figure 2.5: Energy flow for various vehicle configurations.