SIMULATION OF HYDRAULIC REGENERATIVE BRAKING SYSTEM TEST-RIG FOR HYRO-PNEUMATIC DRIVELINE

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DECLARATION

I declare that this thesis entitled "SIMULATION OF HYDRAULIC REGENERATIVE BRAKING TEST-RIG FOR HYDRO-PNEUMATIC DRIVELINE" 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.

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APPROVAL

I hereby declare that I have checked this report entitled "SIMULATION OF HYDRAULIC REGENERATIVE BRAKING TEST RIG FOR HYDRO-PNEUMATIC DRIVELINE" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechanical Engineering with Honors

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DEDICATIONS

This thesis is dedicated to my parents who sacrifices a lot for my studies at UTeM. They become one of my toughest inspirations to put my hardest effort into making this thesis complete and successful. They also helped me a lot in my basis of life wherein morally, spiritually, emotionally and the most important thing is in financially. Also not forgetting my siblings and cousins who had experience in thesis writing and also engineering terms.

ABSTRACT

The main advantages of hybrid vehicle are to capture the energy and reuse to save fuel consumption because consuming more fuels lead to many negative impacts to nature. This study builds the necessary simulation models for the hydraulic regenerative braking system which can be installed in normal cars. This research aims to design and run an experiment on hydraulic regenerative braking using Automation Studio software. Using the help of the electric motor, the flywheel will spin using inertial force and hydraulic fluid is forced to flow from the bi-directional pump into the high-pressure accumulator. The amount of hydraulic fluid transmitted would be the same as the amount of hydraulic fluid obtained, because the system is a closed system. The simulation results indicate the maximum liquid volume stored in a high-pressure accumulator is 17.86062 L. According to simulation's results, the overall efficiency of the system is satisfactory and has great efficacy on implementing in a real vehicle, even though the percentage and the pace of energy recovery are dependent on many factors. The schematic diagram can be used in further research by changing the diameter of the flywheel to create a bigger moment of inertia.

ABSTRAK

Kelebihan utama kenderaan hybrid adalah memperangkap dan menggunakan semula tenaga untuk menjimatkan penggunaan bahan bakar. Kajian ini telah membina model simulasi yang sesuai untuk sistem brek regeneratif hidraulik yang boleh dipasang di kereta biasa. Matlamat kajian ini ialah untuk merekacipta dan mengeksperimen sistem brek regeneratif hidraulik dengan menggunakan perisian Automation Studio. Roda tenaga akan berpusing dengan bantuan motor elektrik melalui daya inertia dan cecair hidraulik akan mengalir dari pam dua hala ke dalam penumpuk tekanan tinggi. Kuantiti cecair hidraulik yang sampai adalah sama dengan kuantiti cecair hidraulik yang diperoleh kerana ini adalah sistem brek tertutup. Hasil kajian menggunakan simulasi menunjukkan bahawa isipadu cecair yang disimpan di penumpuk tekanan tinggi ialah 17.86062 L. Hasil keberkesanan keputusan simulasi adalah memuaskan dan mempunyai keupayaan yang tinggi untuk dipasang di kenderaan. Walaubagaimanapun, peratus dan tempoh pemulihan tenaga bergantung kepada banyak lagi faktor. Gambarah skematik boleh digunakan dalam hasil kajian masa depan dengan menukar diameter roda tenaga untuk mencipta moment inertia yang lebih besar.

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LIST OF ABBREVIATIONS

ICE	Internal Combustion Engine
HHV	Hydraulic Hybrid Vehicle
HEV	Hybrid Electric Vehicle
DC	Direct Current
AC	Alternating Current
CVT	Continuously Variable Transmission
PHHV	Parallel Hybrid Hydraulic Vehicle
SHHV	Series Hybrid Hydraulic Vehicle
PSHHV	Power-Split Hybrid Hydraulic Vehicle
PRV	Pressure Relief Valve

LIST OF SYMBOLS

P_{EM}	Power of electric motor (kWatt)
T_{EM}	Torque of electric motor (N.m)
v_{EM}	Speed of electric motor (RPM)
P_{HP}	Power of high-pressure accumulator (kWatt)
p_2	Pressure at the accumulator outlet (Pa)
Q_2	Fluid flow rate at the accumulator outlet (m^3/sec)
I	Moment of Inertia ($N.m^2$)

CHAPTER 1 INTRODUCTION

1.1 Background

Hydraulic system is a drive technology where the pressure of the liquid is used in mechanical work. A closed-circuit hydraulic system where the liquid streams constantly through the system from the pump to motor and back with just case channel oil getting back to the reservoir. A pneumatic system works by utilizing gas or pressured gas to move mechanical parts. The standards for the pneumatic system resemble the hydraulic system. Since air and gas are compressible, this made the pneumatic system produce less pressure force compared with the hydraulic system. Most pneumatic system applications use pressure around 550 to 690 kPa, while the hydraulic system utilizes pressure from 6.9 to 34.5 MPa.

The integration of an internal combustion engine with an electric motor is a hybrid vehicle in which both systems work to move the vehicle. Sometimes both of system works separately and sometimes they work together. The first hybrid car was invented in 1899 by Dr. Ferdinand Porsche, founder of the Porsche company. The idea of a regenerative braking system was come up by a car company called American Motor Car company (AMC) which created a regeneration brake for their concept electric car, AMC Amitron. AMC Amitron is an electrical subcompact car built with several features including a regenerative braking system and advanced battery design to provide 240 kmph. The development ended so fast because of high-cost battery and technology issues. Examples of the hybrid technology that has been developed are hybrid electric, hybrid flywheel, hybrid hydraulic, and pneumatic. For hybrid hydraulic and pneumatic have been classified into four categories, which are the hydro-pneumatic driveline, internal combustion engine (ICE), transmission system, and control system. Under the hydro-pneumatic driveline, there are five subsystems named propulsion, transmission, control subsystem, regenerative system storage.

The hydraulic regenerative braking system (HRBS) is commonly used in a hybrid vehicle because it uses high power density. The hydraulic regenerative braking system is a system that stores the energy that has been created when brakes are applied to the vehicle. The energy which is usually lost in the form of heat due to friction is captured and stored in pressure energy into a pressure tank. The stored energy is utilized to propel the vehicle without using engine power. This paper will focus on the hydraulic regenerative braking system for the hydro-pneumatic driveline.

1.2 Objectives

1. To design a hydraulic regenerative braking system.
2. To determine the effect of fluid power parameters on the performance of regenerative braking.
3. To determine the effect of angular speed and pressure changed through simulation.

1.3 Scope of Project

This paper is more focused on regenerative braking systems which require further analysis is to develop a better system that stores more energy and stops more easily. The scope is to design and run an experiment on hydraulic regenerative braking technology. The regenerative braking system is a process for energy recovery that slows a moving vehicle down by transforming its kinetic energy into a form that can be used immediately or stored until appropriate. This research aims to study the state of regenerative braking and its impact on the ability of the accumulator. Total energy, temperature change, and pressure will influence the regenerative braking system.

1.4 Problem Statement

There is a lot of propulsion system and the most used in this era which is petrol combustion engine and diesel engine. Based on previous research, the fuel consumption of the vehicle is not very effective because not all the energy produced by the engine is completely transmitted to the driveline. Several amounts of energy losses in the form of heat will be produced as the braking of the vehicle and additional energy is consumed to continue the vehicle acceleration. This kind of inefficiency will cause more fuel consumption. Previous research has been developed a propulsion system and storage system but without regenerative braking. Thus, the developer created a hybrid vehicle using a regenerative braking system to overcome this problem. This method will lead to higher efficiency compared to other hybrid cars. This improvement also will reduce global warming and greenhouse effects. The driveline seems to be the focus of the current hydro-pneumatic hybrid system. Another improvement system has been integrated, called the hydraulic regenerative braking system. Therefore, perhaps this simulation can illustrate the same idea on regenerative braking and formed to the stage of development.

1.5 Hypothesis

Designing a functional regenerative braking system is the result of this study. An experiment on the regenerative braking system will be conducted to find the efficiency of the simulation model. Once the shaft achieves the desired rotational speed, the power is distributed and can be calculated by using the clutch to disconnect it from the motor. All this process can be illustrated and demonstrate in simulation performance.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Hydraulic systems and pneumatic system analysis will be covered in this chapter. The starting point will be discussing hydraulic regenerative braking system (HRBS) alongside types of HRBS, applications, history, and challenges. Advantages and disadvantages also will be discussed. This chapter will also discuss the component of hybrid vehicles, operations, the problem exists and current development. The information of regenerative braking systems is discussed with a component used, operational details, problems, and current development available in the market. Next, a further subtopic will be discussing propulsion systems, all types of propulsion systems used in regenerative braking are analysed. The development of the rig will also be evaluated.

2.2 Hybrid Vehicle

2.2.1 Components

An electric motor (EM), battery, converter, ICE, fuel tank, and control board are the main components in an HEV. All these components can be categorized into three groups: Drive trains: The ICE power supply and electric drive are physically connected. Battery/energy storage system (ESS): Emphasizes broad or modest capacities for energy storage and electricity. Control system: Instructs electrical systems/ICE and regulates the HESS. These modules may be incorporated in numerous forms and sizes, resulting in vehicle design variations. Drive trains primarily involve series, parallel, and power split designs based on component integration. Six separate types, which are mild/micro-parallel, parallel, series, power split, mixed and through-the-road (TTR) hybrids, have been categorized into the HEV architecture. (Singh et al., 2019).

The power sources in the HEV series supply electrical energy to the DC bus, which is then converted into traction power. Traction capacity in parallel HEVs may be provided by ICE or EM alone, or by both sources combined. Using regenerative braking, the EM is used to charge the HESS. The parallel mild HEV is an optimal choice since it offers a prime trade-off between the cost and efficiency of the vehicle. Complex HEVs combine both parallel and sequence architecture characteristics. But for the difference of power flow of the generator, which is bidirectional in complex hybrid and unidirectional in series-parallel HEVs, they are much like the series-parallel hybrid. The limitation to dynamic hybrids is their architectural complexity. (Singh et al., 2019).

Architecturally, except for a massive onboard battery, PHEV is similar to HEVs, having high energy capacity and efficiency. A lot of advanced management strategy management than in very HEV is required for this combination of CS and CD modes. PHEVs start operation in CD mode; and before long because the battery hits the SOC threshold before the vehicle is position and recharged, the battery switches to CS mode. But for an external photovoltaic (PV) plate, which charges the battery on a sunny day, the architecture of a solar-driven HEV (PVHEV) is identical to the PHEV. The maximum power point tracker (MPPT) algorithms are implemented to obtain the maximum power from PV panels. (Singh et al., 2019).

<u>Gasoline Engine</u>

In an HEV, the petrol engine is identical to that used in a traditional ICE car. In this, gasoline engines are typically considerably smaller than those used in equivalent standard cars. Larger engines are mainly heavier, consuming more energy during accelerations or ascending inclinations; in a larger engine, pistons along with other parts are heavier, decreasing strength and contributing to the vehicle's total weight. The main source of power for the car is the diesel engine, and the secondary source of power is the electric motor. The Toyota Prius for example can run in standalone electric mode at low speeds (usually up to 15 mph) and can provide assistance during heavy acceleration or when it needs a power boost. Unlike the Toyota Prius, Honda's REV does not have an electric-only mode, but the ICE automatically shuts off at stops at junctions and lights and only starts again when the accelerator is pressed. The Honda Civic features Integrated Motor Assist (IMA), which integrates both the gasoline engine and the e1ectric engine, to provide improvements in the vehicle's efficiency and fuel economy. (Sánchez-repila et al., 2006).

<u>Electric Motor</u>

The electric motor is principally accustomed drive low-speed HEVs and supporting the internal combustion engine once extra power is needed. the electrical motor will act as a generator to transform energy into electricity from the engine or by regenerative braking, which is then preserved within the tank. This practicality acts because the motor adds to the drive train a resistive force that enables the wheels to abate. Then the energy from the wheels continues to remodel the electrical motor, creating it to act as a generator, turning this sometimes unused energy into power by coasting and braking. (Sánchez-repila et al., 2006).

Generator

Only the electric motor is attached to the wheels in a series configured by HEV. There is a different generator for a series HEV that is combined with the gasoline engine. In the electric motor, the engine/generator set provides the energy provided by the batteries. The coupled generator and engine ensure the battery system's effective use during operation. (Sánchez-repila et al., 2006)

Energy Storage

Within REV s, the batteries are an integral part. It is possible to draw electrical energy from the batteries to the electric motor; this method may also be operating in reverse by recapturing energy by regenerative braking. The only time when there is a high electrical energy demand is during the electric-only mode, inside the entire vehicular structure the electrical loads are conveniently controlled much of the time. Because of the higher cost improvement in the energy storage battery, it is much more cost-effective to use the engine at higher loads as the main power supply for the car, rather than increasing the amount of energy storage. (Sánchez-repila et al., 2006)

2.2.2 Operations

Regenerative braking

In a REV, regenerative braking is an innovative feature that helps the electric motor to act as a generator to restore energy that would have once been wasted by heat dissipation and frictional losses.

a. Physical brief

As anybody, a REV follows the rules of physics: F=ma

If F is the force applied, m is the mass (in this case, the mass of the car) and an is the acceleration of the vehicle. The faster you expect an object to acce1erate, the more energy you have to add to it, in simpler language. Such fundamental concepts explicitly link back to the configuration of a REV. First, energy from the battery is transferred to the coil windings inside the electrical motor, concentrating on the e1ectric motor. On the rotor of the motor, a magnetic force is then produced, allowing the creation of torque on the output shaft. The torque generated is applied through the coupled gears and shafts to the vehicle's wheels. The wheels then spin, applying a force in the process to the ground. This force is due to the friction between the wheels as well as the pavement, causing the car to roll around the floor.

b. Regenerative braking concept

Not only for traditional engines but for REVs as well, the problem of frictional failure must be considered. In standard cars, torque is produced to lift the wheels on the ground to propel the car. Friction is created during driving activities, and losses occur. The uniquely engineered rubber in the brake pads was able to withstand heat changes by applying the brakes to the drums and rotors to keep the wheel from spinning. To drive the car, a typical vehicle requires friction losses and uses friction to stop the vehicle. The condition may also be viewed as a lose/lose situation. (Sánchez-repila et al., 2006).

Continuously variable transmission (CVT)

The Continuously Variable Transmission (CVT) further increases the quality of an HEV designed in parallel. A CVT has the same capacity as a parallel HEV, delivering improved fuel economy and minimizing process emissions. Hence, the mixture of the two is a logical and rational one. A beneficial choice for recruiting. The CVT in an HEV allows for an unlimited number of transmission gear ratios within the limits of the system, unlike traditional vehicles that have a fixed gear ratio that usually provides 4 to 6 gear choices. This is useful because it maximizes the powertrain's performance while allowing the driver to have a much smoother journey, thanks mostly to jolt-free acceleration. The key reasons for switching from manual to CVT were so that the engine can always operate at its optimal regime and throttle positions while adjusting to the changing road conditions and power demands. Traditional vehicles do not use CVT, one explanation for this is that its belt-driven orientation restricts its application with engine size vehicles above 1.2 liters, rendering this type of transmission incompatible with a range of conventional vehicles. Its large scale and weight have other drawbacks. However, improvements are aimed at reducing these consequences and, in the future, making the CVT a more feasible means of transmission for all forms of vehicles. (Sánchez-repila et al., 2006).

Integrated motor assist

The Integrated Motor Assist (IMA) device owes the implementation of various innovations built over the last four decades to much of its outstanding efficiency. For starters, Honda used their experience in lean-bum combustion, low-emissions, variable valve timing, high-efficiency engines, regenerative braking, and nickel-metal hydride batteries to their benefit in designing their Insight model's IMA system. Their goal was to create the most fuel-efficient car powered by gasoline in the world. Honda optimizes the efficiency of each of the technologies within their knowledge base to produce a powerful, lightweight, and portable hybrid drive system. (Sánchez-repila et al., 2006).