EXPERIMENTAL OF FREE-LOAD HYDRO-PNEUMATIC PROPULSION SYSTEM

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DECLARATION

I hereby declare that this project entitled “Experimental of Free Load Hydro-Pneumatic Propulsion System” is the result of my own work except as cited in reference.

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APPROVAL

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 (with Honour).

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DEDICATION

To my beloved family for the endless support that they had gave, especially to my beloved father and mother, Muhammad Yusoff bin Ibrahim and Azlina binti Aziz.

ABSTRACT

The hydro-pneumatic hybrid system is one of the new hybrid systems, where it is a combination of the Internal Combustion Engine (ICE) and hydraulic system. This system promises an advantage in term of environment, fuel efficiency, and more efficient compared to a conventional car. However, the problem of this system is there too little data regarding its driveline behavior and there are no data for the maximum RPM of the system. This research is focused on experimental free load hydro-pneumatic propulsion system. The hydro-pneumatic propulsion system has been designed and the simulation was run by using Automation Studio software. The fabrication also involves in this research were to fabricate the test rig. This research aims to find free load RPM, flow, pressure losses and to calculate the free load efficiency of the system. The experimental method was chosen in this research in order to obtain the value of RPM, flow, pressure losses, and system efficiency. The experiment was conducted with a pressure of 100, 120, 140, 160, 180 and 200 bar. The analysis of the flow, pressure difference, power, torque, system efficiency and motor efficiency to the system pressure have been analyzed. Based on the experiment result, the highest value of RPM is achieved at maximum setting pressure which is 236.477 while the flow rate is proportional to the system pressure. The efficiency of the system is decreased with increasing the pressure. This is due to the high-pressure losses in the system. It can be concluded that the value of RPM, flow and power are depending on the input pressure.

ABSTRAK

Sistem hibrid hidro-pneumatik adalah salah satu sistem hibrid yang baru, di mana ia adalah gabungan Sistem Pembakaran Dalaman (ICE) dan sistem hidraulik. Sistem ini menjanjikan kelebihan dari segi persekitaran, kecekapan bahan api, dan lebih cekap dibandingkan dengan kereta konvensional. Walau bagaimanapun, masalah sistem ini ada terlalu sedikit data dan tidak ada data maksimum untuk putaran per minit (RPM). Kajian ini menumpukan pada eksperimen sistem penggerak hidro-pneumatik yang tidak mepunyai beban. Sistem penggerak hidro-pneumatik telah direka dan simulasi dijalankan dengan menggunakan perisian Automation Studio. Fabrikasi juga terlibat dalam kajian ini, di mana untuk menghasilkan rig ujian. Tujuan penyelidikan ini adalah untuk mencari nilai maksimum putaran per minit, aliran, kehilangan tekanan dan untuk mengira kecekapan sistem. Kaedah eksperimen dipilih dalam kajian ini untuk mendapatkan nilai putaran per minit, aliran, kehilangan tekanan dan kecekapan sistem. Eksperimen ini dijalankan dengan tekanan pada 100, 120, 140, 160, 180 dan 200 bar. Analisis aliran, perbezaan tekanan, kuasa, tork, kecekapan sistem dan kecekapan motor kepada tekanan sistem telah dianalisis. Berdasarkan hasil eksperimen, nilai putaran per minit tertinggi dicapai pada tekanan maksimum iaitu 236.477 manakala kadar aliran adalah berkadar terus dengan tekanan sistem. Kecekapan sistem berkurang apabila tekanan sistem dinaikkan. Ini disebabkan oleh kehilangan tekanan tinggi di dalam sistem. Secara kesimpulannya, nilai putaran per minit, aliran dan kuasa bergantung pada tekanan sistem.

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TABLE OF CONTENT

DECLARATION
APPROVAL
DEDICATION
ABSTRACT **i**
ABSTRAK **ii**
ACKNOWLEDGEMENT **iii**
TABLE OF CONTENT **iv**
LIST OF TABLES **vii**
LIST OF FIGURES **viii**
LIST OF ABBREVIATIONS **x**
LIST OF SYMBOLS **xi**

CHAPTER 1 **1**
1. INTRODUCTION **1**
1.1 Background 1
1.2 Problem statement 2
1.3 Objective 3
1.4 Scope 3
1.5 Hypothesis 3

CHAPTER 2 **4**
2. LITERATURE REVIEW **4**
2.1 Introduction 4
2.2 Hybrid system 4
2.3 Hydraulic hybrid vehicle 5
2.4 Hydro-pneumatic system 7
2.5 Type of propulsion 9
2.5.1 Internal combustion engine (ICE) 9
2.5.2 Electric motor 11
2.5.3 Hydraulic motor 12
2.6 The hydraulic motor propulsion system 13
2.7 Type of hydraulic motor 14
2.7.1 Gear motor 15
2.7.2 Vane motor 17
2.7.3 Piston motor 19

2.8 Hydraulic control system 21
2.9 Hydraulic motor for dual function 27

CHAPTER 3 28
3. METHODOLOGY 28
3.1 Introduction 28
3.2 Flow chart 29
3.3 Literature review 31
3.4 Design 31
3.4.1 Introduction 31
3.4.2 Pictorial diagram 31
3.4.3 Schematic diagram 32
3.4.4 Test Rig 34
3.5 Simulation 35
3.5.1 Schematic diagram 35
3.5.2 Functional simulation 36
3.6 Experimental set-up 38
3.6.1 Introduction 38
3.6.2 Component and instrumentation 39
3.7 Experiment 40
3.7.1 Introduction 40
3.7.2 Procedure of experiment 40
3.7.3 Measuring instrument 41
3.7.4 Model/ Equation 42
3.8 Data collection 44
3.9 Report 44
3.10 Gantt chart 44

CHAPTER 4 45
4. FABRICATION 45
4.1 Test Rig 45
4.2 Component 46
4.3 Fabrication Process 48
4.4 Product Assembly 49

CHAPTER 5 **51**
5. TESTING **51**
5.1 Standard Operating Procedure 51

CHAPTER 6 **55**
6. RESULT AND ANALYSIS **55**
6.1 Introduction 55
6.2 Power, torque and efficiency calculation 55
6.2.1 Power Calculation 55
6.2.2 Torque Calculation 56
6.2.3 System Efficiency Calculation 56
6.2.4 Motor efficiency calculation 57
6.3 Flow rate versus pressure system 58
6.4 Pressure Difference versus pressure system 59
6.5 Power Analysis 60
6.6 Torque versus pressure system 61
6.7 System Efficiency 62
6.8 Motor efficiency 63

CONCLUSION AND RECOMMENDATION **64**
Conclusion 64
Recommendation 65

REFERENCES **67**
APPENDICES **69**

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Advantage and disadvantage of external gear motor (N.d., 2017)	15
2.2	Advantage and disadvantage of Internal gear motor	16
2.3	Advantage and disadvantage of the unbalanced vane motor (N.d., 2015)	18
2.4	Advantage and disadvantage of balanced vane motor (N.d., 2015)	19
2.5	Types of hydraulic pump	22
2.6	Types of hydraulic pump	25
3.1	Component and Instrument specification	39
4.1	Name and function of the component involved	46

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Configuration of the accumulator	7
2.2	Hydro-pneumatic suspension (sphere)	8
2.3	Schematic diagram hydro-pneumatic suspension	8
2.4	Hydro-pneumatic water tank	9
2.5	Spark ignition gasoline engine	11
2.6	Compression ignition diesel engine	11
2.7	Working principle of DC motor	12
2.8	Hydraulic cylinder circuit (N.d., 2018)	14
2.9	Hydraulic motor circuit (N.d., 2018)	14
2.10	External gear pump	16
2.11	Direct drive gerator motor (N.d., 2014)	17
2.12	Unbalanced vane motor (N.d., 2014)	18
2.13	Balanced vane motor	19
2.14	Radial-piston motor (N.d., 2014)	20
2.15	Axial-piston motor	21
2.16	Basic hydraulic system (Mahato, 2018)	21
2.17	Symbol of the pump (Mahato, 2018)	23
2.18	Types and symbols of hydraulic motor	23
2.19	Symbols for the hydraulic cylinder	24
2.20	Symbol for flow control valve	26
2.21	Type and symbol of the directional control valve	27
3.1	Flow chart	30
3.2	Pictorial Diagram	32

3.3	Hydraulic system schematic diagram	33
3.4	Isometric view	34
3.5	Hydraulic circuit configuration	36
3.6	Initial state of the system	37
3.7	Second state of the system	38
3.8	Pressure gauge	41
3.9	Data logger	41
3.10	Hydraulic system model	42
4.1	Orthographic view	45
4.2	Isometric view	46
4.3	Coating process	48
4.4	Final product	49
4.5	Orientation of the component	50
4.6	Full assembly	50
5.1	(a) Shutter valve 1 and Shutter valve 2. (b) Shutter valve 3. (c) Throttle valve	52
5.2	Start button and pressure gauge	52
5.3	(a) Shutter valve 1 at open position. (b) Shutter valve 2 at open position. (c)	53
5.4	Shutter valve 2 and shutter valve 3 in open position	54
6.1	Graph of Flowrate vs system pressure	58
6.2	Graph of Pressure difference vs system pressure	59
6.3	Graph of Power vs system pressure	60
6.4	Graph of torque vs system pressure	61
6.5	Graph of System efficiency vs system pressure	62
6.6	Graph of Motor efficiency vs system pressure	63

LIST OF ABBREVIATIONS

ICE	Internal Combustion Engine
HEV	Hybrid Electric Vehicle
HHV	Hybrid Hydraulic Vehicle
FCV	Flow Control Valve
PCV	Pressure Control Valve
DCV	Directional Control Valve
RPM	Revolution per minute
SOP	Standard Operating Procedure

LIST OF SYMBOLS

p	Pressure (bar)
Q_{avg}	Average flow rate
Δp	Pressure difference
$Pout$	Power output at hydraulic motor
N	Speed in RPM
T	Torque
Pin, sys	Input power at the system
p_{sys}	System pressure
η_{sys}	System efficiency
η_{motor}	Motor efficiency
Pin	Power Input

CHAPTER 1

INTRODUCTION

1.1 Background

The hybrid technology system is the system that combined two or more technologies to achieve an efficient system. In this era of technology and globalization, the hybrid system is now growing in popularity in the automotive field due to its advantages in term of the environment, fuel-efficiency and more efficient compared to a conventional car (N.d., 2016). In a field of automotive, hybrid means the vehicle that use two or more different power sources that are work together to move the vehicle or create power. Hybrid hydraulic technology is famous among the heavy vehicle such as buses and a garbage truck, and this technology is still in research and development for applying at the passenger car (Wasbari, Anas and Abu Bakar, 2016).

The hydro-pneumatic hybrid system is a new hybrid system that been introduced. It is a combination of the internal combustion engine (ICE) and hydraulic system for the propulsion and pneumatic system for the energy source. The hydro-pneumatic driveline consists of five sub-systems which are propulsion, regenerative system, storage, transmission, and control system (Wasbari, Anas and Abu Bakar, 2016). Propulsion is a mechanism to move a vehicle. Regenerative system or know as the regenerative braking system is a system that captures the energy loss during the braking or decelerates that are in the form of kinetic energy and change the energy to compression energy. The compression energy is then be stored in a hydraulic-pneumatic accumulator in the form of the potential

energy. When the energy required by a car to accelerate, the stored energy will be a channel to the hydraulic motor to rotate the wheel.

Hydro-pneumatic hybrid offers a few advantages and disadvantages over the other hybrid vehicle. Hydro-pneumatic hybrid requires less energy conversion compare to an electric hybrid vehicle. An electric hybrid will convert kinetic energy to electrical energy and then to chemical energy to store in the battery. For the hydro-pneumatic hybrid, it converted kinetic energy to fluid pressure energy and stored in the storage system. Due to less energy conversion by hydro-pneumatic hybrid, this leads to higher efficiency compared to electric vehicle (Kumar, 2012). Besides its advantage, the hydro-pneumatic hybrid also has its disadvantages which is in parallel hydro-pneumatic hybrid it does not allow the engine to turn off when the vehicle does not result in motion, unlike a hybrid electric car. The vehicle will always burn gas (Valente and Ferreira, 2012).

This research is focusing on the hydro-pneumatic driveline. The free load running experiment is important to find the net power supplied to the by the energy storage. The system efficiency will be calculated.

1.2 Problem statement

The hydro-pneumatic hybrid system is a new system that is still in the research and development stage for a passenger car. This system can contribute higher efficiency compare to another hybrid vehicle. Due to this is a new system, there are a few data regarding it driveline is still not studied. This paper focuses on finding free load RPM, flow, pressure and pressure losses. Next, the efficiency of the free load system will be calculated.

1.3 Objective

(i) To find the free load RPM, flow, pressure and pressure losses.

(ii) To calculate the efficiency of free load system.

1.4 Scope

The energy that gains from brakes will store in the accumulator. The concern in this project is to run an experiment to find the net power supplied by the energy storage. The simulation has been conducted by using Automation Studio software. After connecting the system to shaft and differential, the power will drop so it can be calculated. The data then will be used to calculate the system efficiency. This project will only involve design and experimentation.

1.5 Hypothesis

This research is expected to get the net power supplied by the energy storage. To obtain the net power supply, the free load experiment will be carried out. Other than that, system efficiency also will be calculated. Once the system is connected to the shaft and differential, the power will be drop so it can be calculated.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, a review of the hybrid system and hydraulic hybrid vehicle will be discussed. Next, a review of the hydro-pneumatic system is being discussed. This chapter also includes types of propulsion which describe the different types of propulsion and its advantage and disadvantage. Other than that, the hydraulic motor propulsion system is also included in this chapter where it discusses more detail about the hydraulic motor propulsion system. On section 2.7, type of hydraulic motor and their advantages and disadvantages are discussed. This chapter also included a hydraulic motor control system. On section 2.9, discussed hydraulic motor for dual function.

2.2 Hybrid system

The hybrid system can be defined as a combination of a different approach. In a term of automotive, hybrid means that the vehicle that uses two different forms of power such as electric motor and internal combustion engine (ICE) for propulsion. The hybrid system has been introducing due to environmental concerns demand improvement in fuel economy and lowering emission for a passenger vehicle (Hawkins, 2012). Hybrid electric vehicle (HEV) have proven to be the best choice due to the usage of the smaller battery pack and its similarities to the conventional vehicle (Bitsche and Gutmann, 2004). HEV is also the most efficient fuel consumption compared to another hybrid vehicle (N.d., 2013a). However, with

a new system that is called “Hybrid Air” PSA claim that this system will be far most cost-effective than the petrol-electric drivetrain (Holloway, 2014). Based on the experiment that been carried out, for the 11km drive, the fuel consumption for the HEV is 0.37 liter while for the hybrid-hydraulic vehicle (HHV) Hybrid Air are about 0.32 liter (Boretti and Zanforlin, 2014). This show that the HHV is more efficient fuel consumption compared to HEV.

2.3 Hydraulic hybrid vehicle

Hydraulic hybrid vehicle is also known as HHV is a new hybrid system that is still in the research process. It consists of an internal combustion engine (ICE) and energy storage device. This system is the same as hybrid electric vehicle (HEV), but it will store the kinetic energy that was originally momentum as potential energy in the form of pressure. Hydraulic hybrid mainly consists of two accumulators that are high pressure and low-pressure accumulator. The high-pressure accumulator is operating between 135 and 485 bar while low-pressure accumulator is operating between 3.5 and 13.5 bar (Boretti and Zanforlin, 2014). When the vehicle decelerates, the hydraulic pump will pump the fluid that is from the low-pressure accumulator to high-pressure accumulator. When the vehicle accelerates, the pressure will be released from the accumulator which will spin the drive shaft and accelerates the vehicle. The engine will remain idle while the pressure is released and when the accumulator is empty, or desired speed is achieved, the engine will start operating to maintain a constant velocity or to accelerate beyond the limit of accumulator capable (Kumar, 2012). Figure 2.1 shows that the configuration of the accumulators in the vehicle. The red represents the high-pressure accumulator while the green represents low-pressure accumulator.

There is a lot of advantage and disadvantage of the hydraulic hybrid vehicle. The main advantage and disadvantage are:

- Environmentally friendly

  One of the biggest advantages of the HHV over ICE is it runs clearer and has better gas mileage. It is because the hybrid car runs two engines and cut fuel consumption and converse energy.

- Regenerative braking system

  Each time the brake is applied, the energy loss during braking will then be stored in storage devices and will be used to accelerates.

- Less dependence on fossil fuels

  The hybrid car requires less fuel consumption which means less emission and less dependent on fossil fuel. It also helps in reducing the price of gasoline in the market.

- Built from light material

  Mostly, all hybrid vehicle made of light material which means it requires less energy to run.

- Less power

  The gasoline engine which is the primary engine is much smaller compared to a single gasoline car engine. The combination of the gasoline engine in the hybrid and the hybrid system provides less power. This car is suitable for city driving and not for speed and acceleration.

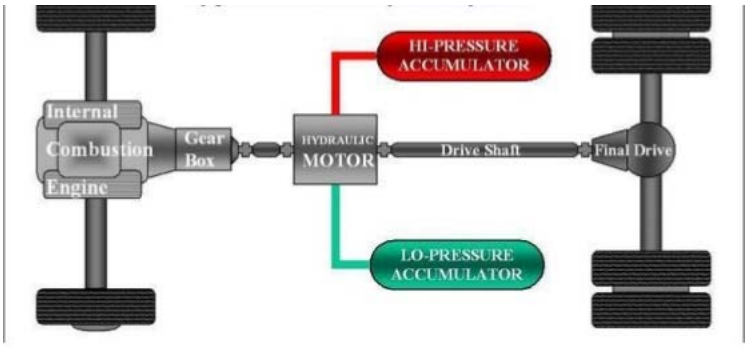

Figure 2.1: Configuration of the accumulator

2.4 Hydro-pneumatic system

Hydro-pneumatic can be defined as a system that operates using both fluid and air or other gases (Radu, 2013). The hydro-pneumatic system has been used for many applications such as car suspension system, hydropneumatic tanks, and other applications.

The hydro-pneumatic suspension has been introducing by Citroen employee Paul Mages (Radu, 2012). Basically, cars use spring to act as a shock absorber, to protect the passengers from the jolts when the car undergoes imperfection of the road. The spring and shock absorber system has replaced by a sphere that contains nitrogen gas and hydraulic fluid. Both of it is separated by a flexible membrane. Figure 2.2 below shows an example of hydro-pneumatic suspension (sphere). Every wheel was attached to a control arm, and the movement of the arm will push the hydraulic fluid. Generally, the car that equipped with this hydro-pneumatic system has five or six spheres, which is one for each corner as shown in Figure 2.3 below. The main advantage of these systems, it improves and provides the ride quality and comfortability of the vehicle.

Figure 2.2: Hydro-pneumatic suspension (sphere)

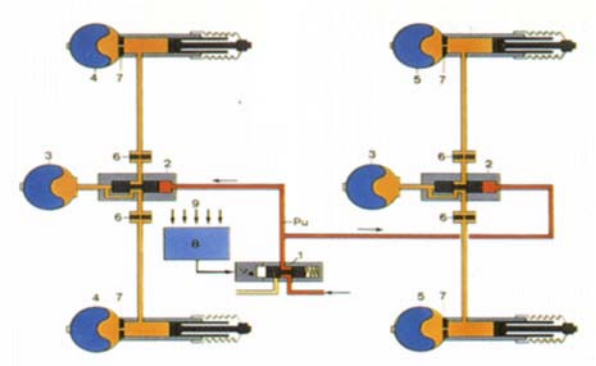

Figure 2.3: Schematic diagram hydro-pneumatic suspension

Hydro-pneumatic tanks is a storage tank that is designed to store water and air under pressure. It does not have a bladder, where the air and water are direct contacts. The purpose of hydro-pneumatic tanks is to provide pressurized water quickly and do not require the use of a pump often. In a well water application, the water will be provided when the pressure range is reached. It is to reduce the pump from running constantly. By having hydro-pneumatic tanks system, the system can be more effective; this is because when the small amount of water is needed, hydro-pneumatic tanks can supply it without the need to start up or use the pump. The main advantage of this system is it prevents the constant use of the pump even if a small amount of water is needed for the system. Next, this system also could reduce the water hammer. Figure 2.4 shows an example of the hydro-pneumatic water tanks.

Basically, the hydro-pneumatic system is the type of system that is consist of hydraulic and air. Hydraulic being used in order to compress the bladder inside the accumulator that contain nitrogen gas. The compressed air will then be used to pressurize the hydraulic fluid through the system.

Figure 2.4: Hydro-pneumatic water tank

2.5 Type of propulsion

Propulsion can be defined as creating a force that will lead to a movement. Propulsion comes from a word propeller which means to push away. The modern meaning of the propulsion is the act of moving forward. The propulsion system consists of a mechanical power source where it converts the mechanical power into a propulsive force. This concept of force is explained in Newton's third law of motion where the force of the first object is in the opposite direction of the force in the second object. There are several types of propulsion system that is an internal combustion engine, electric motor, and hydraulic motor.

2.5.1 Internal combustion engine (ICE)

Internal combustion engine (ICE) is a type of propulsion system that is widely used for power generating devices. It can be divided into two groups which is continuous