DEVELOPMENT OF HYDRAULIC LAUNCH ASSIST TESTBENCH

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List of abbreviations

HAB = Hydraulic Acceleration Boost,

HHV = Hydraulic Hybrid Vehicle

WLTP = World Harmonised Light Vehicle Test Procedure

HEV = Hybrid Electric Vehicle

NC valve = Normally Closed Valve

Abstrak

Sistem hibrid hidraulik direka untuk mengurangkan penggunaan bahan api kenderaan dalam industri automotif. Sumber tenaga sekunder untuk sistem hidbrid hidraulik adalah komponen hidraulik yang disambungkan ker simpanan tenaga. Tenaga itu digunakan oleh hidraulik motor semula untuk membantu kenderaan semasa pecutan Tumpuan penyelidikan ini adalah untuk merangka konfigurasi yang sesuai untuk Perodua Myvi untuk diubahsuai menjadi kenderaan hibrid hidraulik. Konfigurasi dirancang untuk dipasang pada roda belakang untuk mengelakkan kerumitan oleh kerana Perodua Myvi adalah pemacu roda hadapan dan roda belakang bebas berputar. Disebabkan itu, sistem rangsangan pecutan hidraulik dilakukan ke gandar belakang Perodua Myvi. Prestasi hidraulik komponen diukur dan dibandingkan dengan kitaran pemacu oleh Prosedur Ujuan Kenderaan Ringan Berharmoni Sedunia. Peratusan yang berbeza untuk pecutan maksimum dari hasil yang dikira dengan kiratan pemacu ialah 65.412%. Bagi purata pecutan dari hasil yang dikira dengan kitaran pemacu ialah 38.412%. Pemulihan tenaga semasa ransangan pecutan hidraulic juga diukur. Tegana yang dapat pulih dalam lingkungan 23% hingga 29%.

Abstract

The hydraulic hybrid systems are design to reduce the fuel consumption of vehicle in automotive industry. The secondary power source for hydraulic hybrid systems are hydraulic component that is connected to energy storage. The energy use back to assist the vehicle during acceleration by hydraulic motor. The focus of the research is to design a suitable configuration for the Perodua Myvi to be modified to become a hydraulic hybrid vehicle. The configuration that is plan to be installed on the rear wheel to avoid complexity since Perodua Myvi is front-wheel-drive the rear wheels are spin freely. Due to that, the hydraulic acceleration boost system is implement onto the rear axle of Perodua Myvi. The performance of the hydraulic component is measured and compared to the drive cycle by World Harmonised Light Vehicle Test Procedure, (WLTP). The percentage different for the maximum acceleration from the result and drive cycle is 65.412 %. For the average acceleration from the result and drive cycle is 38.412%.The energy recovery during the hydraulic acceleration boost is also being measured. The energy that are able to recover is in the range 23% to 29 %.

CHAPTER 1

INTRODUCTION

1.1 Background

Hydraulic hybrid system is one of the technologies created to reduce the fuel consumption of vehicle in automotive industry. The main power source of a vehicle is from an internal combustion engine and the addition power source is hydraulic that is link to energy storage. The energy use back to assist the vehicle during acceleration by hydraulic motor. The focus of the research is on hydraulic hybrid vehicle (HHV) which uses hydraulic motor as it secondary power source to power the wheel.

In hydraulic hybrid system, the main components are accumulator, hydraulic pump and hydraulic motor. The accumulator is used to store the high pressure fluid. Next, the hydraulic pump and motor use pressurized fluid to rotate them from and to the accumulator. During braking the kinetic energy is converted to potential energy by hydraulic pump to store the potential energy in the accumulator known as regenerative braking. The potential energy is converted back to kinetic energy from the hydraulic motor to rotate the wheel.

Hydraulic launch assist, (HLA) is hydraulic hybrid system that produced by Eaton Corporation for refuse trucks. The system use the same concept of converting the kinetic energy to potential energy. The kinetic energy from the deceleration is store to accumulator. The potential energy in the accumulator is use during acceleration by hydraulic motor to propel the wheels. The idea is to reduce the amount of work done by the internal combustion engine. Thus, reducing the fuel consumption of the vehicle.

The hydraulic hybrid vehicle, (HHV) is known to be high power density compare to hybrid electric vehicle, (HEV). HEV is known to be high energy density compare to HHV. HHV can deliver large amount of energy for a short time. HEV can store a large energy in a small amount of mass which the energy can be use for a long period of time. Due to this, the HHV is suitable is to be implement to a small vehicle in urban area because of stop and start. A similar concept is design and implement for Perodua Myvi using hydraulic acceleration boost system to analyst the performance.

1.2 Objectives

- To design and implement the hydraulic acceleration boost system onto the rear axle of Perodua Myvi that need to be design fabricated to the testbench.

- To calculate the perfomance of the hydraulic acceleration boost and evaluate the workability by comparing to the drive cycle by World Harmonised Light Vehicle Test Procedure (WLTP).

- To measure the energy recovery during the hydraulic acceleration boost.

1.3 Scope of research

The focus of the research on this project is on designing a hydraulic hybrid vehicle system onto the rear axle of a Perodua Myvi that is designed and fabricate to the testbench. The testbench will be designed with the appropriate connection of the hydraulic circuit. On top of that, the hydraulic components need to be assembled and welded onto the rear axle of a Perodua Myvi. The sizing of the hydraulic motor, pump and other components are selected based on the simulation done on Matlab. The performance of hydraulic acceleration boost is calculated based on related formulas and evaluate the workability by comparing to the drive cycle by World Harmonised Light Vehicle Test Procedure, (WLTP).

1.4 Problem Statement

The pullution and energy resources issues are something that is concerning the world. One way to cope up the issue is by intruduce hydraulic hybrid vehicle, (HHV) and hybrid electric vehicles ,(HEV) since they are proven to be effective. The HHV is capable to capture more energy compared to HEV during braking., which make it suitable for urban driving due to frequent stop and start. Although, pure electric vehicles have high performance and low pollution but their constraint are their short driving range and high battery costs. In HEVs the energy management is crucial because it can affect the vehicle performance and component size. The research will implement the hydraulic components designed to be a hydraulic acceleration boost to assist the vehicle during acceleration. The system is to be design on a Perodua Myvi and the performance of the system is analyse and compare with drive cycle.

1.5 Limitation

The results are calculated theoretically but the result cannot be compare to the experimental result yet due to the installation of the components take longer than expected. The result is compare to the drive cycle by World Harmonised Light Vehicle Test Procedure, (WLTP). The calculation are assume for a flat road only, which involve frequent stop and starts.

Chapter 2

LITERATURE REVIEW

2.1 Hydraulic Hybrid Vehicle (HHV)

Firstly, in a series configuration HHV the engine is turn off when the sensor sense the braking paddle is pressed. A hydraulic pump is used to convert the kinetic energy from the braking to charge the pressurized fluid to the accumulator and after the accumulator is fully filled with pressurized fluid. The pressurized fluid then move to the hydraulic motor to turn the wheel during accelerate using only the stored energy. After the pressurized fluid is at the minimum level the engine is used back for the rest of the cruising until the braking happen again.

The vehicle's wheels are propel fully by the hydraulics. A hydraulic pump/motor is connected to engine shaft which is connected to accumulator allow it to store energy. The clutch is used to allow disengage and engage of engine for on and off management (Stelson, J. Meyer et al. 2008).

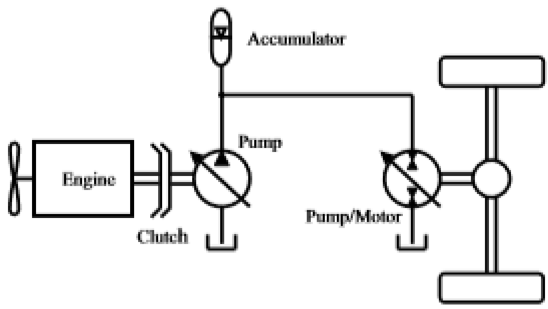

Figure 1: Series hybrid configuration,(Stelson, J. Meyer et al. 2008)

Next, in parallel HHV configuration the engine is off or on depending on the control unit. When the sensor sense the braking paddle is pressed. A hydraulic pump is used during deceleration to convert the kinetic energy from the braking to charge the pressurized fluid to the accumulator or known as regenerative braking and after the accumulator is fully filled with pressurized fluid. The pressurized fluid then move to the hydraulic motor to assist the vehicle's wheel during accelerate using only the stored energy while the engine is still power the wheels. After the pressurized fluid is at the minimum level the engine continue to power for the rest of the cruising until the braking happen again. In the past research, parallel configuration show the effectiveness on reduced fuel consumption from the regenerative braking and re-use back the energy (Hui, Lifu et al. 2010).

The vehicle's wheels are propel by the hydraulic. A hydraulic pump/motor is connected to the transmission and the engine through the drive shaft. The accumulator is connected to hydraulic pump/motor. The clutch is used to allow disengage and engage of engine for on and off management.

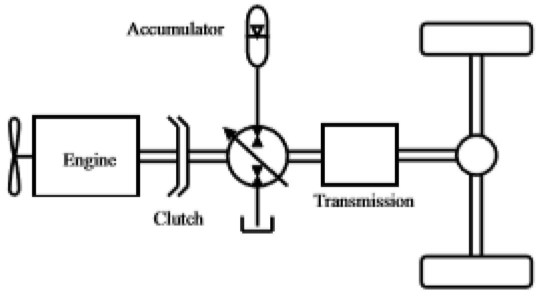

Figure 2: Parallel hybrid configuration (Stelson, J. Meyer et al. 2008).

Lastly, in power-split HHV configuration of parallel and series are combined into one. The configuration use hydraulic components and internal combustion engine. The configuration used the hydraulic pump/motor in series and parallel. Power-split use the combination of parallel and series, combining both advantages making it more complex to control (Tvrdić, Podrug et al. 2018).

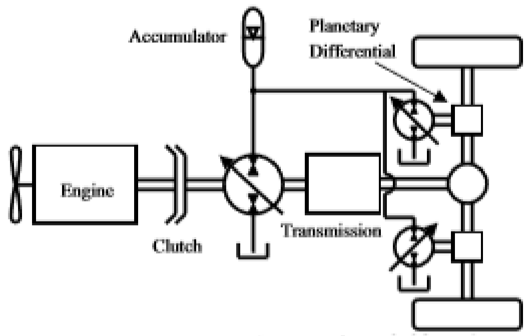

Figure 3: power-split hybrid configuration (Stelson, J. Meyer et al. 2008)

The HHV is prone to be used in heavy vehicles because it requires large space for the hydraulic accumulator to store the energy and re-use it. Heavy vehicles should have enough space for all HHV components. Meanwhile, Hybrid electric vehicle,(HEV) is likely to be used for smaller passenger vehicles because it does not require large space for the electric battery compared to an accumulator.

The HHV is known for its power density. The power that is produced per unit volume is higher compared to HEV. A big amount of energy is able to transfer in short amount of time is what make HHV unbeatable. The efficiency of the regenerative braking is HHV is much higher than HEV regenerative braking efficiency for an urban driving which involve stop and start [4].
The energy that HHV can save is almost 80% of the kinetic energy, while HEV can save only 30% of the kinetic energy of the vehicle. The initial and maintenance cost for HHV is lower compared to HEV (Tvrdić, Podrug et al. 2018). As for the current technology, the HEV has been a mass produced for the passenger vehicles because of high energy density compared to HHV. The electric batteries have high energy density which allow a large storage.

As for the result, the hydraulic should be used in the passenger vehicles since the power density is high for the hydraulic pump, hydraulic motor and accumulator. The HHV has been focus on heavy vehicles for example, Lorries, buses, delivery trucks and etc. Studies show different control strategies for different heavy vehicles to improve fuel economy (Stelson, J. Meyer et al. 2008). The configuration that fit the research is by using parallel configuration but with slightly different because the hydraulic components are design and install on the rear axle of the Perodua Myvi for the regenerative braking and launch assist. Most of the research main focus on the fuel economy not the acceleration performance of the HHV. This research is focus on the performance of the hydraulic acceleration boost on a passenger vehicle. To avoid any complex control of the configuration to the vehicle, this front-wheel-drive vehicle that runs fully on internal combustion engine system is not going to be disturb.

CHAPTER 3

METHODOLOGY

3.1 Hydraulic Acceleration Boost (HAB) system design

The components in the system are chosen based on the Matlab simulation to find the optimum sizing of components for the system. The rear axle of a Perodua Myvi is modified to be able to install the hydraulic components. The components in the system are clutch, hydraulic pump, hydraulic motor, oil tank, accumulator, pressure relief valve, check valve, normally closed valve (NC valve), flow controller.

The design of this system is on the rear axle of the Perodua Myvi which is completely not interfering with the front-wheel of the vehicle. The performance of the engine for the car is still the same as it is. The hydraulic components are added to the vehicle to as an additional power source to the vehicle. An electric motor is used on testbench to represent a rotating wheel of the vehicle while moving.

The assembly of all components on the testbench in Solidworks is shown below.

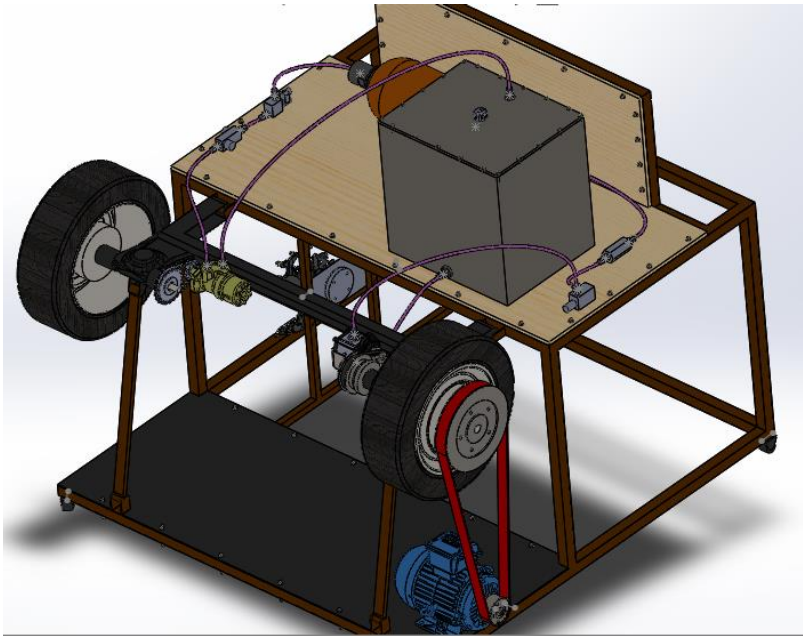

Figure 4: Assembly of all the components on testbench in Solidworks

3.2 Working principle

Hydraulic acceleration boost (HAB) system is started when the throttle paddle is pressed the normally closed valve, (NC valve) is open to allow the pressurized oil to transfer to flow controller to regulate the speed of pressurized oil to the hydraulic motor to propel the wheels. The potential energy is convert back to kinetic energy from the hydraulic motor to assist acceleration by rotate the wheel.

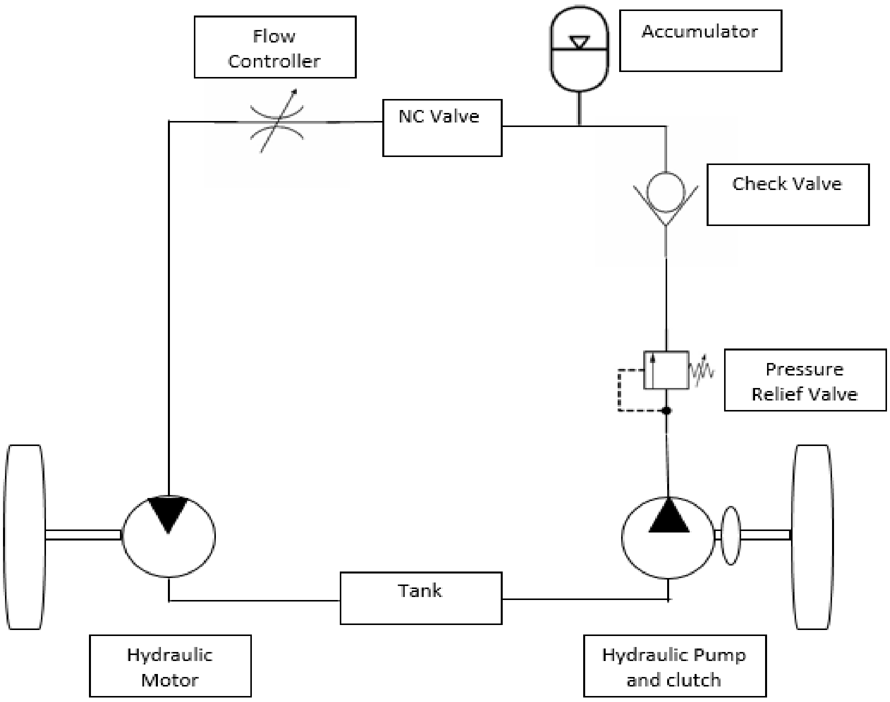

Figure 5: Design configuration of the HAB system

3.2.1 Flow control

This is the plan for the flow control for the HAB system. The flow chart start with a sensor sensing the throttle paddle is pressed. if the state of charge is more than 10 percent. This is to indicate there is pressurized oil stored in the accumulator. A 1:2 gear ratio for hydraulic motor. if the wheel is faster than 377.5 rpm the NC valve is closed. The maximum speed of motor is 755 rpm. If the wheel speed is less that 377.5 rpm the NC valve will open to allow the pressurized oil to hydraulic motor to propel the wheel. If the any of those two requirement is not satisfy then NC valve is closed. This plan can be change in the future in order to achieve the target performance of the system.

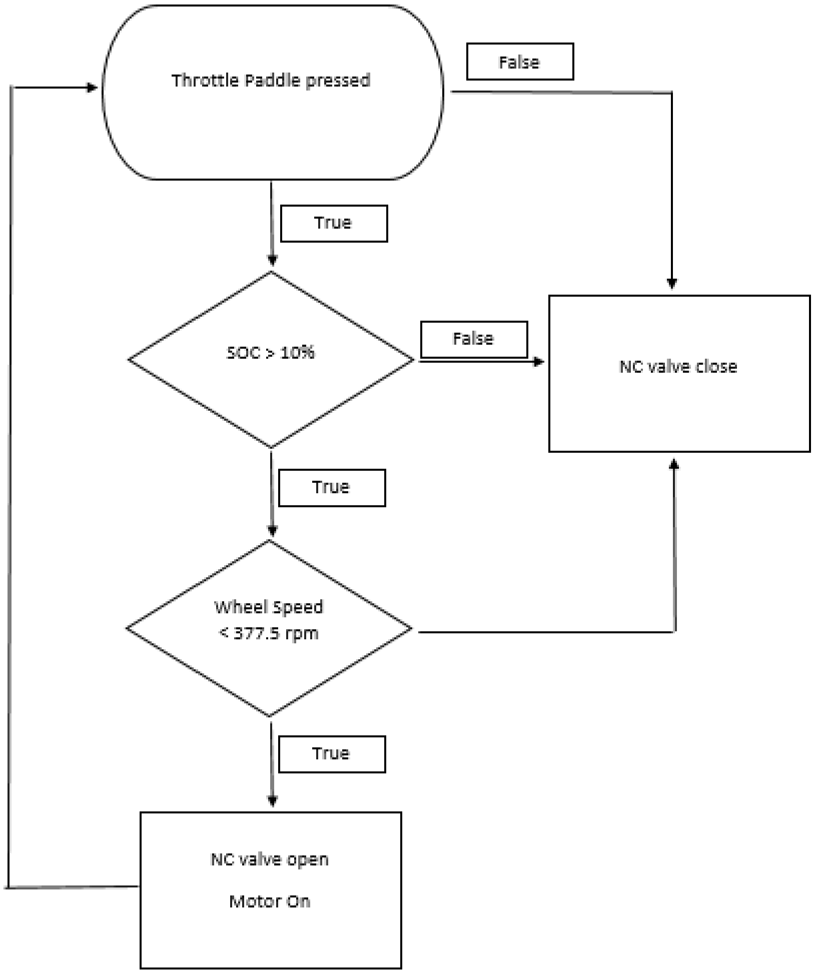

Figure 6: Flow Chart of HAB

3.2.2 Free body diagram of car accelerating

The acceleration of the car is assume on a flat road. The free body diagram is shown below with the forces that acting on a car. The traction force is the force to generate motion between a body and tangential surface. Drag force is a force that will resist the motion and roll resistance force is also will resist the wheel to roll on the surface. The equation for the summation forces for the car is shown below.

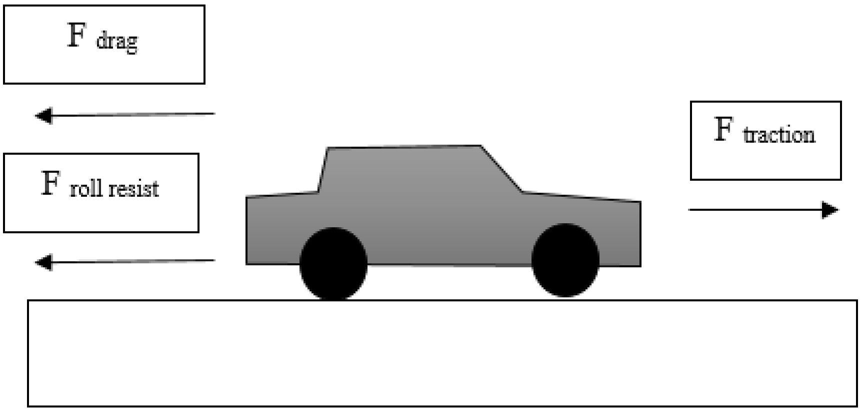

Figure 7: Free body diagram of car accelerating

The formulas use for the forces are shown below:

$$F_{traction} = \frac{wheel\ torque, \tau}{wheel\ radius, r}$$ (Equation 5)

$$F_{drag} = \frac{Cd \times \rho \times v^2 \times Af}{2}$$ (Equation 6)

$$F_{roll\ resistance} = total\ mass \times g \times 0.01, rolling\ coefficient$$ (Equation 7)

$$\Sigma F = mass, m \times acceleration, a$$ (Equation 8)

$$\frac{F_{traction} - (F_{drag} + F_{roll\ resist})}{m} = acceleration$$ (Equation 9)

3.3 HAB components

The components for the HAB system are listed below.

1. Rear axle

A 2005-2008 Perodua Myvi rear axle use for the research

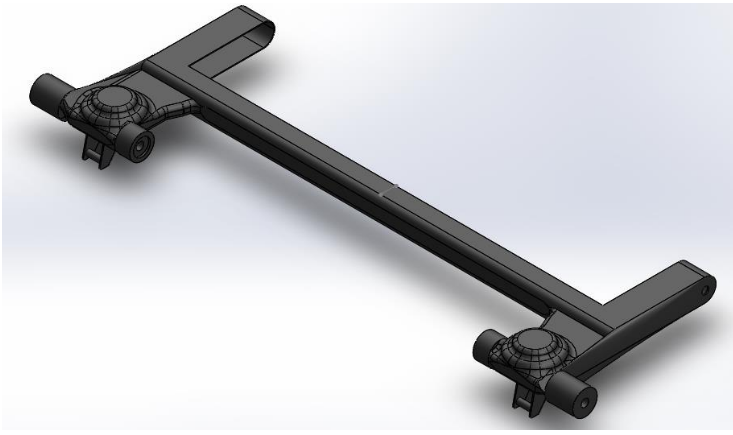

Figure 8: Solidworks of rear axle of Perodua Myvi

2. Hydraulic motor

BM2-50 a 50CC hydraulic motor by STANDCO. This hydraulic motor is at best efficiency and economy in medium load applications. A hydraulic motor is used to convert the potential energy into rotational mechanical energy. Specification of hydraulic motor is shown below.

Displacement (ml/r) =50	Continuous
Flow (LPM)	50
Maximum Speed (RPM)	755
Pressure (Mpa)	14
Torque (N*m)	100

Table 1: Hydraulic motor specification

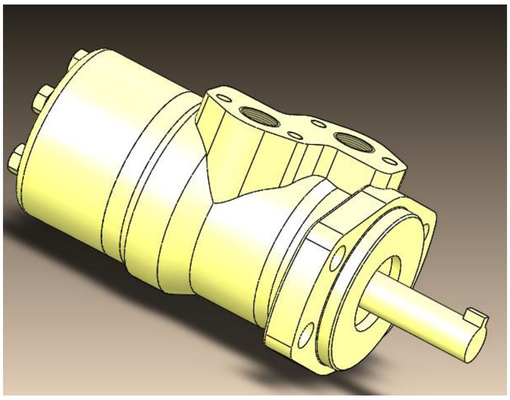

Figure 9: Solidworks of hydraulic motor

3. Hydraulic pump

A 25cc hydraulic pump by STANDCO. A hydraulic pump is used to convert mechanical energy to potential energy by pumping the oil to accumulator.

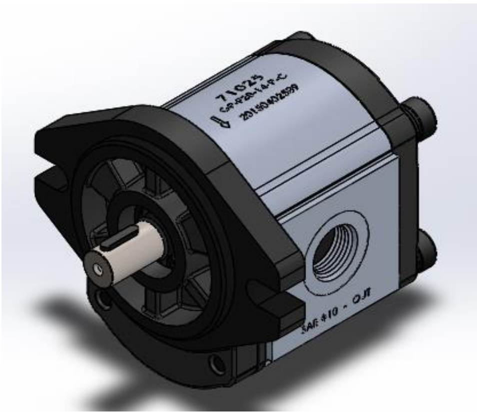

Figure 10: Solidworks of hydraulic pump

4. Accumulator

A 10 L bladder accumulator by STANDCO. A pressure vessel used for storing the hydraulic pressure by compressible and decompressible nature of nitrogen gas.

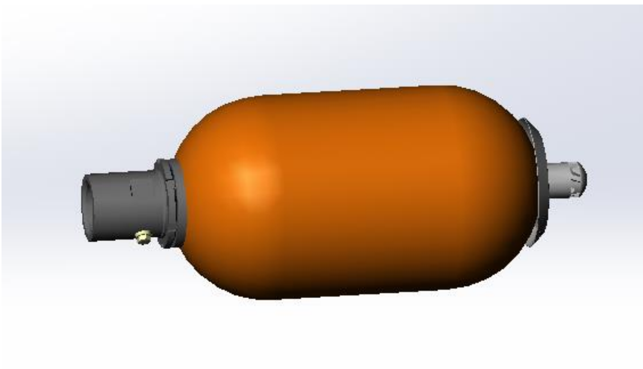

Figure 11:Solidworks of accumulator

5. Pressure relief valve

Pressure relief valve by STANDCO. A presssure relief valve is used to control the system pressure. Specific pressure is set to be reached for the oil to flow and excess flow of oil is transfer back to tank.

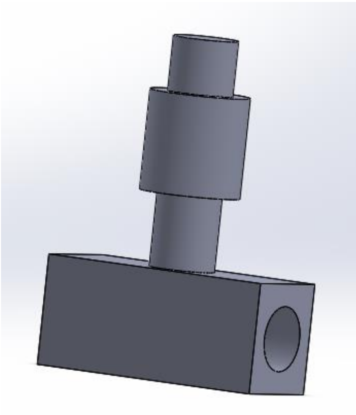

Figure 12: Solidworks of Pressure relief valve

6. Inline check valve

Inline check valve by STANDCO. An online check valve is used to ensure the oil flow in one direction only.

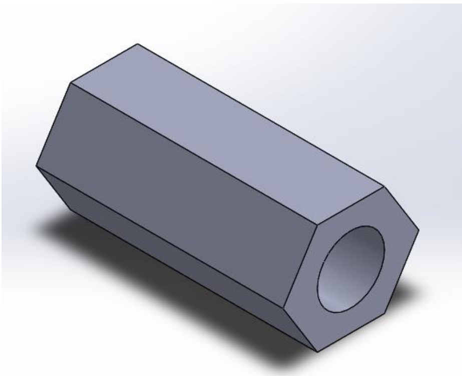

Figure 13: Solidworks of inline check valve

7. Normally closed valve

A normally closed valve by STANCO. Normally closed valve is used to block the flow until it a comand to open the valve.

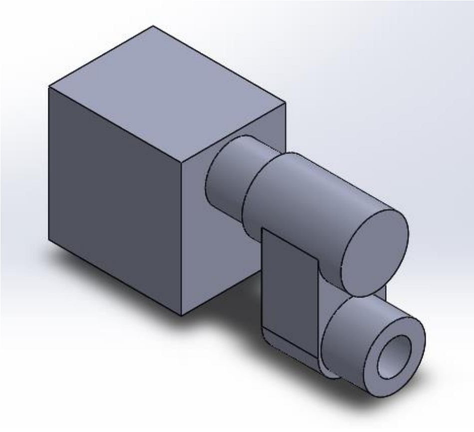

Figure 14: Solidworks of normally closed valve

8. Flow controller

A flow controller by STANDCO. A flow controller is used to control the flow to a desire flow.

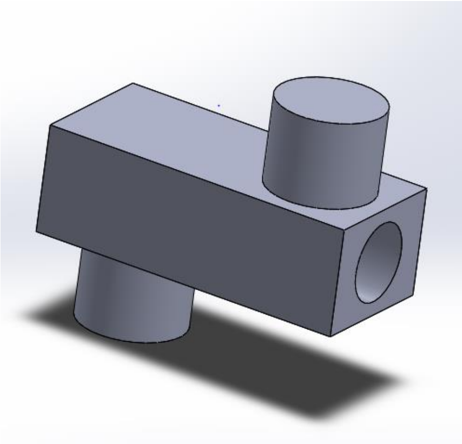

Figure 15: Solidworks of flow controller

3.4 List of fixed parameter

Here are the lists for the fixed parameter that are use in calculation

1. Maximum volume (accumulator) = 10 Liter
2. Maximum pressure in accumulator = 14 MPa
3. Minimum pressure in accumulator = 7 MPa
4. Compressed volume in accumulator = 5.867302 Liter
5. Motor size = 0.05 L/ rev or 50 cc
6. Gear ratio = 1:2
7. Gamma = 1.3
8. Total car mass = 1139.5 kg
9. Mechanical efficiency = 0.9
10. Hydraulic efficiency = 0.6
11. Rolling resistance coefficient, Cr = 0.01
12. Coefficient of drag, Cd = 0.32
13. Frontal area of car, Af = 2.306 m^2
14. Radius of wheel, r = 0.288 m
15. F roll resistance = 111.78495 N
16. Air density = 1.225 kg/m^3
17. Car mass = 1020 kg

3.6 List of equations

$$V_{displaced} = flow\ rate, \mathrm{Q} \times \text{change of time}, \Delta\mathrm{T} \quad \text{(Equation 1)}$$

$$P_{previous} {V_{previous}}^{\gamma} = P_{current} {V_{current}}^{\gamma} \quad \text{(Equation 2)}$$

$$State\ of\ Charge, SOC = \frac{P_{curent} - P_{min}}{P_{max} - P_{min}} \quad \text{(Equation 3)}$$

$$Motor\ Torque, \tau = Pressure, P \times Displacement, D \quad \text{(Equation 4)}$$

$$F_{traction} = \frac{wheel\ torque, \tau}{wheel\ radius, r} \quad \text{(Equation 5)}$$