Palestine Polytechnic University

College of Engineering and Technology
Mechanical Engineering Department

Graduation Project

Building And Design Of Hydraulic Hybrid Vehicle

Project Team

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Hebron-Palestine

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According to the project supervisor and according to the agreement of the Testing committee members, this project is submitted to the Department of Mechanical Engineering at college of engineering and technology in partial fulfillment of the requirements of (B.SC) degree.

Project Supervisor Signature

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Examine community Signature

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Department Head Signature

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Dedicated

To our parents

To all students

To who love the knowledge

To every one who appreciate the value of science

To all of our friends

Acknowledgments

We want to thank the Supervisor Eng. Hussein amr, who gave us a lot of his time and expertise to complete the project and achieve its objectives, as well as to thank for Eng. Zuhair Wazwaz, who gave us what we need of help, and gave us the opportunity to start life science in real life that asks us to do this work, We would also like again, I thank Abd Al-Salam Natshe who gave us everything we need to complete this project and we thank all those who helped us to complete project of graduation.

Abstract

This project comes as a response to the modern trends In the automotive world ,and developed of hybrid technology, which could be summarized into to improving both fuel efficiency and overall operating economy of vehicles. The principle of this project is to build a hydraulic system on the rear wheels besides the vehicle original internal combustion engine for (front-wheel-drive vehicle). The purposes of this system is to regenerative braking energy by taking the movement of the rear wheels which are connected to a hydraulic pump that compress the hydraulic fluid into a high pressure accumulator, and this energy is recovered from the accumulator to be converted into kinetic energy by the hydraulic motor to rotate the rear wheel when needed . And the other purpose of this project is that the hydraulic system can works as brake in the downgrade by operating the pump according to the wanted constant speed ,by controlling the directional control valve, this system is a flexible vehicle application and lower cost relative to any of competitive alternatives.

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Select project																
Collect information about project																
Identification design																
Studying the component and design																
Mathematical calculation																
Evaluation and reviewing																
Writing																
Final edition																

Time table of the second semester

Time(week) / Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Collect more information about project																
Studying the design																
Identification design																
Calculation for selecting component																
Built the system on vehicle																
Evaluation and reviewing																
Writing																
Final edition(conclusion and recommendation)																

History of Hydraulic hybrid

A hydraulic hybrid vehicle uses hydraulic and mechanical components. As variable displacement pump, and a hydraulic accumulator (which stores energy as highly compressed nitrogen gas). Hydraulic hybrid technology was originally developed by Volvo Flygmotor and was used experimentally in buses from the early 1980s and is still an active area. Initial concept involved a giant flywheel for storage connected to a hydrostatic transmission, but It was later changed to a simpler system using a hydraulic accumulator connected to a hydraulic pump/motor. It is also being actively developed by Eaton and several other companies, primarily in heavy vehicles like buses, trucks and military vehicles. An example is the Ford F-350 Mighty Tonka concept truck shown in 2002. It features an Eaton system that can accelerate the truck up to highway speeds.

The first advanced hydraulic hybrid sport utility vehicle will be publicly in years 2004 is displayed by EPA, along with its partners, at the 2004 Society of Automotive Engineers World. This vehicle demonstrates that hydraulic hybrid technology has the potential to dramatically and cost-effectively improve the fuel economy of sport utility vehicles (SUVs) while at the same time improving performance. This technology responds to development and climate goals by reducing fuel consumption and greenhouse gas emissions.

The technology is on the road in the form of a UPS delivery truck. In 2005, engineers unveiled the first-ever series hydraulic hybrid diesel urban delivery vehicle, which was developed through years of research by UPS, the U.S. Environmental Protection Agency, Eaton Corp., International Truck and Engine, and the U.S. Army.

UPS-branded P-100 truck prototypes represent the first-ever hybrid delivery vehicles to use hydraulic technology. The first vehicle will operate a daily delivery route in the Detroit area for a few months. Then, the prototype will be returned to EPA's lab in Ann Arbor, Mich. for analysis. In 2007, similar testing of a second prototype vehicle will occur.

Nomenclature

HV	Hydraulic Vehicle.
HHV	Hydraulic Hybrid Vehicle
Fw	The component of weight in downward.
Fa	The aerodynamic drag.
Fh	The hydraulic force.
Ft	The Friction force.
m	The vehicle mass.
a:	Vehicle acceleration.
ρ:	The air density,(kg/m ^3).
p:	The atmospheric pressure in(kpa).
T:	Air temperature in degrees (Celsius).
V	The vehicle velocity, (m/s).
Cd	The drag coefficient, (dimensionless).
A	The frontal area of vehicle, (m^2).
Pa	Aerodynamic power.
Hp	The hydraulic power.
Pw	The component weight power.
Pr	Friction Power.
Fr	The Friction Force, pounds or Newton's.
μ	The friction coefficient, dimensionless.
W	The weight on the vehicle, pounds or Newton's.
m	Mass of vehicle.
–	The steepness of the hill, angle between horizontal and the road surface.
g	The acceleration of gravity, (9.8 m/s^2).
ω	The angular velocity, (rad/s).
R	The wheel radius (m^2).
Q	The Volume flow rate(m^3/s).

p	Is work pressure for system that impose as available component
N	Pump speed (rpm)
vd	Pump displacement (cm^3/rev).
$p1$	Is the pressure of accumulator before charge (bar)
$p2$	Is the pressure of accumulator after charge (bar)
$v1$	The volume of accumulator before charge
$v2$	The volume of accumulator after charge
vr	Is Reservoir size.
r:	The gear reduction radius
N	Number of bolt.
τ:	Shear stress (Mpa).
Ssy	yield shear strength pt the bolt.
A	Bolt area(m^²).
d	Bolt diameter (m).
x	The distance between the first position for force and new position.

Chapter 1. Introduction.

1.1 introduction.

A hybrid vehicle is a vehicle that uses two or more distinct power sources to move the vehicle. The term most commonly refers to hybrid hydraulic vehicles is (HHVs), which combine an internal combustion engine and one or more hydraulic pump.

The potential value of Hydraulic Hybrid drive trains has been recognized for about 100 years. With consistently high fuel costs and growing environmental concerns related to vehicle emissions, fleet interest in HH technology has reached a new high and today's technical advancements have made Hydraulic Hybrid option, the hybrid vehicle may be classified into two types: the first it is hydraulic hybrids which stores energy in hydraulic accumulators and use hydraulic pump-motors, the second it is electric hybrid which stores energy in batteries and/or ultra-capacitors and use electric generator-motors.

Hydraulic hybrid vehicles (HHVs) store and retrieve energy using hydraulic components, such as pumps and accumulators. It enables recovery and reuses energy normally lost in conventional vehicles during the act of braking. also eliminates idling and reduces engine operation, resulting in significant fuel economy improvement.

The hydraulic hybrid vehicles may be classified either parallel or series ,The parallel hydraulic hybrid vehicle design, keeps the conventional transmission and drive shaft system, and a hydraulic pump/motor adds and subtracts power through the mechanical drive system as shown in figure 1.1. The parallel design does not decouple the ground speed from the engine speed. Testing indicates that the parallel hydraulic hybrid design offers enormous potential for fuel economy improvement and emission reduction compared to traditional drive trains.

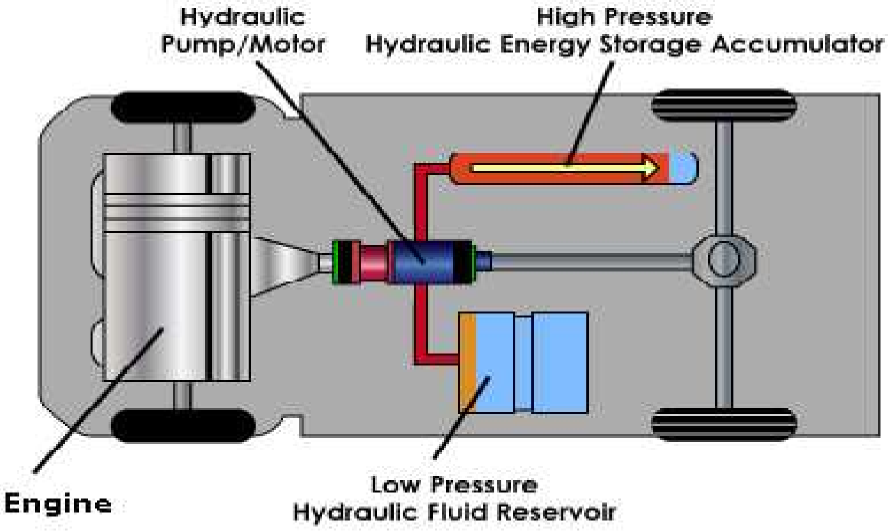


Figure 1.1: Parallel HHV.

The series hydraulic hybrid vehicle as shown in figure 1.2 design eliminates the conventional transmission and drive shaft system, allow the vehicle's ground speed and the engine speed to be decoupled. This permits the engine to be shut off when is not needed such as when the vehicle is in braking or accelerating and to run at best efficiency . In some vehicle applications, the engine can be downsized with no loss of vehicle functionality resulting in more fuel savings. series hydraulic hybrid vehicles have the potential for the biggest efficiency at the lowest cost[1].

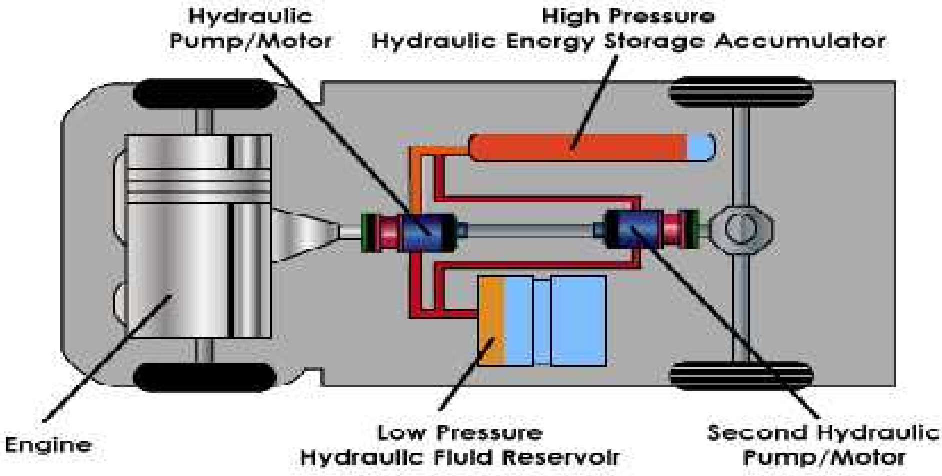


Figure 1.2: Series HHV.

1.2 Why HHV.

The new hydraulic hybrid vehicles technology is designed mainly to improve both fuel efficiency and overall operating economy of vehicles by capturing braking energy and then reusing it to help accelerate the vehicle. HHV components are relatively simple and made out of common materials using well established manufacturing processes, and therefore relatively low cost, compared to Hybrid Electric Vehicle components. Additionally, HHVs are very efficient in recovering, storing, and converting energy.

1.2 The advantages and disadvantages of HHVs :

Advantages:

-Increase vehicle fuel economy through regenerative braking and uses energy normally lost in braking .

-Reduce vehicle emissions .

- Reduce vehicle maintenance costs

-Can increase acceleration performance.

- HHVs are very safe.

Disadvantages:

-Whenever the amount of energy storing in accumulator increase the size of accumulator it is increase.

-When operates this system as a brake the accumulator must be full charged.

1.4 Project description .

Building a hydraulic system on the rear wheels besides the vehicle original an internal combustion engine for front-wheel-drive car as shown in figure 1.3 . This system consists of hydraulic pump/motor ,high pressure hydraulic accumulator , hydraulic oil reservoir , direction control valve, relief valve, tube link and hydraulic fluid.

The purpose of the built hydraulic system is to store the braking energy by taking the movement of the rear wheels, a hydraulic pump that compresses the hydraulic fluid in accumulator , this energy is recovered from the accumulator which to be converted into kinetic energy by a hydraulic motor.

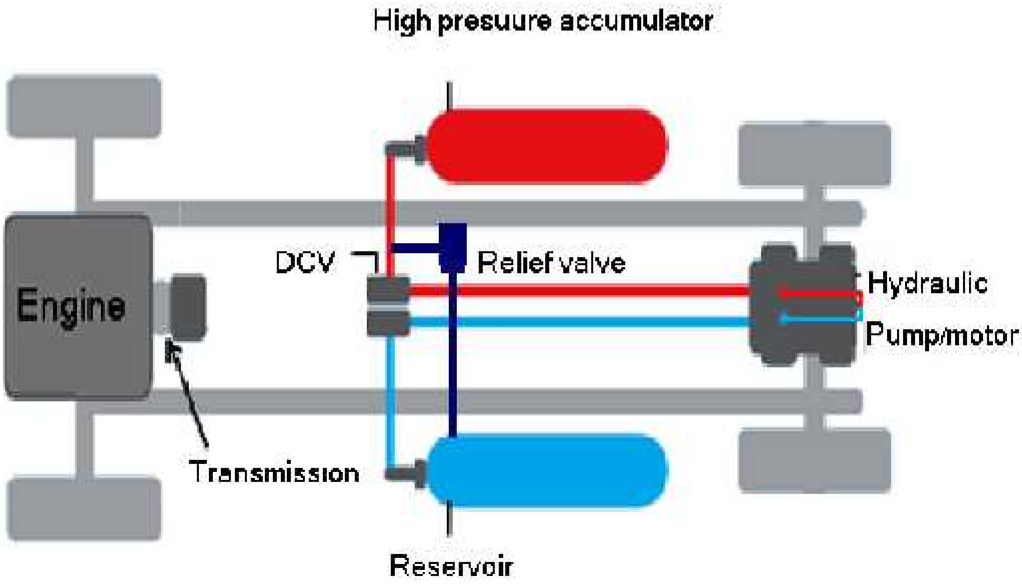


Figure 1.3: Drawing for our project.

1.5 Project stages scheduling.

The first stage sufficient information were collected about the components of the hydraulic system from several references, including books, scientific papers, journals and specialized websites. In second stage is divided the project is divided into parts according to order of work. In third stage the equations that are needed to perform the calculations were selected. In the forth stage the project work time table was set. In the fifth stage a particular hydraulic system specifications were in order to perform a real working model. in the end stage design and built the system on vehicle and take the results.

1.6 Organization of the project .

This work is divided into six chapters, the first chapter is introduction, which gives overview of the project. The second chapter describes the project in details clarifying the principle of operation, operation condition and describes the operation and specification of each component will be used in the project. Chapter three the calculations for excessive power in the braking phase and the calculations for all components were performed . In chapter four the selection of the hydraulic system components was performed. The fifth chapter design the project which builds in the vehicle. In the end chapter analysis the project and writing the results.

Chapter 2 : project details.

2.1 introduction.

Hydraulic hybrid vehicles are much like electric hybrid vehicles. which can recover and utilize more energy than a typical electric hybrid vehicle .That is the nature of hydraulics.

Hydraulic hybrids vehicle draw from two sources of power to operate the vehicle the (diesel or gasoline engine) and the hydraulic system. In other words, a typical diesel-powered or gasoline powered vehicle can be fitted with hydraulic components as a secondary energy source. The hydraulic components used in storing energy are high pressure hydraulic accumulator capable of storing hydraulic compressed fluid against nitrogen gas , hydraulic pump/motor units which regulate the braking power, and a hydraulic oil as a working fluid[1].

Hydraulic drive trains are particularly attractive for vehicle applications . A major benefit of a hydraulic hybrid vehicle is the ability to capture and use a large percentage of the energy normally lost in vehicle braking. Hydraulic hybrids can quickly and efficiently store and release great amounts of energy due to a higher power density. This is a critical factor in maximizing braking energy recovered and increasing the fuel economy benefit. While the primary benefit of hydraulics is higher fuel economy, hydraulics also increase vehicle acceleration performance. Hydraulic hybrid technology effectively allows the engine speed or torque to be independent of vehicle speed resulting in cleaner and more efficient engine operation.

The hydraulic drive system hydraulic pump/motor , connected to rear wheel axis to take the motion of the rear wheels and converted it into energy stored in the accumulator. which used to drive the rear wheel when required.

2.2 Hydraulic power.

Hydraulic power is the technology that deals with the generation ,control and transmission of power, using fluid. Fluid power is called hydraulic when the fluid is liquid and it is called pneumatics when the fluid is a gas, hydraulic systems use liquids such as petroleum oils and water. There are actually two different types of fluid systems. Fluid transport and fluid power. Fluid transport system have as their sole objective the delivery of a fluid from one location to another to accomplish some useful purpose. Fluid power systems are designed specifically to perform work . the work is accomplished by a pressurized fluid bearing directly on an operating fluid cylinder or fluid motor produces a torque resulting in rotary motion. Thus in a fluid power system, cylinders and motors(which are also called actuators), of course control components such as valves are needed to ensure that the work is done smoothly accurately, efficiently and safely[2].

Liquids provide a very rigid medium for transmitting power and thus can operate under high pressures to provide huge forces and torques to drive loads with utmost accuracy and precision.

2.2.1 Advantages of fluid power.

1.Ease and accuracy of control.
2.Multiplication of force. A fluid power system can multiply forces simply and efficiently from a fraction of an ounce to several hundred tons of output.
3.Constant force or torque. only fluid power system are capable of providing constant force or torque regardless of speed change.

4.Simplicity, safety, economy. Fluid power system use fewer moving parts than comparable mechanical or electrical system .Thus ,they are simpler to maintain and operate hydraulic pump which is the heart of hydraulic system, converts mechanical energy into hydraulic energy.

Hydraulic motor extract energy from a fluid and convert it to mechanical energy to perform useful work.

The hydraulic hybrid vehicles is different to other vehicle in some cases and the following table comparing between hybrid vehicles and conventional vehicles.

Table 2.1: compared between hybrid and conventional vehicle.

Type of comparing	Conventional vehicle	Hydraulic Hybrid vehicle
Initial Cost	The Conventional vehicle is less expensive comparing with hybrid vehicle.	Hybrid vehicle more expensive than a conventional vehicle by approximately 30% from price
Fuel consumption and economy	The fuel consumption is high comparing with hybrid vehicle.	Less fuel consumption
Emission	conventional cars pollute the environment higher than hybrid vehicles.	Hybrid vehicle are less emission comparing with Conventional vehicle
maintenance cost	The maintenance cost higher than Hybrid vehicle	Less maintenance cost
Efficiency	Higher Efficiency	Less Efficiency

2.3 Hydraulic system design.

The hydraulic system design is shown in figure 2.1,and it is consisting from the following components:

1.The hydraulic pump which takes its power from the rear wheels during vehicle braking to compress the hydraulic oil fluid into the high pressure accumulator .
2.The high pressure accumulator used to store the hydraulic oil against the high pressure nitrogen.
3.The hydraulic oil reservoir .
4. The hydraulic motors used to drive the rear wheel when the stored energy in accumulator is required.
5. All hydraulic lines and fittings.
6.Directional control valve : used to control the direction of the hydraulic oil from-to - or - from the pump, in other words to operate the pump/motor unit as a pumping unit in one phase and as motor in other phase.
7.Relief valve : to control the pressure in the accumulator.

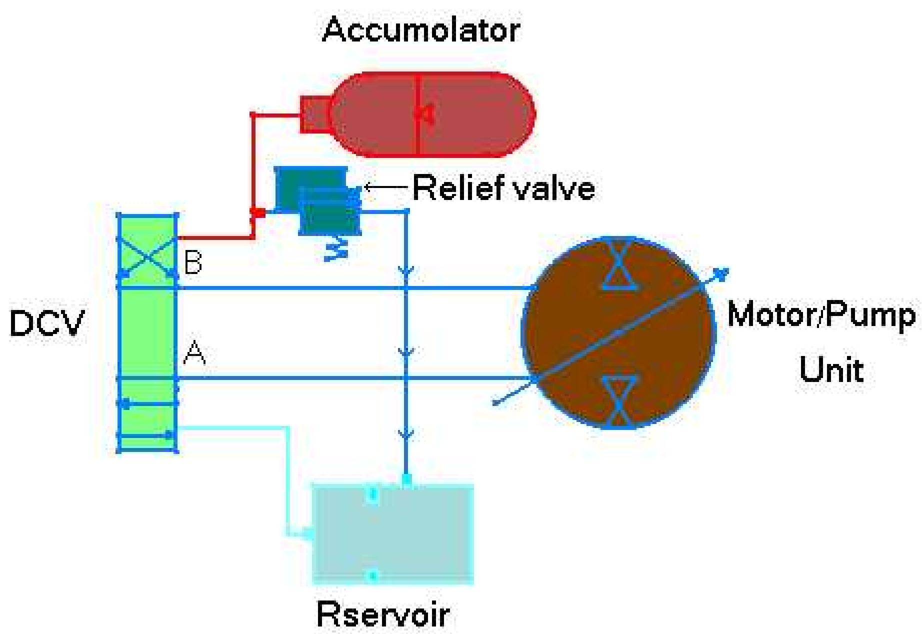


Figure 2.1:Drawing of the hydraulic system.

2.4 Operation principle.

There are two mode of the hydraulic hybrid vehicle operation :

Mode 1: braking.

Mode 2: acceleration.

2.4.1 Braking.

When a vehicle is in braking phase, the kinetic energy must be lowered by changing it to another form of energy. In a conventional brake system, the mechanical braking action changes the kinetic energy into heat energy through friction between the brake components. This heat energy can not be reused to power the vehicle. Regenerative braking is attempt to recapture the kinetic energy of the vehicle during braking to allow it to be used later. This energy is stored in the accumulator for future use to increase the efficiency of the vehicle, and the direction of oil is shown in figure 2.2.

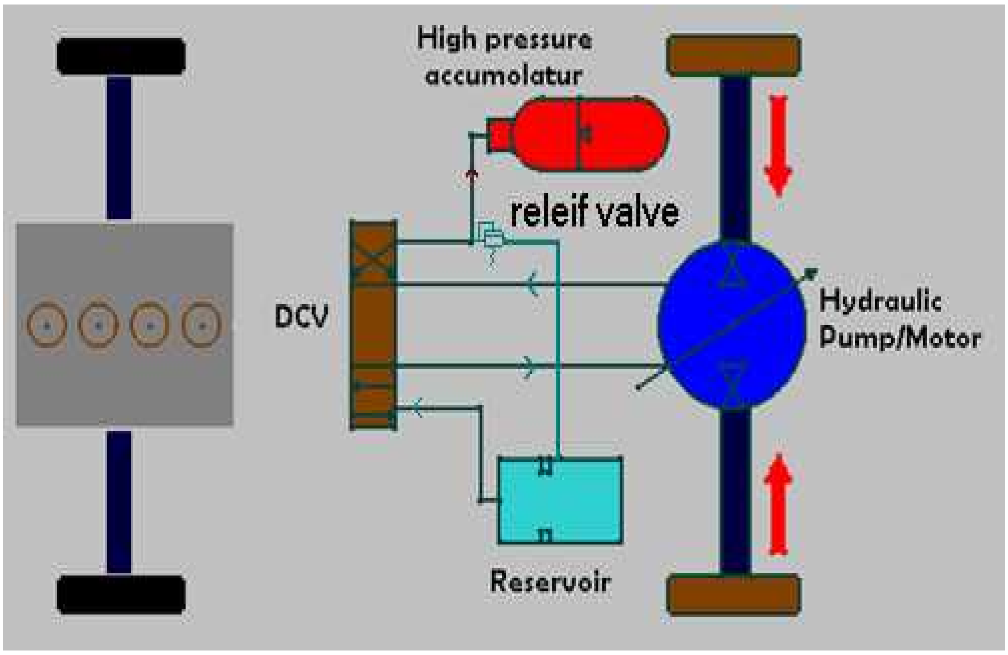


Figure 2.2: Saving energy normally wasted while braking.

There are limits to the amount of energy of the system can accumulated depending on the volume of the accumulator , the temperature and the period of braking.

The hydraulic axial piston unit is coupled to the differential at the rear wheels. During braking, the axial piston unit converts kinetic energy of the wheels into hydraulic energy, and pumps hydraulic fluid into the high pressure accumulator, increasing the pressure in the accumulator.

Energy storage in the hydraulic system requires two devices: a high-pressure accumulator and a low-pressure reservoir as shown in figure 2.3. The energy conservation is applied to the nitrogen gas being compressed by the hydraulic fluid from the pump and throw the reservoir.

Due to fast compression and expansion, the nitrogen gas temperature fluctuates significantly and heat transfer effects are included in the model. since increased heat capacity generally improves accumulator efficiency. The internal friction and the pressure losses at the inlet/outlet and along the connecting hoses are also included in the accumulator model. Typically, the accumulator average efficiency calculated based on the ratio of total energy flowing in and out.

If the period of braking phase exceeds the period that needed to drive the accumulator for it is full capacitance, in this case the relief valve redirected the oil fluid to the reservoir ,thus the pump operating under no load.

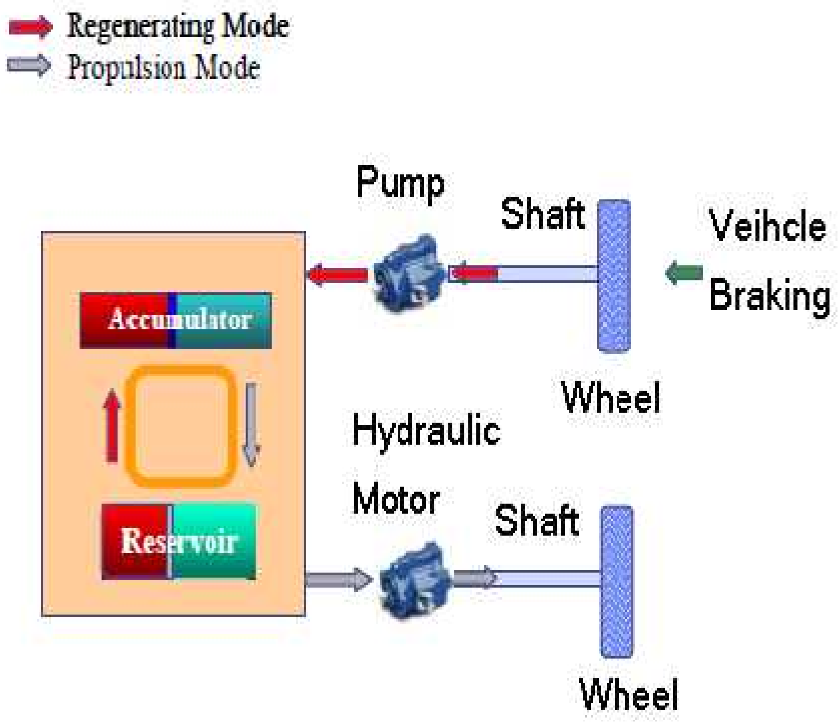


Figure 2.3: Storing and re-delivering
of braking kinetic energy back to the rear wheels.

2.4.2 Acceleration.

During acceleration, the pump inlet and outlet ports will be switched by direction control valve to work as a hydraulic motor. The nitrogen gas forces the hydraulic fluid back into the pump which is now working as a motor to apply torque to the drive the rear wheels, the direction of the fluid is shown in figure 2.4.

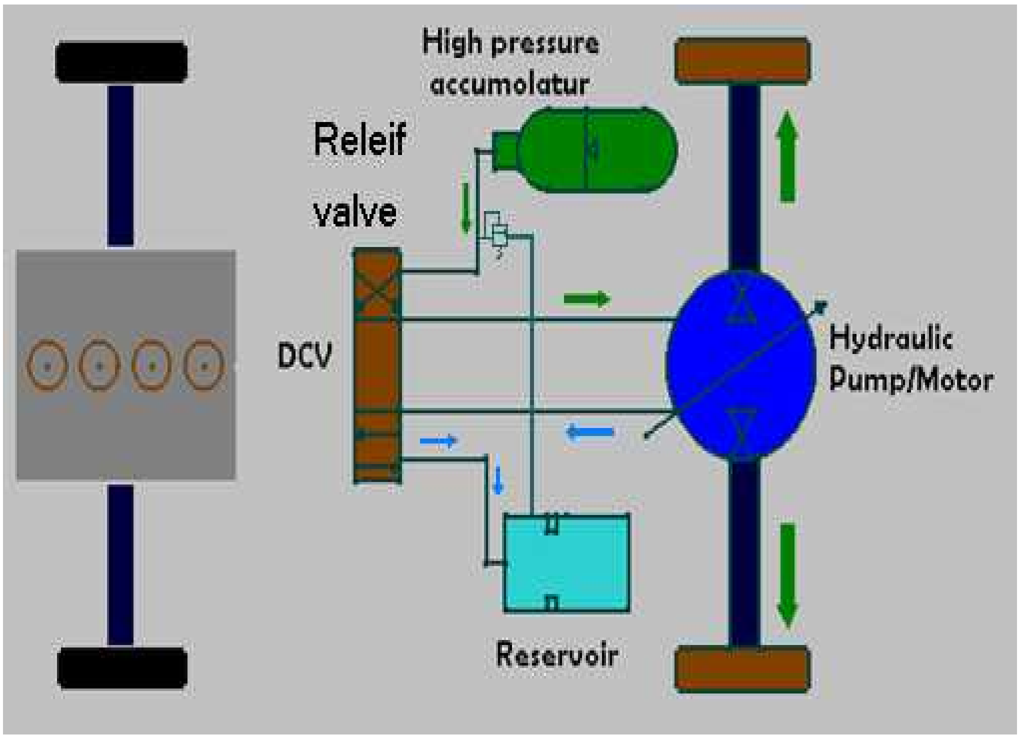


Figure 2.4: Direction of fluid flow in acceleration.

2.5 Components.

The designed parameters of hydraulic hybrid system have remarkable influence on the working performance and fuel saving capacity. Therefore the following hydraulic components were selected:

2.5.1 Hydraulic pump/motor.

The main hydraulic component of a hydraulic hybrid vehicle is the hydraulic pump/motor. The selected pump/motor is a axial-piston variable-displacement type. as shown in Figure 2.5. This type of closed-circuit pump has been used reliably in various hydraulic applications for many years. Depending on which port is pressurized, the pump/motor can operate in both counterclockwise and clockwise directions and as a pump or motor with the same efficiency of between 85% and 90%

depending on speed. Because of this characteristic, the pump/motor can either add power to the system or be used to pump hydraulic fluid to a high-pressure accumulator and store that energy for use in its opposite mode of operation.

Figure 2.5: Axial Piston Pump.

During braking, hydraulic pump/ motor is adjusted via inclination of the swash plate to produce desired braking torque.

2.5.2 Hydraulic accumulator.

A hydraulic accumulator is a pressure storage reservoir in which a non compressible hydraulic fluid is retained under pressure from an external source. Its main function is to store hydraulic energy and gives this energy to the system when the pressure source stopped. A hydraulic accumulator is also referred as the capacitance of the system. The accumulator types may be classified as follows:

Type 1. Dead weight.

The dead weight accumulator consists of a piston loaded with a dead weight and moving within a cylinder that exerts pressure on the hydraulic oil. The dead weight may be of some heavy material such as iron, concrete block, pig or scrap iron etc. For minimum leakage past the piston, it must be a precision fit in the accumulator tube to ensure a long life.

Type 2. Spring loaded**.**

Whether single-spring or multiple-spring type, the springs in this accumulator as shown in figure 2.6 , act against a hydraulic piston forcing the fluid into the hydraulic system. A spring loaded accumulator consists of a cylinder body, a movable piston and a spring. The spring applies force to the piston. As fluid is pumped to it, the pressure in the accumulator is determined by the compression rate of the spring[3].

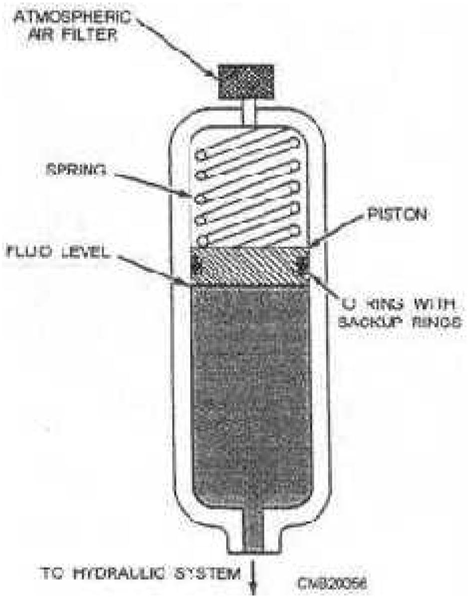


Figure 2.6 Spring loaded.

Type 3. Hydro-pneumatic.

The hydro-pneumatic accumulators are the most commonly used accumulators and apply force to the liquid by using a compressed gas that acts as the spring. It uses only dry nitrogen as there is a danger of exploding an air-oil vapor, in the case of compressed air and the different types of hydro-pneumatic accumulators used are (Non-separator type, but not used due to possibility of foaming) which is consists of a cylinder with hydraulic fluid and the charging gas with no separation between them. They are generally used on die casting machines or other similar places. They are always to be mounted vertically, and the other type (Piston) as shown in figure 2.7, which is consists of a cylinder body and a movable piston. The gas that occupies the volume above the piston is compressed as the cylinder body is charged with liquid, and the third type(Diaphragm) which is consists of two metal hemispheres which are separated by flexible, synthetic rubber diaphragm. The storing action is effected by the compression of the volume of nitrogen enclosed in the diaphragm, and ended type (Bladder**)** as shown in figure 2.8which is consists of a synthetic polymer rubber bladder like chloroprene, nitrile, etc. inside a metal (steel) shell. The bladder is filled with compressed gas. It responds quickly for receiving or expelling flow of oil. There is always a possibility of bladder failure that needs to be taken into consideration.

Figure 2.7 Piston accumulator.

Figure 2.8 Bladder accumulator.

The accumulator contains the hydraulic fluid and inert gas such as Nitrogen, separated by a bladder is used for energy storage in HHV. As the pump transfers the hydraulic fluid into the accumulator, the pressure of the gas sealed inside of it increases, thus storing energy. When discharging, fluid flows out through the motor and into the reservoir. Hydraulic accumulator is designed to have adequate capacity for storing the braking energy of loader.

The accumulator performs the following functions:

a. It controls oil delivery to the hydraulic system from the hydraulic pump.

b. It maintains a constant pressure on the hydraulic system.

c. It reduces shock to the system when control valves are operated.

2.5.3 Reservoir.

A reservoir stores a liquid that is not being used in a hydraulic system as shown in figure 2.9. A properly constructed reservoir should be able to dissipate heat from the oil, separate air from the oil, and settle out contaminates that are in it. Reservoirs range in construction from small steel stampings to large cast or fabricated units. The large tanks should be sandblasted after all the welding is completed and then flushed and steam cleaned. Doing so removes welding scale and scale left from hot-rolling the steel. The inner surface then should be sealed with a paint compatible with the hydraulic fluid. Non bleeding red engine enamel is suitable for petroleum oil and seals in any residual dirt not removed by flushing and steam-cleaning[4].

The size of reservoir sizes will vary. However, a reservoir must be large enough so that it has a reserve of oil with all the cylinders in a system fully extended. An oil reservoir must be high enough to prevent a vortex at the suction line's opening. A reservoir must have sufficient space to hold all the oil when the cylinders are retracted, as well as allow space for expansion when the oil is hot.

Figure 2.9:Reservior.

2.5.4 Directional control valves.

Directional control valves are one of the most fundamental parts in hydraulic machinery. They allow fluid flows into different paths from one or more sources as shown in figure 2.10. They usually consist of a piston inside a cylinder which is electrically controlled. The movement of the cylinder restricts or permits the flow, thus it controls the fluid flow[4].

Figure 2.10 :Directional Control Valves.

2.5.5 Relief valve.

Relief valve are the most common type of pressure-control valves, as shown in figure 2.11. The relief valve function may vary, depending on a system's needs. They can provide overload protection for circuit components or limit the force or torque exerted by a linear rotary motor.

The internal design of all relief valves is basically similar. The valves consist of two sections: a body section containing a piston that is retained on its seat by a spring(s), depending on the model, and a cover or pilot-valve section that hydraulically controls a body piston’s movement. The adjusting screw adjusts this control within the range of the valves.
valves that provide emergency overload protection do not operate as often since other valve types are used to load and unload a pump.

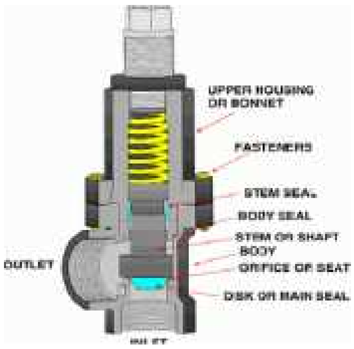


Figure 2.11:Relief valve.

2.5.6 Fittings and Connectors.

Fittings are used to connect the units of a fluid-powered system, including the individual sections of a circulatory system as shown in figure 2.12. Many different types of connectors are available for fluid-powered systems. The type that you will use will depend on the type of circulatory system (pipe, tubing, or flexible hose), the fluid medium, and the maximum operating pressure of a system. Some of the most common types of connectors are described below: threaded connectors and flared connectors[4].

Fittings are made of steel, aluminum alloy, or bronze. The fittings should be of a material that is similar to that of a sleeve, nut, and tubing. fittings are available in many different thread combinations.

Figure 2.12: Fitting and connecter.

Chapter 3: Mathematical calculation of HHV systems.

3.1 Introduction.

Hydraulic hybrid system is designed and sized to capture the braking energy from normal–moderate braking operating modes while ensures working in higher efficiency region.

In order to calculate the dispositive power, the vehicle was consider first as a particle moving on inclined surface as it showed in figure 3.1.a, all forces acting on vehicle in this case considering the hydraulic hybrid system was installed on the vehicle are; the friction force F_r, the hydraulic force F_h, the air resistance force F_a, the vehicle weight component in the direction of the vehicle movement F_w, and the resultant inertia force ma.

Second the vehicle considered as a particle moving on horizontal plane as it is shown in figure 3.1b, considering that the hydraulic hybrid system is disabled, then all the force that acting on the vehicle in the direction of the vehicle movement in this case are; the friction force F_r, the air resistance force F_a and the resultant inertia force **ma**.

By comparing the two cases in figure 3.1.a and figure 3.1.b, we can conclude that, the additional forces that act on the vehicle in figure 3.1.a is the hydraulic force F_h, which acts as a resistance (decreasing vehicle velocity)force and F_w, which acts positively in increasing the vehicle velocity, then by choosing a suitable hydraulic force the effect of the additional force F_w can be canceled and, also the possibility for moving the vehicle in figure 3.1.a in constant velocity which means **a=0** can be achieved.

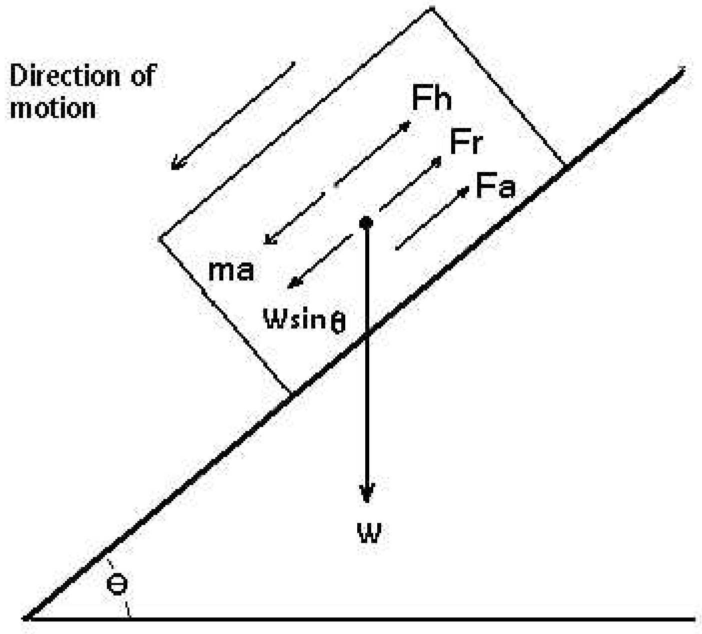


Figure 3.1.a The forces effect on the vehicle when moving on inclined surface with hydraulic system

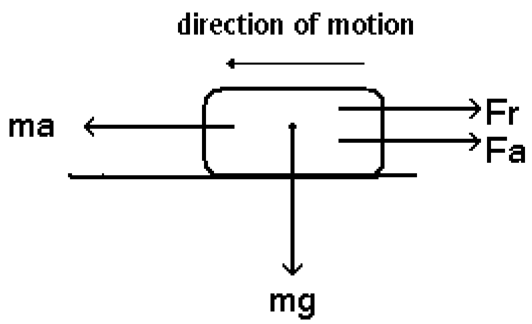


Figure 3.1.b The all force act on vehicle when moving in horizontal plane

Where:

F_w = wsin¯: the component of weight in downward.

F_a: the aerodynamic drag.

F_h: the hydraulic force.

F_r: the Friction force.

m: the vehicle mass.

a: vehicle acceleration.

Taking the free body diagram for the vehicle in figure 3.1.a and figure 3.1.b the force act on vehicle are.

For figure 3.1.a $$\mathbf{F_w - F_r - F_h - F_a = m \times a} \quad 3.1$$

For figure 3.1.b $$\mathbf{F_w - F_r - F_a = m \times a} \quad 3.2$$

3.2 Aerodynamics Force.

At even modest speeds, the major force retarding the motion of a car or truck is aerodynamic drag. In the 1930s, the first attempts were made to reduce aerodynamic drag. The aerodynamic design was based less on science than on “what looks good.” In this century, aerodynamic design has a firm foundation in theory, tests in wind tunnels, and computational fluid dynamics (CFD). some of the 1930s aerodynamic designs had drag coefficients as low as modern cars. The aerodynamic drag going backward than going forward. Aerodynamic drag, F_a, is given by[5].

$$F_a = \frac{1}{2} \times \rho \times V^2 \times Cd \times A \quad 3.2$$

$$\rho = 1.22 \ \frac{p}{101.325} \times \left(\frac{288.16}{273.16 + T}\right) \quad 3.3$$

Where:

F_a: the aerodynamic drag, (N).

ρ: the air density,(kg/m^3).

p: the atmospheric pressure in(kpa).

T: air temperature in degrees (Celsius).

V: the vehicle velocity, (m/s).

C_d: the drag coefficient, (dimensionless).

A: the frontal area of vehicle, (m^2).

Power to overcome aerodynamic drag, *P*a, in watts is

$$Pa = (\frac{1}{2} \times \rho \times V^2 \times C_d \times A) \times V \qquad 3.4$$

Where:

Pa: Aerodynamic power.

The power to overcome drag varies as cube of the vehicle velocity. In the automotive press, the statement is made occasionally that Pa varies as the square of v; however, it varies as the cube of V. This statement is true for high speeds and upward; other retarding forces become less important.

3.3 Friction Force:

The Friction Force(rolling resistance) of a vehicle is due mainly to wheel bearing friction and to the deformation of the tires or road surface. Its value depends upon the nature of the road surface, type and size of tires used,. The force on the tire is also the force on the road surface. The two forces are equal and opposite. The value of the μ, the friction coefficient, changes for different road surfaces, such as dry, covered with ice or snow. And The friction coefficient also depends on the tire design.

3.3.1 Tire and brake.

Almost all forces acting on the vehicle originate in, or are transferred to, the tire patch on the road. Forces between the tire and the road are essential for control of the car. Knowledge of tires is necessary to understand braking.

Its value is also found to increase by too low an air pressure in the tires. The rolling resistance is generally to be independent of the vehicle speed and the total mass of vehicle.

$$Fr = \mu \times W \qquad 3.5$$
$$W = m \times g \qquad 3.6$$

This equation when vehicle travel in straight line. But when the vehicle is being travelled in the downward must the neutralize the effect of component of the vehicle down. The slope is depends entirely upon the steepness of the slope. This equation becomes

$$W = \mu(m \times g \times cos\theta) \qquad 3.7$$

Where:

F_r: the Friction Force, pounds or Newton's.

μ : the rolling friction coefficient.

W : the weight on the vehicle, pounds or Newton's.

m: mass of vehicle.

¯ : the steepness of the hill, angle between horizontal and the road surface.

g: the acceleration of gravity.

Power to overcome Friction Force**:** *Pr*, in watts is

$$P_r = \mu(m \times g \times cos\theta)V \qquad 3.8$$

The power to overcome friction force varies the vehicle velocity and weight .

3.4 The component weight F_w.

It is the force that resultant from the component of weight in downward, this force is the source for external force act on vehicle. It can increase with the increasing the angle of gradient, so this force can be used as a source for energy when it move downward, the amount of it can be determined by the following equation.

$$F_w = m \times g \times sin\theta \qquad 3.9$$

Where;

m : the mass of vehicle, (kg).

g : the acceleration of gravity, (9.8 m/s²).

¯: the steepness of the hill, angle between horizontal and the road surface, (degree).

The power resultant of component of the vehicle weigh in downward varies as the vehicle velocity and weight. So that the power is

$$P_w = v \times F_i \quad 3.10$$

$$P_w = v \times m \times g \times sin\theta \quad 3.11$$

3.5 Hydraulic power.

Hydraulic power is the technology that deals with the generation ,control and transmission of power, and also which use the fluid Liquids to provide a very rigid medium for transmitting power and thus can operate under high pressures to provide huge forces and torques to drive loads with utmost accuracy and precision.

Now , we have established the concepts of flow rate and pressure then the power delivered can be found by a hydraulic fluid to a load- driving devices such as hydraulic motor or pump. This power is called hydraulic power[3].

Hydraulic power = pressure* volume flow rate

That is for pump and for hydraulic motor

$$Hp = T \times \omega \quad 3.13$$

$$T = F_h \times R \quad 3.14$$

$$Hp = F_h \times R \times \omega \quad 3.15$$

$$v = r \times \omega \quad 3.17$$

$$Hp = F_h \times v \quad 3.18$$

Where:

ω : the angular velocity, (rad/s).

R: the wheel radius (m²).

Q : the Volume flow rate(m³/s).

F_h: the hydraulic force(N).

Hp: the hydraulic power.

The purpose of making hydraulic system is to store the braking energy by taking the movement of the rear wheels and converted into energy stored in the accumulator, we can do this by compressing hydraulic fluid by using the pump and this energy is recovered from accumulator. The pump will be selected by calculating this energy (hydraulic power) by using equation 3.1 and substituting all force magnitude will found.

.

$$m \times g \times sin\theta - \mu \times m \times g \times cos\theta - Fh - 1/2 \times \rho \times v^{\wedge}2 \times C_d \times A = m \times a \qquad 3.19$$

Where :

a: the acceleration of vehicle(m/s²)

But considering acceleration of vehicle is zero .

So that

$$m \times g \times sin\theta - \mu \times m \times g \times cos\theta - F_h - 1/2 \times \rho \times V^{\wedge}2 \times Cd \times A = 0 \qquad 3.20$$

But

$$F_h = Hp/V \qquad 3.21$$

So that

$$m \times g \times sin\theta - \mu \times m \times g \times cos\theta - Hp/V - 1/2 \times \rho \times V^{\wedge}2 \times Cd \times A = 0 \qquad 3.22$$

By convert all this force equation to power equation that are

$$V \times m \times g \times sin\theta - V \times \mu \times m \times g \times cos\theta - Hp - 1/2 \times \rho \times V^{\wedge}3 \times Cd \times A = 0 \qquad 3.23$$

$$P_w - P_r - Hp - P_a = 0 \qquad 3.24$$

$$Hp = P_w - P_r - P_a \qquad 3.25$$

3.6 Hydraulic pump/motor.

The assistant power source in HHV is an axial piston pump/motor with variable displacement, whose displacement is adjusted via inclination of the swash plate to absorb or to produce desired torque .While launching, hydraulic pump/motor provides the total propulsion power avoiding engine operating in the regions of low efficiency and significant emissions. During braking, hydraulic pump/motor is adjusted via inclination of the swash plate to produce desired braking torque. Accordingly, hydraulic pump/motor displacement is determined by the following equations.

$$P = p \times Q \qquad 3.26$$

$$Q = N \times vd \qquad 3.27$$

Where:

$\boldsymbol{P}$: is power calculate before in equation number 3.11 (bar)

$\boldsymbol{p}$: is work pressure for system that impose as available component

Q : the volume flow rate (cm^3)

$\boldsymbol{N}$: pump speed (rpm)

$\boldsymbol{vd}$: pump displacement (cm^3/rev).

3.7 Hydraulic accumulator:

The hydraulic accumulator contains the hydraulic fluid and inert gas such as Nitrogen, separated by a bladder which is used for energy storage in HHV. As the pump transfers the hydraulic fluid into the accumulator, the pressure of the gas will be sealed inside Because its size will be increased , this is the storing energy. When discharging, fluid flows out through the motor and into the reservoir. Hydraulic accumulator is designed to have adequate capacity for storing the braking energy of loader. The volume of hydraulic accumulator by assuming isothermal may be expressed as:

$$P1 \times v1 = P2 \times v2 \qquad 3.28$$

It is well known that the value of pressure after discharge

$$p1 = 0.7 \times p2 \qquad 3.29$$

$$\frac{v2}{v1} = p1/p2 \qquad 3.30$$

$p1$: is know that is work pressure for system that impose as available component .

where:

$p1$: is the pressure of accumulator before charge (bar)

$p2$: is the pressure of accumulator after charge (bar)

$v1$:the volume of accumulator before charge

$v2$:the volume of accumulator after charge

After that the ratio between volume before and after charge is know Based on this result, It would be possible to know the size of accumulator with return to Special schedules and choose that based on this result.

3.8 Sizing of reservoir.

The design of a reservoir is based on the following criteria:

1. It must allow for the dirt and the chips to settle and for the air to pass.
2. It must be able to hold all the oil that might drain into the reservoir from the system.
3. It must maintain the oil level high enough to prevent a whirlpool effect at the pump inlet line opening.
4. It should have a large surface area enough to dissipate most of the heat generated by the system.
5. It must have adequate air space in order to allow the internal expansion of the oil.

A reservoir having a capacity of three times. The volume flow rate of the pump has been found to be adequate for the most hydraulic systems where average demands are expected. this relation is given by.

Reservoir size(m^3)=3*pump flow rate (m^3/min).

$$vr = 3 \times Q \quad 3.31$$

Where :

vr: is Reservoir size.

3.6 Regenerative Braking.

The obvious function of braking is to stop or to reduce the vehicle speed. In addition, brakes must be worked in order to maintain directional stability. The brakes must avoid locked wheels that have a negative effect on steering and stability. For regenerative braking, the goal is to recover as much as possible of the vehicle kinetic energy (KE) .Regenerative braking is not a new concept. Regenerative braking was used in hybrid vehicles in 1900s.Also, regenerative braking has been used in trolleys and street cars for 100 years; the generated power goes back into the power line[6].

Brakes are a critical component for safety. A fail-safe mode requires high braking capability; hence, friction brakes must be as large as possible for a conventional car without regenerative braking. Peek under a hybrid—the brakes are big, if not bigger, than a conventional car. If regenerative braking were 100% efficient, friction brakes would be unnecessary. During normal driving, much of the braking load is carried by regenerative braking; hence, therefore, friction brakes should last very long.

Chapter 4: Component Selection for actual design.

4.1 Introduction.

The final design of the hydraulic system is shown in fig 4.1 and it consists of an axial hydraulic pump motor, the high pressure hydraulic accumulator ,3/4 way direct control valve, the oil reservoir, relief valve and the tubes.

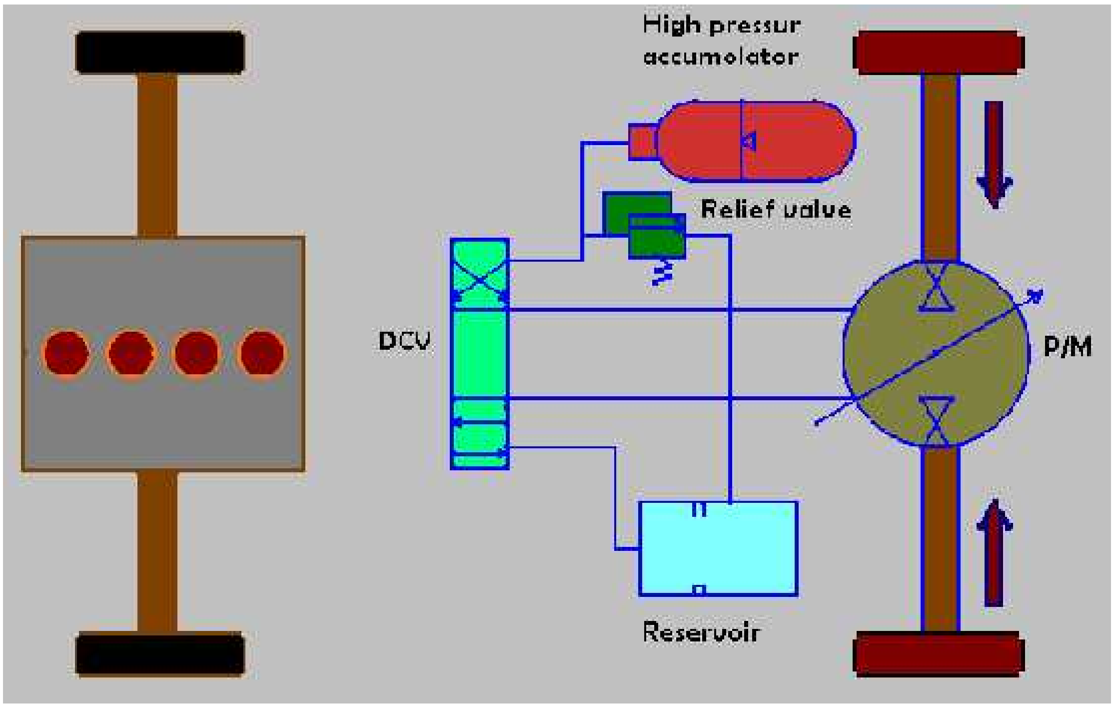


Figure 4.1 The component of hydraulic hybrid system.

The specification of these components will be selected based on our particular design of the hydraulic for a vehicle of the type Mitsubishi Magnum L200 with the following Specifications.

1. the mass of the vehicle is 1700 kg.
2. the front area A is $1.8m^2$.
3. the drag coefficient Cd is 0.45.
4. moving inclined surface at an angle equal 20 degree.

5. the atmospheric pressure $\boldsymbol{p}$ is 0.96 bar.
6. the friction coefficient μ=0.32.
7. the air temperature $\boldsymbol{T}$ is 20 ° C.
8. the wheel radius $\boldsymbol{R}$ is 30cm.
9. choosing legal speed for driving of about 50km/h.
10. the final drive gear redaction $\boldsymbol{gr} =$ 2.1

The value of selected speed is based on the Palestinian regulations for city driving allowed speed, after that, the amount of absorb power at that speed is calculated by the using the Excel program. Based on this information, the power that must be absorbed by hydraulic system will be known, then the working pressure for the system will be chosen based on the availability of the hydraulic components in the local market and will be 150 bar.

4.2 Power Calculation.

The amount of power that must be absorbed by the hydraulic system at wanted speed is calculated by the equation 3.23 , which give the Instantaneous power at any speed.

And by evaluating of equation 3.3 the density of the air is equal:

$\boldsymbol{\rho = 1.15kg/m\text{^}3}$

Now, by substituting all variable in equation 3.1 the hydraulic power at the selected speed is

Hp =8.356 k watt.

$\boldsymbol{Hp =}$**11.18 hp.**

The calculation of the hydraulic bump power will change with the change of the pressure and the displacement volume. The hydraulic power can be calculated by using equation 3.26 and equation 3.27 that are:

$$P = p \times Q$$

In this case, it will be considered that the pump power equal to the hydraulic power. The maximum working pressure of the system is equal 150 bar as it noted before then,

$$Q = Hp/p$$

$$Q = \frac{11.18 \times 10^3}{150 \times 101.325 \times 10^3}$$

$$Q = 7.35 \times 10^{-4} \ \frac{m^3}{s}$$

$$Q = 7.35 \times 10^{-4} \times 1000 \times 60$$

$$Q = 44.1\ Lpm$$

$$Q = N \times vd$$

$$N = (V \times gr/60)$$

$$N = \frac{50 \times 60 \times 2.1}{3.6}$$

$$\mathrm{N} = 1750\ rev/min$$

$$vd = \frac{Q}{N}$$

$$vd = \frac{44.1}{1750}$$

vd =**0.0252 l/rev**

The flow rate is Q= 44.1 Lpm and the maximum pressure is 150 bar and hydraulic power =8.356KWAtt , according to this result and from table (1.1) the input speed 1750 rpm and depending on this speed and the pressure from table(4.1) the input torque is 181Nm,by taking the torque and the hydraulic max power the selected pump is (ADU041) and it is of piston type.

Table 4.1:Cataloge of selected pump.

POWER AND TORQUE RATINGS

Modal Series	Maximum Input Power at Maximum Speed and 280 bar (4000 psi) kW (hp)	Standby Power Loss at Maximum Speed and Minimum Pressure kW (hp)	Maximum Torque at 280 bar (4000 psi) Nm (lb-ft)
ADU041	53.9 (67.9)	.98 (1.3)	185 (135)
ADU049	61.1 (81.5)	.98 (1.3)	220 (161)
ADU062	75.9 (101.3)	1.1 (1.5)	279 (204)

MASS MOMENT OF INERTIA VALUES

Displacement	Nm-sec² (lb-in-sec²)
ADU041	.0033 (.0286)
ADU049	.0033 (.0286)
ADU062	.0096 (.0409)

NOISE LEVEL

Per ISO 3740; Semi-anecohic; Average of 6 microphones
Full Flow @ 49°C (120°F), 210 bar (3000 psi), zero inlet

Model	rpm	dB(A)
ADU062	1800	75

4.4 Hydraulic Accumulator.

In this case, the accumulator will be considered isothermal system, then the different in temperature before and after charge is negligible because there are enough time to charge. So that the volume ration for accumulator depend on inert gas that is nitrogen so, the ratio can be calculated using ideal gas low for isothermal systems which shown in equation 3.28. Where the magnitude P1 between (50-70%) from P2 which is generally known from the industry of accumulator. then the pressure after discharge equal :

$$P1 = 150 \times 0.6$$

$$P1 = 90\ bar$$

$$\frac{v2}{v1} = \frac{p1}{p2}$$

$$\frac{v2}{v1} = \frac{150}{20}$$

$$\frac{v1}{v2} = 7.5$$

The accumulator was chosen is Bladder Accumulator.

The main advantages of a bladder accumulator are fast acting, no hysteresis, not susceptible to contamination and consistent behavior under similar conditions. Accumulators are easy to charge with the right equipment. Because there is no piston mass, the speed of the bladder accumulator is governed by the gas, which reacts very fast to changes in hydraulic system pressure. Hence bladder accumulators are the best choice for pressure pulsation damping. Also, the bladder attachment internal to the accumulator has proven to be very reliable in service. Of course, there is always the potential for bladder failure, which is a failure that would not usually be detectable in service. Also, temperature differences on the gas will have some affect on performance. The main limitation of bladder accumulators is the compression ratio (maximum system pressure to recharge pressure) which is limited to approximately 4 to 1. Hence gas accumulators will be larger than other accumulators for the same flow requirements. The recharge pressure is typically set to approximately 80% of the minimum desired hydraulic system pressure.

4.5 Choosing Reservoir.

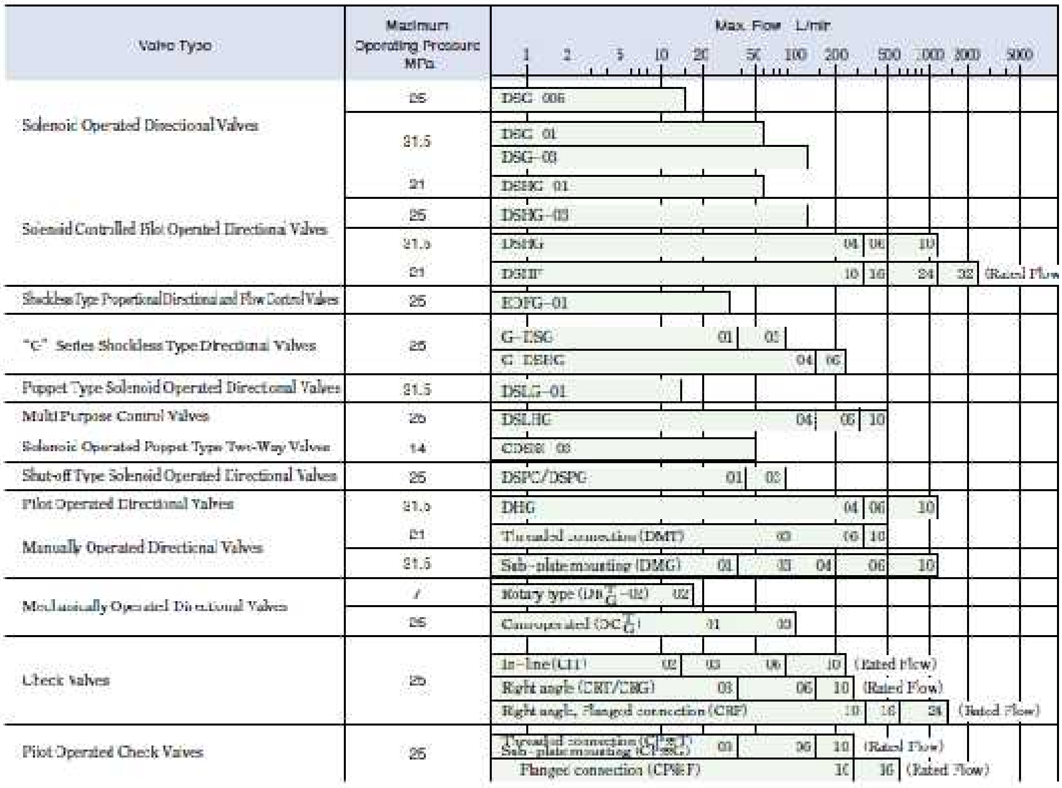
A reservoir stores a liquid that is not being used in a hydraulic system. It also allows gases to expel and foreign matter to settle out from a liquid. The oil level should be high as possible as above the opening to a pump's suction line. This prevents the vacuum at the line opening from causing a vortex or whirlpool effect, which would mean that a system is probably taking in air. Aerated oil will not properly transmit power because air is compressible. Aerated oil has a tendency to break down and lose its lubricating ability.

A reservoir must be large enough, so that it has a reserve of oil with all the cylinders in a system fully extended. An oil reserve must be high enough to prevent a vortex at the suction line's opening. A reservoir must have sufficient space to hold all the oil when the cylinders are retracted, as well as allow space for expansion when the oil is hot.

4.6 Direction Control Valve.

The maximum pressure of the system is 250 bar and maximum flow rate is 44.1 L/min, according to this information the (shockless type proportional directional and flow control valve) was chosen the DCV from table 4.2.

Table 4.2 :table selection the DCV.



4.7 Relief Valves:

Relief valves are the most common type of pressure-control valves. The relief valves' function may vary, depending on a system's needs. They can provide overload protection for circuit components or limit the force or torque exerted by a linear actuator or rotary motor.

The relief valve use To calibrate the pressure within the system in hydraulic system, if the pressure of system increase about the range of work, the relief valve will open the return line to oil reservoir, it connect between entrance of accumulator and oil reservoir. The pressure work for hydraulic system is 150 bar, the relief valve will choosing to work if pressure increase above 150 bar .and from catalog choosing the valve.

4.8 Fitting and Tube.

Pipes and fittings, with their necessary seals, make up a circulatory system of liquid-powered equipment. Properly selecting and installing these components are very important. If improperly selected or installed, the result would be serious power loss or harmful liquid contamination. The following is a list of some of the basic requirements of a circulatory system:

• Lines must be strong enough to contains liquid at s desired working pressure and the surges in pressure
that may develop in s system.

• Lines must be strong enough to support the components that are mounted on them.

• Terminal fittings must be at all junctions where parts must be removed for repair or replacement.

• Line supports must be capable of
damping the shock caused by pressure surges.

• Lines should have smooth interiors to reduce turbulent flow.

• Lines must have the correct size for the required liquid flow

• Lines must be kept clean by regular flushing or purging.

• Sources of contaminants must be eliminated.

Fittings are used to connect the units of a fluid-powered system, including the individual sections of a circulatory system. Many different types of connectors are available for fluid-powered systems. The type that you will use will depend on the type of circulatory system (pipe, tubing, or flexible hose), the fluid medium, and the maximum operating pressure of a system. From table 1.3 will chose the type of tube at work pressure at 150bar is 10C2A.

Table 1.2 catalog for selected tube:

Recommended For : High pressure hydraulic oil lines. Meets or exceeds the requirements of SAE 100R2A and performance requirements of DIN 20022 2ST/EN 853 2ST.

Tube : Black, oil-resistant, synthetic rubber (Nitrile).

Reinforcement : Two braids of high-tensile steel wire.

Cover : Black, oil and abrasion resistant synthetic rubber (Modified Nitrile).

Temperature Range : -40°C to +100°C constant. For water emulsions, etc., see page 24.

Made in India for Domestic & Global Markets

Skiving Required

SPECIFICATIONS

Description	Hose I.D.		Hose O.D.		Braid O.D.		Working Pressure		Minimum Burst Pressure		Minimum Bend Radius
	in.	mm	in.	mm	in.	mm	psi	bar	psi	bar	in.
4C2A	1/4	6.4	0.69	17.5	0.50	12.8	5,800	400	23,200	1,600	4.0
5C2A	5/16	7.9	0.75	19.1	0.57	14.4	5,075	352	20,400	1,408	4.5
6C2A	3/8	9.5	0.84	21.3	0.65	16.6	4,800	331	19,200	1,324	5.0
8C2A	1/2	12.7	0.97	24.6	0.78	19.7	4,000	276	16,000	1,104	7.0
10C2A	5/8	15.9	1.09	27.7	0.91	23.0	3,625	250	14,500	1,000	8.0
12C2A	3/4	19.0	1.25	31.8	1.06	26.9	3,100	214	12,400	856	9.5
16C2A	1	25.4	1.56	39.6	1.37	34.8	2,400	166	9,600	664	12.0

Chapter 5. Model Analysis.

5.1 introduction.

The hydraulic system was built in the rear wheels of the vehicle as shown in figure 5.1, this system is working in three phases:

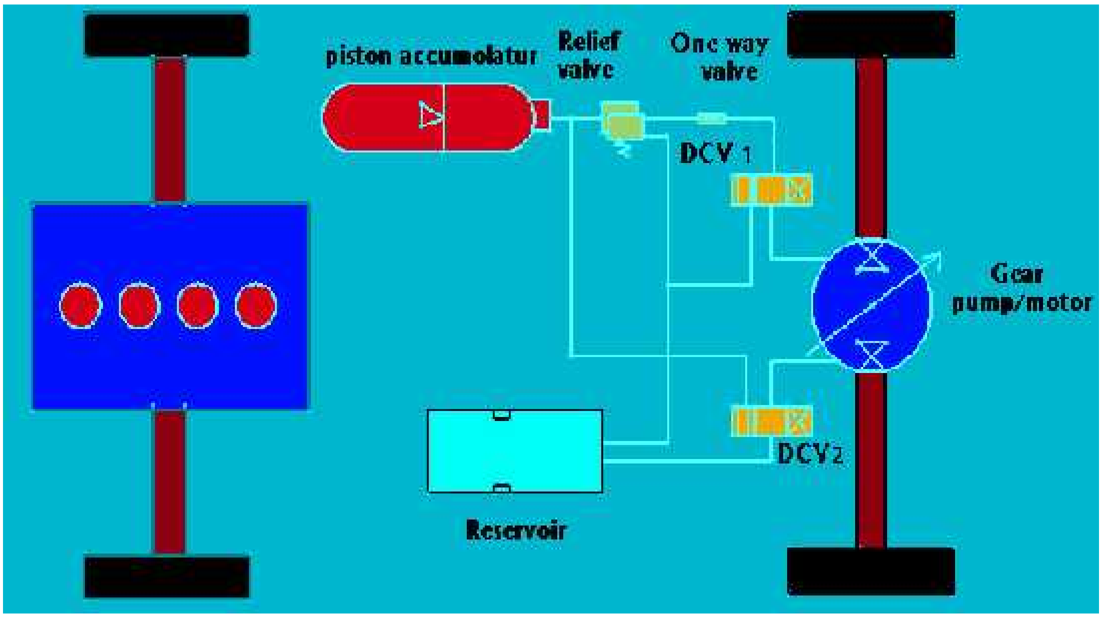


Figure 5.1:The hydraulic model was built on vehicle.

Phase 1: The stage of charging the accumulator when the driver press the brake pedal. The hydraulic pump is working by taking the movement from the rear wheel and flow the fluid in the direction of the accumulator and the DCV (1) is opened to allow the fluid to inter the accumulator and pressurize the nitrogen gas to about 150 bar (accumulator full charge), if the pump continues fluid flow and the accumulator is full charge the mechanical relief valve is opened and changed the direction of fluid flow to the reservoir.

Phase 2 :When the accumulator is fully charged and the pump continues working, the hydraulic circle works as neutral under no pressure, in this stage the second purpose of this project is achieved and the system can be operated system as braking system. by applying brake on the rears wheel and which affects on the speed of the vehicle, in this stage the DCV (1) is opened to the reservoir.

Phase 3:When the energy stored in the accumulator is needed to produce acceleration, the DCV (2) can opened in the direction of the pump by the on/off switch to allow the fluid to operate the pump as a motor to accelerate the rear wheel, in this case the DCV (1) is opened in the direction of the reservoir.

5.2.Analysis the component.

The component which selected to building the model on vehicle is different from those selected in ideal model due to several factors including price of this component and available in the local market.

5.2.1.1. Hydraulic Pump/Motor.

Hydraulic pumps which convert mechanical energy from a prime mover (engine or electric motor) into hydraulic (pressure) energy. The pressure energy is used then to operate an actuator, pumps push on a hydraulic fluid and create flow.

All pumps create flow, They operate on the displacement principle, fluid is taken in and displaced to another point.

The pump/motor which was selected in the previous chapter because of it's high efficiency is axial piston variable displacement pump but the pump which is used in the model is external gear pump/motor.

5.2.1.1External gear pump/motor overview:

External gear pumps are a popular pumping principle and are often used as lubrication pumps in machine tools, in fluid power transfer units, and as oil pumps in engines and consists of two gears, pressure and suction ports ,drive shaft, As shown in Figure 5.2 :

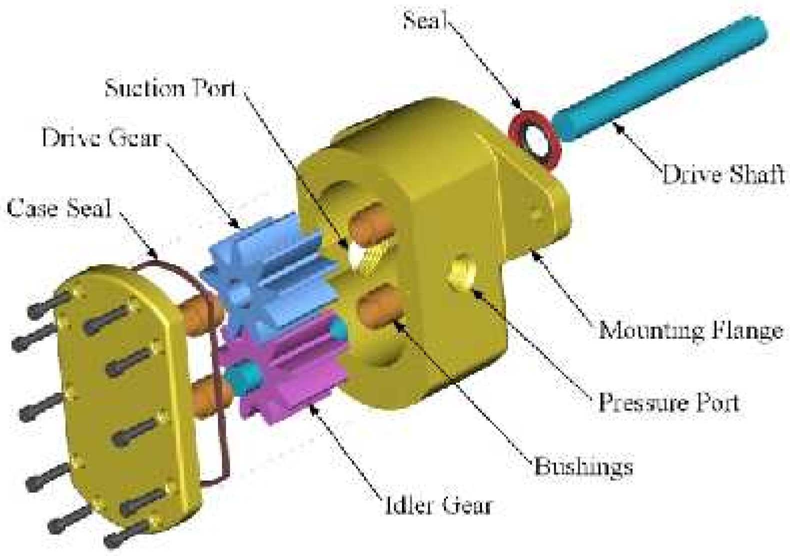


Figure2.2 : External gear pump.

5.2.1.2.External Gear Pumps Work:

External gear pumps are similar in pumping action to internal gear pumps in that two gears come into and out of mesh to produce flow. However, the external gear pump uses two identical gears rotating against each other , one gear is driven by a motor and it in turn drives the other gear. Each gear is supported by a shaft with bearings on both sides of the gear, which show in the figure 5.3.

Figure 5.3: Principle of operation for gear/pump motor.

1. As the gears come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the gear teeth as they rotate.

2. Liquid travels around the interior of the casing in the pockets between the teeth and the casing -- it does not pass between the gears.

3. Finally, the meshing of the gears forces liquid through the outlet port under pressure.

Because the gears are supported on both sides, external gear pumps are quiet-running and are routinely used for high-pressure applications such as hydraulic applications. With no overhung bearing loads, the rotor shaft can't deflect and cause premature wear[4].

5.2.1.3.Advantages.

- High speed.
- High pressure.
- No overhung bearing loads.
- Relatively quiet operation.
- Design accommodates wide variety of materials.

5.2.2. Piston accumulator.

Piston accumulators provide a means of regulating the performance of a hydraulic system, They are suitable for storing energy under pressure, the Accumulator used in this project was designed by us because it is not available in the local market at suitable price. A cylinder has been selected with it is piston of a particular type of bulldozers as described in the figure 5.4:

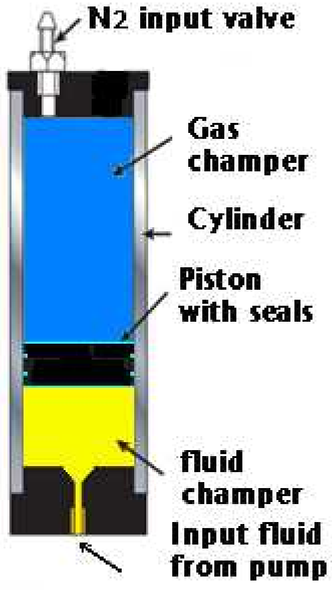


Figure 5.4 :Piston accumulator.

The piston accumulator type consists of a fluid section and a gas section with the piston acting against the nitrogen gas. The fluid section is connected to the hydraulic circuit so that the piston accumulator draws in fluid when the pressure increases and the gas is compressed. When the pressure drops, the compressed gas expands and forces the stored fluid into the circuit.

In designing the accumulator, the following factors was considered

➔ maximum working pressure.

- ➔ fluid capacity.
- ➔ gas capacity.
- ➔ flow rate, port type and size.
- ➔ mounting space and orientation.

The accumulator which was chosen has the following properties:

A : Specification

Max. working pressures 250 to 350 bar.

Bore sizes (nominal):

Working temp. range shell: -20 to +150°C .

Fluid volumes about 12 liters.

Max. piston speed 4m/s.

Gas valve 350 bar rated cored type.

B : Materials

Shell – high strength steel.

End caps – steel.

Pistons – lightweight steel alloy.

Piston and end cap seals – NBR (standard): other compounds to suit application.

Piston seal backup washers – PTFE.

Gas valve assembly – stainless steel.

Gas valve protector – steel.

5.2.3. Oil reservoir.

The hydraulic reservoir is the fluid store tank , It contains a finite amount of liquid fluid that must be stored and reused continually as the system works, in this project chose a reservoir expands 20 liters oil which are sufficient to operate the system.

The reservoir as shown in the figure 5.5 is used in the system, which located at level above the pump to achieve smoothly flow to the pump. it capacity is cabable of containing the return fluid from the system.

Figure 5.5:Oil Reservoir.

The properties of this reservoir are:

-has large surface area to transfer heat from the fluid to the surrounding environment.

-access to remove used fluid and contaminants from the system and to add new fluid.

-simple connected to other component.

5.3.4.Directional control valve:

Directional control valves are one of the most fundamental parts in hydraulic machinery. They allow fluid flow into different paths from one or more sources. They usually consist of a piston inside a cylinder which is electrically controlled. The movement of the cylinder restricts or permits the flow, thus it controls the fluid flow.

In the component selection in the project in the previous chapter, the 3/4 directional control valve is chosen to control the hydraulic system in the vehicle in the model the 3/4 DCV is replaced by 2-two way directional control valve as show in the figure 5.6 which can be controled by electric switch by the driver of the vehicle to switch on or off the hydraulic model[7].

Figure 5.6:directional control valve.

5.3.5. Relief valve:

The relief valve is a type of valve used to control or limit the pressure in a hydraulic system which can build up, The pressure is relieved by allowing the pressurized fluid to flow. The relief valve is designed to open or redirect the fluid flow at specific pressure, and may be in the form of mechanic or electronic types.

The mechanic relief valve as shown in figure 5.7 is used in the model which connected with one way valve as shown in the figure 5.8 to prevent the fluid flow back in the same pipe when discharging the accumulator[7].

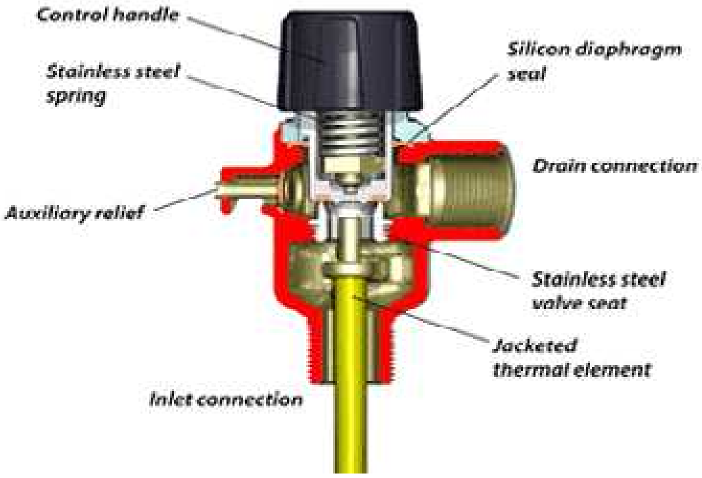


Figure 5.7:Mechanic relief valve

Figure 5.8:One way valve.

When the accumulator is fully charged (the pressure of nitrogen gas is 150 bar) the relief valve is open and redirect the fluid flow from pump to reservoir, which can system work as neutral ,and in this case can operates the system as a braking.

5.3.6.Fitting and tube.

A typical hydraulic tube consists of an inner tube, one or several reinforcement layers, and an outer cover. Each component is vital for the performance and reliability of the tube. The inner tube must be compatible with the fluid it carries. Typical tube materials are thermoplastic compounds, synthetic rubber, and Teflon.

The reinforcement layer (or layers) is wrapped around the tube so that the hose can withstand the operating pressure.

The inside diameter of a hose must be large enough to minimize the pressure losses. This lowers the heat generated by the losses and reduces the turbulence. Hose manufacturers recommend using a Fluid Velocity nomogram for the proper hose ID selection. This nomogram normally is available in hose catalogs[7] .

Fittings as shown in Figure 5.9 are used to connect the units of a fluid-powered system, including the individual sections of a circulatory system. Many different types of connectors are available for fluid-powered systems. The type that you will use will depend on the type of circulatory system (pipe, tubing, or flexible hose), the fluid medium, and the maximum operating pressure of a system[4].

Figure:5.9. Fitting and tube.

5.3.8. Hydraulic fluid:

The primary function of a hydraulic fluid is to convey power. In use, however, there are other important functions of hydraulic fluid such as protection of the hydraulic machine components. The following characteristics and properties are Taken into account for selected the type hydraulic oil:

- Low temperature sensitivity of viscosity;
- Thermal and chemical stability;
- Low compressibility;
- Good lubrication (anti-wear and anti-stick properties, low coefficient of friction);
- Filterability;
- Rust and oxidation protection properties;
- Low flash point(the lowest temperature, at which the oil vapors are ignitable);
- Resistance to cavitation;
- Low foaming;

Chapter 6. Model Design.

6.1. Introduction.

This part of the project shows, the mechanical parts used in the project, clarify the design method, and the parts arrived by welding and bolts, through the use of the program CATIA:

1. Show pieces and assembled.

2. Work simulation of the pieces on the program through the selected types of materials used and the choice of materials used for the collection(welding and bolts) and the compilation of these are pieces as they are on the ground.

3 . Analysis of the forces and mechanical parts to illustrate the results by report from the same program.

6.2. Show pieces and assembled.

After drawing mechanical parts, each one alone, to identify the dimensions, identify materials used, chose the appropriate type of welding and type the appropriate screws, pieces have been grouped together according to the existing practice, in figure 6.1:

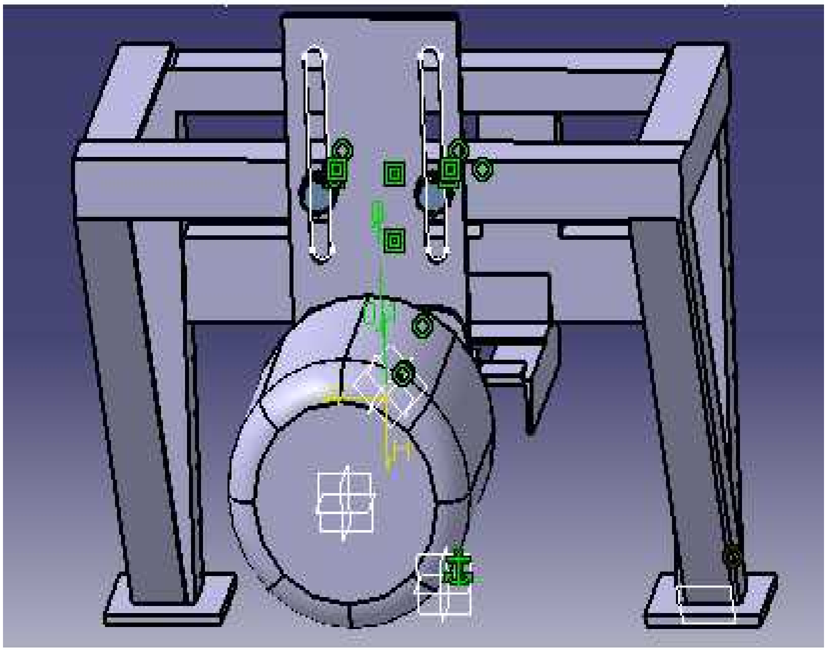


Figure 6.1:Actual Model On Vehicle.

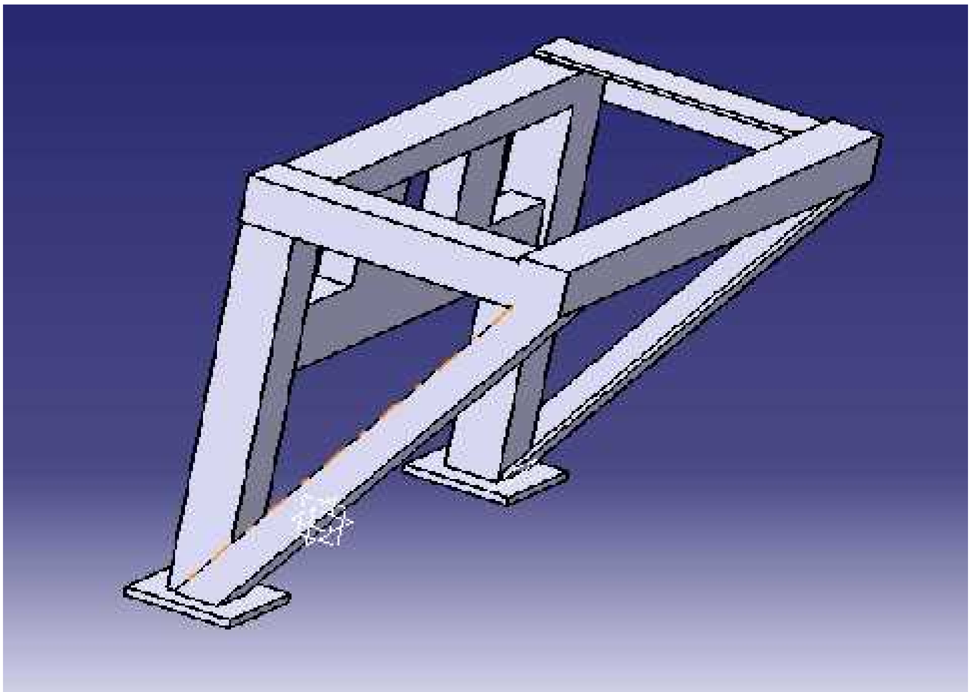


Figure 6.2: Base body.

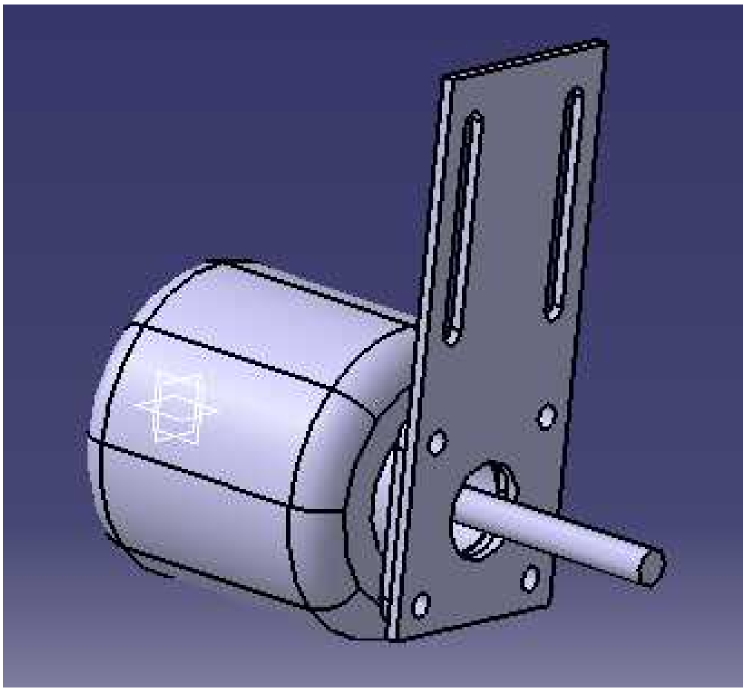


Figure 6.3: Hydraulic pump/motor.

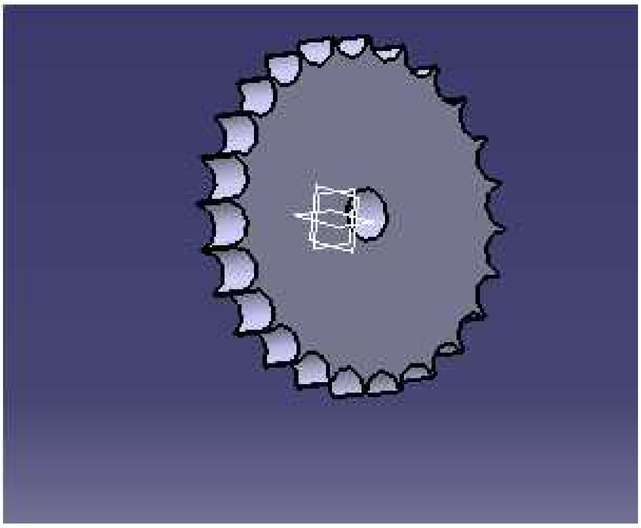


Figure 6.4: Gear.

6.3.Work simulation of the pieces.

6.3.1Bolt Mechanical Design.

6.3.1.1 Selection bolt that fix pump with the base body:

4bolt, Iso8.8, d=10mm,

P = F * L 6.1

V=((N*2π)/60)*r 6.2

Where:

p: hydraulic power (kwatt).

N:hydraulic pump speed (rev/min).

V : the speed at out side of gear reduction (m/s).

r :the gear reduction radius (m).

N= 1750 rev/min.

r =0.1 m.

p =8.356 kwatt.

V = (1750*2*3.14*0.1)/60

V=18.55 m/s.

F=p/V 6.3

$F=(8.356\times 1000)/18.55$.

$F=(450+10*9.81)\ N$.

$F=548.1$ N

For bolts to fix the pump the distance between force bolts 4 cm. this force act on bolts as shear force .

Directed load (primary shear).

$$F=f/n \qquad 6.4$$

Moment load (secondary shear).

$$f'=M/\sum r^2 \qquad 6.5$$

$$M*x \qquad 6.6$$

$$f''=f+f' \qquad 6.7$$

$$\tau=f''/A \qquad 6.8$$

The factor of safety guarding a against failure are

N=Ssy/τ 6.9

$$A = (\pi \times d^{2})/4$$ 6.10

Where :

n: number of bolt.

r : the distance between bolt and center of force.

τ: shear stress (Mpa).

Ssy :yield shear strength pt the bolt (210 Mpa)

A: bolt area (m^{2}).

d : bolt diameter (m).

x: the distance between the first position for force and new position.

X=0.04 m.

d=0.1m.

n=4.

f =584.1/4

*f =137.025*N.

M= 584.1×0.04

M=21.9 n.m

f' =21.6/(0.05^2+0.05^2+0.05^2+0.05^2) *f' =21.6/0.01*

f'=2192N

The total shear force act on bolt are:

f'' =137.5+2192

f''= 2329.9 N

t=f''/A 6.11

A=(3.14*0.01*0.01)/4

A=78.5*10^-10

t =29.6 Mpa

n=210/29.6

$n =$ 7>>1 safe

6.3.1.2. Selected bolts for body base :

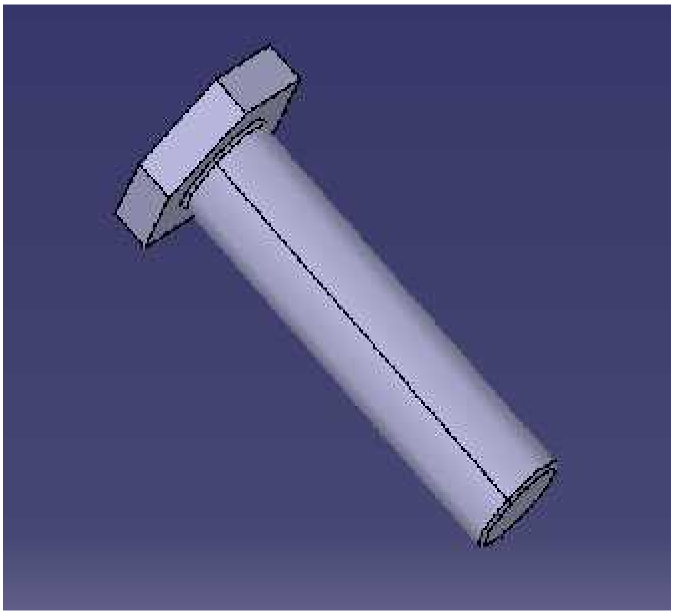


Figure:6.4:Bolt.

The force that act on the center of body base is combination from resultant force of hydraulic motor and weight of hydraulic motor.

F=450+100*9.81

F=450+98.1

F=548.1N

The number of bolt are 8bolt, Iso8.8, d=12mm, so the force that act in every bolt are :

f= 548.1/8

f =68.5 N

This force will made tensile stress . and shear moment.

M=(450*.031)+(9.81*0.35)

M=173.853

Every four bolt in the body base having same distance between bolt hole and force center .

So that we have to distance that are

r1 =27.45 cm.

r2=37.33cm

Now will convert shear moment to shear force , and take design for bolt dependent on shear moment because it's act greater than tensile stress.

f' =M/(4*r1+4*r2)

f' =173.835/(4*.075+4*0.1)

f'= 205.01N

τ= f'/A

A=(π*12*12)*4

A=113.04*10^-6

n=Ssy/τ

n=210/113.04

$$n = 1.8 > \text{safe}$$

6.4.Analysis and results.

Through the use of the CATIA program we got the following results , Through the analysis on the bridge which carries the base of the model, pictures, and tables show the mechanical analysis of the bridge under the spell of all the forces affecting it:

Analysis1

MESH:

Entity	Size
Nodes	35909
Elements	128511

ELEMENT TYPE:

Connectivity	Statistics
TE4	128511 (100.00%)

ELEMENT QUALITY:

Criterion	Good	Poor	Bad	Worst	Average
Distortion	89259 (	28986 (	10266 (	66.238	30.010

(deg)	69.46%)	22.56%)	7.99%)		
Stretch	125449 (97.62%)	3057 (2.38%)	5 (0.00%)	0.079	0.608
Length Ratio	127292 (99.05%)	1150 (0.89%)	69 (0.05%)	15.304	2.059

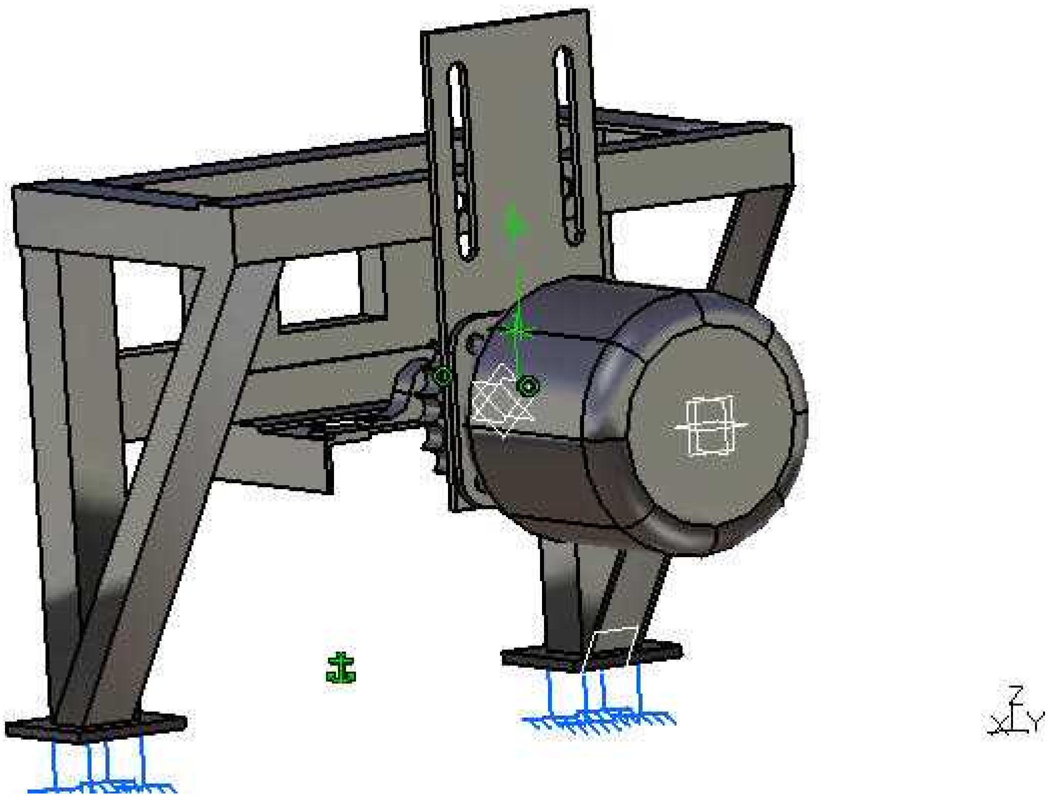
Materials.1

Material	Iron
Young's modulus	1.2e+011N_m2
Poisson's ratio	0.291
Density	7870kg_m3
Coefficient of thermal expansion	1.21e-005_Kdeg
Yield strength	3.1e+008N_m2

Material	Aluminium
Young's modulus	7e+010N_m2
Poisson's ratio	0.346
Density	2710kg_m3
Coefficient of thermal expansion	2.36e-005_Kdeg
Yield strength	9.5e+007N_m2

Static Case

Boundary Conditions



STRUCTURE Computation

Number of nodes	: 35909
Number of elements	: 128511
Number of D.O.F.	: 107727
Number of Contact relations	: 0
Number of Kinematic relations	: 0

Linear tetrahedron : 128511

RESTRAINT Computation

Name: RestraintSet.1

Number of S.P.C : 1122

LOAD Computation

Name: Loads.1

Applied load resultant :

Fx = 0 . 000e+000 N
Fy = 535 . 000e+000 N
Fz = 0 . 000e+000 N
Mx = 0 . 000e+000 N.m
My = 25 . 000e+000 N.m
Mz = 0 . 000e+000 N.m

STIFFNESS Computation

Number of lines	:	107727
Number of coefficients	:	1932222
Number of blocks	:	4
Maximum number of coefficients per bloc	:	499987
Total matrix size	:	22 . 52 Mb

SINGULARITY Computation

Restraint: RestraintSet.1

Number of local singularities	:	0
Number of singularities in translation	:	0
Number of singularities in rotation	:	0
Generated constraint type	:	MPC

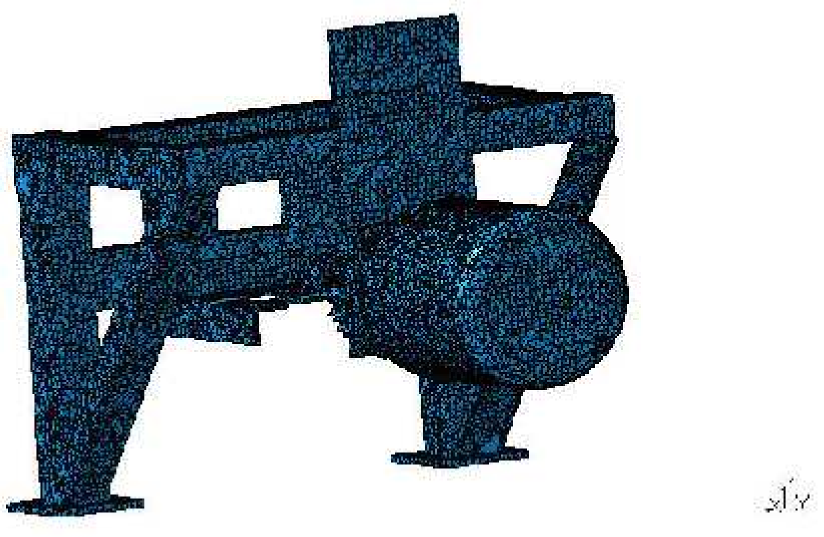
CONSTRAINT Computation

Restraint: RestraintSet.1

Number of constraints	: 1122
Number of coefficients	: 0
Number of factorized constraints	: 1122
Number of coefficients	: 0
Number of deferred constraints	: 0

FACTORIZED Computation

Static Case Solution.1 - Deformed mesh.1



On deformed mesh-- On boundary - over all the model

Conclusion

1-Model was run and managed to achieve the goals of the project are the main braking and acceleration.

2-Does not have an affect on the vehicle and there is possibility of installation this system on all types of cars or light-heavy vehicle.

3- Proved to have high efficiency as a brake and power.

Recommendation:

1- we recommend to replace the control of the system to be dynamic control such that the system by it self can select appropriate operation condition.

2- realize the actual system.

3- testing the fuel consumption of the vehicle after using the system.

Appendix

Mitsubishi L200 Triton Double Cab 4x4 Specifications

Specifications			**2.5 Double cab GLS**	**2.5 Double cab GLS-Limited (A/T)**	**3.2 Double cab GLS-Limited (M/T)**	**3.2 Double cab GLS-Limited (A/T)**
Dimension & Weight	Length	(mm.)	5185	5070		
	Width	(mm.)	1800			
	Height	(mm.)	1780			
	Wheelbase	(mm.)	3,000			
	Front track	(mm.)	1520			
	Rear track	(mm.)	1515			
	Bed interior length	(mm.)	1325			
	Bed interior width	(mm.)	1,470			

	Bed interior height	(mm.)	405			
	Ground clearance	(mm.)	205			
	Approximate Vehicle Kerb weight	(Kg)	1875	1895	1945	1955
Engine	Model		4D56 DI-D Hyper Common Rail Turbo Intercooler		4M41 DI-D Hyper Common Rail Turbo Intercooler	
	Type		4 สูบ DOHC 16 วาล์ว			
	Displacement	(cc)	2,477		3,200	
	Bore x stroke	(mm.)	91.1 X 95.0		98.5 X 105.0	
	Compression ratio		17.0 : 1			
	ECE Net (Max.output-ECE Net)	(Kw) (PS) / (rmpm)	103(140)/4000		121(165)/4000	

	ECE Net (Max.torque-ECE Net)	(rmp)	321/2000		351/2000	
	Type		Electrical fuel injection (Common rail)			
(Fuel system)	Fuel tank capacity	litre	75			
	Clutch		(Mechanical)	(Torque converter)	(Mechanical)	(Torque converter)
(Transmission)	Type		Manual 5speed	(Auto 4speed)	Manual 5speed	(Auto 4speed)
	Model		5M/T (V5MB1)	4A/T (V4A5A)	5M/T (V5MB1)	4A/T (V4A5A)
	Gear Ratio	1st	4.313	2.842	4.313	2.842
		2nd	2.33	1.495	2.33	1.495
		3rd	1.436	1	1.436	1
		4th	1	0.731	1	0.731
		5th	0.789	-	0.789	-
		ถอยหลัง (reverse)	4.22	2.72	4.22	2.72
	Transfer gear ratio	High	1			
		Low	1.9			
	Final gear ratio		4.1			
(Steering)	Type		Rack and pinion with power steering			
	Min. turning radius	(m)	5.9			

(Suspension)	Front		Independent-wishbone, coil springs with stabilizer bar
	Rear		Regid-elliptic leaf springs
Brake	Front		Ventilated discs
	Rear		Leading and trailing drums
(Tyres size)	Front & rear		245/70R16

some picture of our project

References:

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8- http://www.hydraproducts.co.uk/hydraulic_calculator/Pipe-diameter.htm.

9. mechanical engineering design, seventh edition, Joseph E. shigley, Charles R. mischke, Richard G. budynas.

To calculate the hydraulic power at any condition can be use the programming language such as turbo c++ to give the power at any any parameter inserted from the following software :

```
#include<stdio.h>
#include<math.h>
#include<conio.h>
#define g 9.81
main()
{

float A ,P ,T ,CD ,theta ,Vk,Vm ,M ,Mu , Ru;
float result;

printf("Enter the Front area:\n");
scanf("%f",&A);
printf("Enter the Atmospher Pressure:\n");
scanf("%f",&P);
printf("Enter the Air temp in Coefficient:\n");
scanf("%f",&T);
printf("Enter the Area dynamic Coefficient:\n");
scanf("%f",&CD);
printf("Enter the Angel Gradient:\n");
scanf("%f",&thet);
printf("Enter the Vehicle speed km/h:\n");
scanf("%f",&Vk);
printf("Enter the Mass of Vehicle:\n");
scanf("%f",&M);
printf("Enter the Coefficent of friction:\n");
scanf("%f",&Mu);

Ru=1.225*(P/101.325)*(288.16/(273.16+T));
printf("The Density of air is: %f\n",Ru);
Vm=(Vk/3.6);
result=V*(M*g*(sin (thet)-(Mu *cos(thet)))-0.5*Ru*V*V*CD*A);
printf("The Result is: %f\n",result);

getch();
return 0;
}
```