Palestine Polytechnic University
College of Engineering
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Power Generation Using Hydraulic Speed Bump

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Submitted to the College of Engineering
in partial fulfillment of the requirements for the
Bachelor degree in Automotive Engineering

May 21, 2019

Dedication

We dedicate our research project to our beloved parents for their continuous invaluable support and encouragement all through the years and to our dear siblings for providing us with a comfortable environment for study and research.

Acknowledgement

We would like to express our gratitude to our supervisor, Eng Zuhair Wazwaz, for his full support and guidance and remarkable suggestions. We would also like to thank our teachers for all the efforts they have exerted to make us qualified engineers who can assume-with confidence-our role in building our community. Thanks are also due to our classmates and friends for their cooperation and encouragement.

We would also like to thank the Deanship of Graduate Studies and Scientific Research at Palestine Polytechnic University for their financial support.

Abstract

Electrical energy is essentially required for society as well as all-round development of any country. The growing demand of electrical power for different activities has forced scientists and researchers to develop alternate sources of power generation from different sources of renewable energy.
Nowadays the renewable energy sources have become more popular due to their sustainability, renewability and easy availability. One of the economical and environment friendly sources of electrical power generation is the utilization of kinetic energy of vehicles passing over speed bumps over the world.

This project focuses on converting the everyday speed bump reciprocating movement up and down into electrical energy, capable of using the force exerted by a vehicle passing over the speed bump as a new environmental friendly system to produce energy .which utilizes the inertia of passing vehicles on the new hydraulic speed bump, which forces hydraulic fluid to flow through a special tube, and then to rotate hydraulic motor which connects directly to alternator, then produces electricity and stores it in a battery that can be used to recharge plug-in cars, streetlights, and electric charge points for portable devices.

Keywords- speed bump, renewable energy, power generation

الملخص

تعد الطاقة الكهربائية ضرورة أساسيه لتطور المجتمعات, وتعتبر ايضا اساسا في تطور وتقدم الدول, حيث أجبر الطلب المتزايدعلى الكهرباء, واستخدامها في الانشطة المختلفة العلماء والباحثين على تطوير مصادرجديده و بديلة لتوليد الطاقة, ففي الوقت الحاضر أصبحت مصادر الطاقة المتجددة أكثر شعبية بسبب استمراريتها, وامكانيه تجديدها, وسهولة الحصول عليها .

تعد عمليه استغلال الطاقه الحركيه الناتجه عن مرور المركبات على مطبات السرعه واحدة من اهم المصادرالكهربائيه الصديقة للبيئة

يوجه هذا المشروع انظاره نحو تحويل الحركه الترددية اللحظيه لمطبات السرعه صعودا وهبوطا, الى طاقه كهربائيه, وذلك من خلال استغلال القوه الناتجه من مرور المركبات على هذه المطبات, حيث يعد هذا النظام احدى الانظمه الجديده المتعلقه بتوليد الطاقه المتجدده الصديقه للبيئه, والذي يستغل مرور المركبات على المطب الهيدروليكي الحديث، حيث تم تصميم المطب بطريقه تمكنه من الهبوط والصعود نتيجه لوزن المركبه, وبالتالي اجبار السائل الهيدروليكي على المرور من خلال أنبوب خاص معد مسبقا ، والذي يقوم بدوره بتدوير محرك هيدروليكي متصل مباشره مع مولد كهربائي، ثم ينتج المولد الكهربائي الكهرباء ويخزنها في بطارية, حيث يمكن استخدامها في وقت لاحق لإعادة شحن السيارات الكهربائيه ،و اناره مصابيح الشوارع ، واستخدامها ايضا كنقاط لشحن الاجهزه المحموله.

الكلمات المفتاحية – مطبات السرعة , الطاقة المتجددة , توليد الطاقة

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Chapter 1

Introduction

1.1 Introduction

Electricity is the most important source of power for humanity, and the evolution of the world is faster than ever, particularly in regards to vehicle factories producing plug-in cars.

This evolution has created a demand for Green Power Generation, and this concept requires generating new ideas to produce electricity without any harmful effects on environment in or human life. There is large amount of kinetic and potential energies wasted while car passing on speed bumps.

Speed bumps are a small raised area built across a road to force people to drive more slowly, Speed bumps can be found on roads all around the world and this wasted energy can be recovered.

Currently, these bumps only serve to slow down vehicles on the road. Slowing down and traversing the speed bumps wastes kinetic and potential energy of the car.

This project focuses on converting the everyday speed bump energy into electric by harnessing speed bump, the system will be able to use the force exerted by a vehicle passing over the speed bump to generate electricity as a new system which utilizes the inertia of passing vehicles on the hydraulic speed bump, which forces hydraulic fluid to press through a special tube and then to motor turbine, which connects with an alternator to produces electricity and stores it in a battery that can be used to recharge plug-in cars, streetlights, and electric charge points for portable devices.

1.2 Problem Definition

Thousands of cars pass over speed bumps each moment and large amount of energy is wasted at the speed bumps through friction, every time a vehicle passes over it. Speed bumps can be found on roads all around the world. Currently, these bumps only serve to slow down vehicles on the road. Slowing down and traversing the speed bumps wastes the kinetic and potential energy of the car without receiving any energy in return.

1.3 literature review

Electricity is the most important resource of power for humanity, and the evolution of the world is faster than ever, particularly in regards to vehicle factories producing plug-in cars.

This evolution has created a demand for the Green Power Generation, and this concept requires generating new ideas to produce electricity without any harmful effects on environment in general, and specially on human life, so; we have noted that there is a lot of kinetic and potential energies got lost while car passing on the speed bumps, which can be recovered.

Some of the eminent engineers proposed various systems for generating power from speed bumps. those mechanisms can be divided into: -

1.3.1 Roller with Chain Mechanism

Roller consider the main component to produces electricity and this energy is stored in a battery. Whereas the roller is fitted in between a speed bump and some kind of a grip is provided on the speed bump so that when a vehicle passing over speed bump it rotates the roller. See figure 1.1. As the vehicle moves over the roller, the gear arrangement attached to the roller comes into motion. The rotation of larger gear attached to the roller causes the smaller gear to rotate by the help of chain drive, see figure 1.2, the smaller gear of the gear arrangement is attached to the DC alternator, and alternator is used to convert the rotational energy into electrical energy. After then this energy is stored to battery. [1]

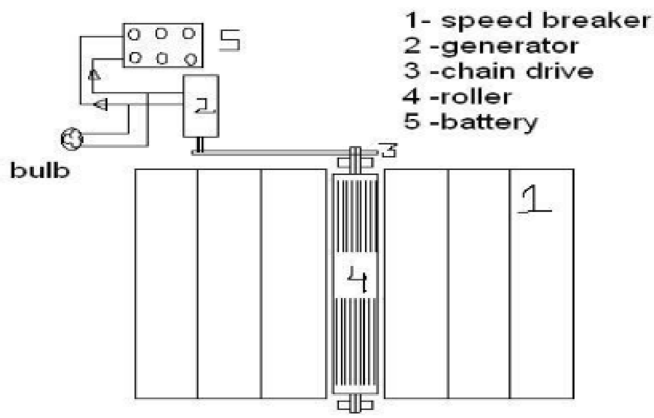


Figure 1.1: Top view of roller with chain mechanism

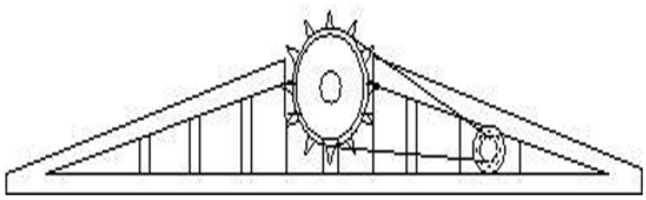


Figure 1.2: side view of roller with chain mechanism

- Advantages: -

1. No consumption of any fossil fuel.
2. low Budget electricity production.
3. less floor area.
4. no obstruction to traffic and Suitable at parking of multiplexes, malls, toll booths, signals, etc.

- Disadvantage: -

1. Maintenance will be very difficult and might cause collision sometimes
2. For this mechanism, smaller gear output speed limited by the large gear used, and this limitation has been overcome with using gearbox.

1.3.2 Roller with Gearbox Mechanism

In this mechanism when vehicle is passing over the roller it tends the roller R1 to move due to friction between the tire and the roller surface. The Rollers R2 and R3 is connected with the R1 so these two rollers also will Rotate. And all three rollers are connected with each other roller will rotate if any of the roller rotates. So, the end of the Roller R1 it is connected to Gearbox with help of Timing unequal pulley. The speed of the roller output is increased by means gearbox. The output of the Gear box is connected to 18 phase generators. The output DC power voltage generated is to be stored in the battery which can be used for the future purpose. [2]

This experimental setup of the roller mechanism with gearbox contains the following items:-

1. Roller.
2. Spur Gear.
3. Bearing.
4. Timing Belt and Pulley.
5. Dynamo.
6. Battery.

•Advantages of this mechanism
1- The best advantages of this mechanism could be increase the number of twists (rotation) according to the following table::

Table 1.1: Output speed of the gearbox shaft connected to the generator

S.no	Speed of the Roller R1(rpm)	Input Speed of the Generator Shaft(rpm)
1	5	350
2	11	760
3	15	1030
4	20	1375

Thus, more energy is produced when the speed of the roller(R1) is increased.

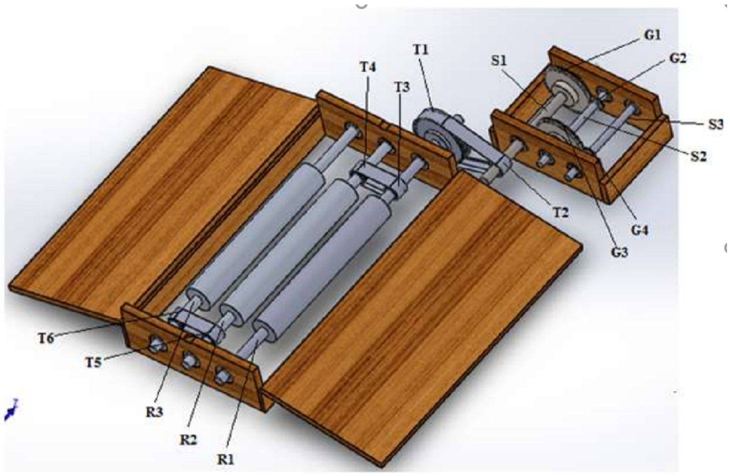


Figure 1.3: roller speed bumps with gear box

- Disadvantage: -

1. Not suitable for all vehicle speed.
2. This mechanism is not efficient for passing more than one vehicle at the same moment, and this problem overcome by using “Rack And Pinion” mechanism.

1.3.3 Rack and Pinion Mechanism

This is done by moving plate installed on the road, this plate captured very small movement from the road surfaces and it transferred to rack and pinion arrangements.

Here the reciprocating motion of the speed bump is converted into rotary motion using the rack and pinion arrangement.
The axis of the pinion is coupled with a gear. This gear is meshed a pinion, As the power is transmitted from the gear to the pinion, the speed that is available at the gear is relatively multiplied at the rotation of the pinion which is coupled to gear arrangement. This speed is sufficient to rotate the rotor of alternator, which generates power and then stores in battery. Then, the spring returns the plate to higher after the pressure is removed. [3]

This system design contains the following items:

1. Top plate
2. Rack and pinion
3. Spur gear
4. Dynamo
5. Battery
6. Spring

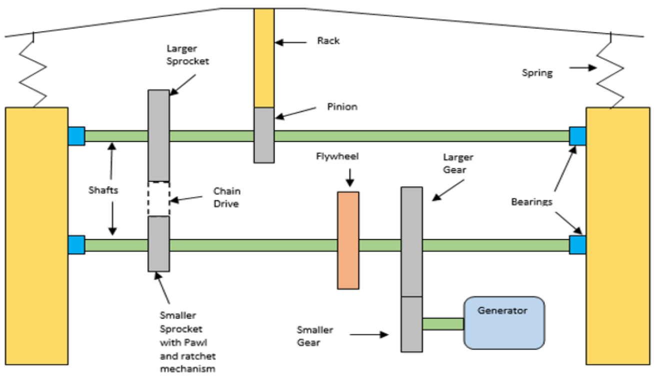


Figure 1.4: Constructional details of Electro-mechanical unit

- Advantages: -

1. Power generation is simply running the vehicle on this arrangement
2. Power also generated by running or exercising on the brake.
3. This is a Non-conventional system
4. Battery is used to store the generated power

- Disadvantages: -

1. Slight inclination is required in the railway track
2. Mechanical moving parts is high
3. Initial cost of this arrangement is high.
4. High friction

These disadvantages lead other engineers to come up with crankshaft mechanism idea, with lower cost.

1.3.4 Crankshaft Mechanism

The speed bumps goes on up and downward motion and crankshaft converted reciprocating motion into rotating motion through connected alternator unit to run the alternator to produce electricity without any environmental pollutions. [4] Advantages

1. This type of source is cost effective
2. user friendly
3. more efficiency
4. By promoting renewable energy sources, we can avoid, Air pollution, soil pollution and water pollution, Country's Economy will increase as well.

But Crank-shafts are required to be mounted on bearings which creates balancing problem leading to mechanical vibrations which in turn damage the bearings, and maintenance will be very difficult and it Might cause collision. [5] so Air system used as an alternative method to overcome these problems.

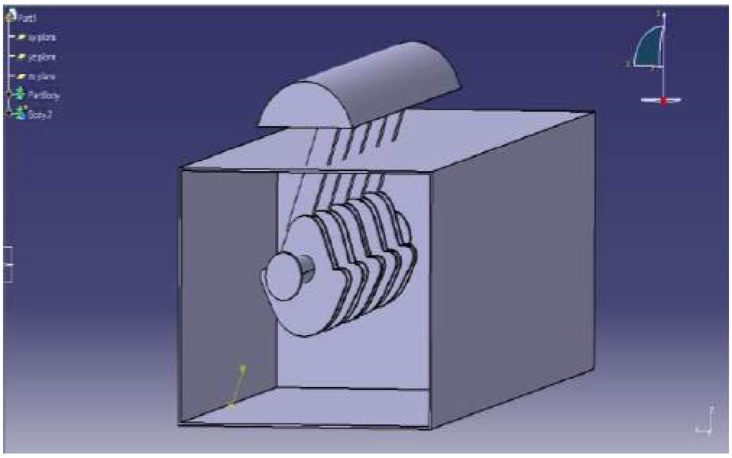


Figure 1.5: Crankshaft Mechanism working assembly in CATIA model

1.3.5 Air System

The number of vehicles passing over the speed bump is increasing day by day. There is possibility of tapping the energy and generating power by making the speed bump as a power generation unit. Generating energy by air compression is an innovative and useful concept of Generating Electricity from Speed bump. [6]
all the setup is place under speed bump when vehicle passing over speed bump it generates electricity. Main benefit of this method is tapping the wasted energy for power generation, whereas when the vehicles passing over speed breaker the pump compress the air and with use of these compressed air turbine can rotate. The turbine is directly connected with the alternator/dynamo from which we get electrical output.

- Advantage: -

1. Eco – friendly: In this mechanism no pollution is created.
2. No fuel used: In power plants there is fossil fuel is used i.e. coal, diesel, gas, etc. but in this mechanism no fuel is used.
3. Maintenance: Less maintenance is required for this system. The main advantage of this mechanism is there is no any rotational parts like crank shaft mechanism and rack and pinion mechanism also no gear is required. So, it requires less maintenance.
4. Operation: Operation is very easy and simple to understand so fewer operating staff is required. There is also no need of 24-hour observation.
5. Adjustable: Here we can also use adjustable speed bumps so it can easily move and transport to any location, so that site selection problem is not so much important.
6. Cost: Running cost is free because there is no fuel is used, and also less installation cost is required, less maintenance cost, so all over cost is less.

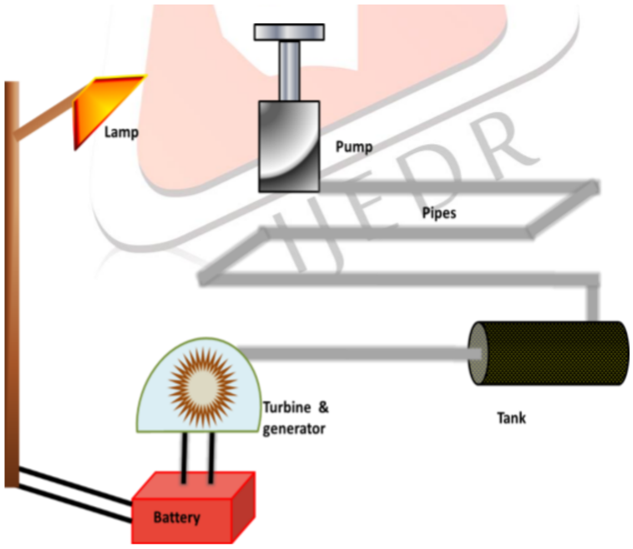


Figure 1.6: Scematic Diagram of air system

- Disadvantage: -

1- cannot give constant power output and It cannot use in less traffic areas.

1.3.6 Hydraulic with Air System

This system includes a series of plates, and each plate displaces a pair of pistons containing hydraulic fluid. This fluid is forced into another piston acting as a two-way hydraulic cylinder.

One side of the cylinder contains hydraulic fluid and the other side contains air. The side that contains air is connected to a pneumatic pressure vessel. This stores the compressed air. The stored air creates electrical energy via a pneumatic-electrical generator. A reliable method to reset the system after a car traverses the device would be ideal; however, it is currently the biggest challenge. The key aspects to the design are the valves in the system, which provides a method of returning the plates to their initial positions by supplying a negative pressure in the pistons. [7]

This system includes a series of plates, and each plate displaces a pair of pistons containing hydraulic fluid. This fluid is forced into another piston acting as a two-way hydraulic cylinder. One side of the cylinder contains hydraulic fluid and the other side contains air. The side that contains air is connected to a pneumatic pressure vessel. This stores the compressed air. The stored air creates electrical energy via a pneumatic-electrical generator

- Advantage: -

1. The energy gathered from the device can be used in various applications including outdoor lighting and tollbooths.
2. This device was developed to help society become more sustainable and environmentally friendly.

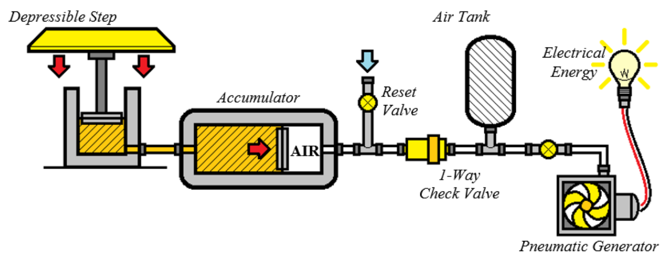


Figure 1.7: Simplified Schematic of Hydraulic/Pneumatic Speed Hump System

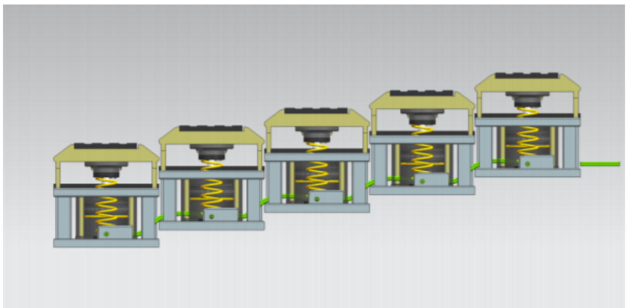


Figure 1.8: System Side View of Hose Organization

- Disadvantage: -

There are some losses that can be founded in this mechanism, divided into:-

1. major losses due to the length and material of the piping
2. minor losses associated with valves and fittings
3. some important factors that will contribute to energy losses are due to friction, heat, and fluid compressibility.

1.4 Project Outline

This project with fully hydraulic system focuses on converting the everyday speed bump movement into an energy harnessing speed bump, capable of using the force exerted by a vehicle passing over the speed bump to generate electricity as a new system which utilizes the inertia of passing vehicles on the hydraulic speed bump, then compress hydraulic fluid, and push it to pass through a special tube to the accumulator, the comprised fluid pass through hydraulic motor to rotate the alternator which then produces electricity and stores it in a battery that can be used to recharge plug-in cars, streetlights, and electric charge points for portable devices.

1.5 Budget

The estimated cost of the project around 1320JOD, the table 1.2 shows the project component with their prices.

Table 1.2: Cost table

Part Number	Part Name	Cost [JOD]
1	Solid Plate	120
2	Pistons	300
4	Springs	100
5	Pipe line and elbow	70
6	Chick and safety valves	100
7	Alternator	120
8	Battery	140
9	power inverter	70
10	Accumulator	50
11	Frame plate	200
12	Oil	50
	TOTAL PRICE	1320 [JOD]

1.6 Time schedule

The project schedule outlines the tasks, activities of the project, the duration, start and end date of each individual task, and the project as a whole is shown in time table 1.3 below.

Table 1.3: Graduation project introduction time table

Tasks \ Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Identification of Project Idea	■	■	■													
Drafting a Preliminary Project Proposal			■	■												
Introduction Chapter (1)				■	■	■	■									
Conceptual Design Chapter(2)							■	■	■							
Mechanical Design Chapter (3)								■	■	■	■	■	■			
Calculation												■	■	■	■	
Project Design													■	■	■	
Printing																■

Table 1.4 below shows the Graduation project outline.

Table 1.4: Graduation project time table

Tasks \ Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Chapters Review	■	■	■	■												
Prototype redesign			■	■	■	■	■									
Prototype Manufacture							■	■	■	■	■	■	■	■		
Prototype test														■	■	
Calculation check														■		
printing															■	

Chapter 2

Conceptual design

2.1 Introduction

This section describes power generation using a hydraulic speed bump workflow, including the system components (subsystems), parts, functions and relations between elements. As shown in figure 2.1 power generation using a hydraulic speed bump system is a relation between three systems that have many subsystems, which will explain in this chapter. The global system consists of a metal plate which rises on the road and looks like a speed bump. It moves down and up again following the movement of the vehicle on the road. A hydraulic single acting cylinder springs up to return the speed bump to its original position after the vehicle passes over. The vane motor connects directly to the alternator which converts mechanical energy into direct current electricity. Finally, there is a valve, like a safety valve, and a relief valve. See Figure 2.2, which shows the block diagram of the system.

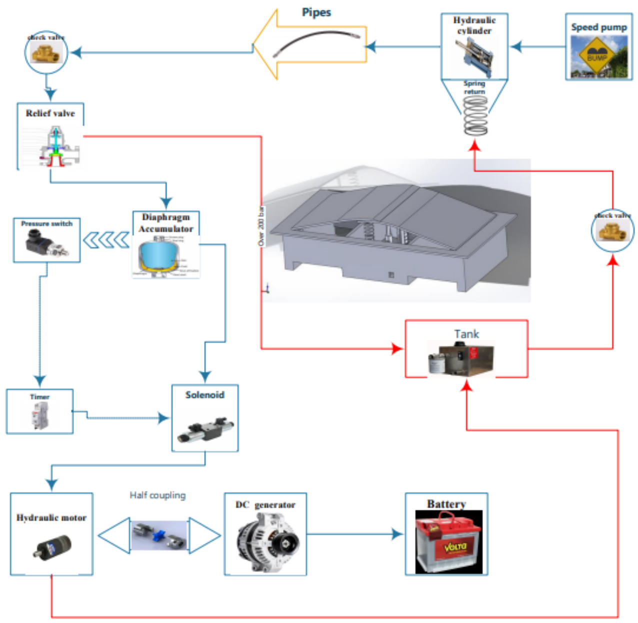


Figure 2.1: Power generation using a hydraulic speed bump system - overall flow chart

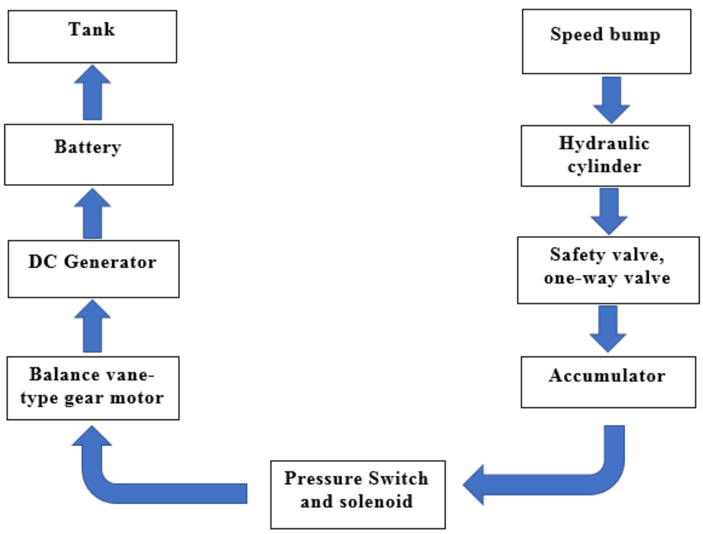


Figure 2.2: Block diagram of the mechanism

2.2 Mechanism Component

This section will explain the mechanism component.
See figure 2.3 which shows briefly the main element of the project.

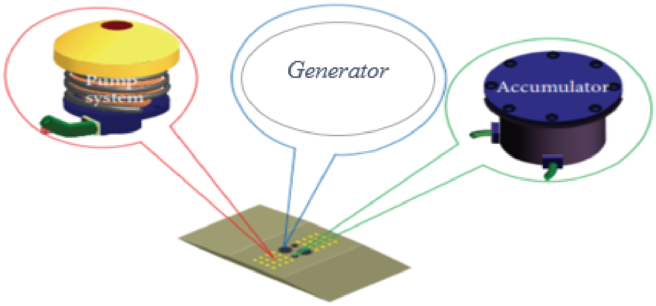


Figure 2.3: main element of power generation using hydraulic speed bump

2.2.1 Speed bump

According to a publication by the Institute of Transportation Engineers, the first speed bump in Europe was built in 1970 in the city of Delft in the Netherlands. A speed bump is a raised part in a road that is designed to make the traffic travel more slowly.

Speed bumps are fixed and have only been used to slow the speed of vehicles, whereas we can replace it with a movement speed bump that can produce power as a result of the downwards and upwards motion experienced when a vehicle passes over it, so this energy can be recovered and utilized for human life,See figure 2.4 which shows the speed bump sign.

Figure 2.4: Speed bump sign

Figure 2.5 [8] below show average speed profile in vicinity of a speed bump.

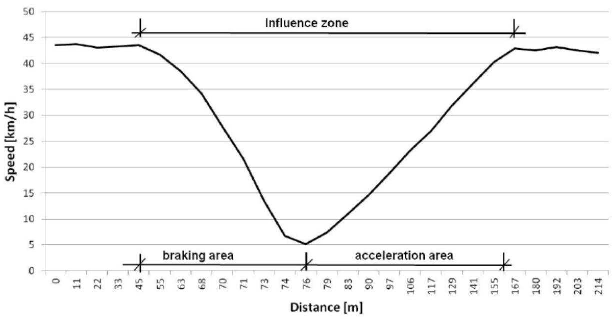


Figure 2.5: Average speed profiles in vicinity of a speed bump

2.2.2 Hydraulic cylinder

In this project we will use two single acting cylinders, which are considered the simplest type of cylinders that have one port. Fluid flows into the cap end of the cylinder. The cylinder extension under the force of a spring retracts by acting on a vertical load like the weight of a car on a speed bump, which forces the fluid to pass into a special tube.
The simplest type of a single acting cylinder is the ram, where the rod and piston are the same diameter (or nearly the same) indeed, often they are a single part. The rod extends as fluid flows into the cylinder. Typically, we will use the load of the vehicle to make the rod retract.
A hydraulic cylinder contains these components, which are mentioned in Figure 2.6 [9].

1. Port
2. Piston
3. Piston Seal
4. Piston Rod
5. Barrel

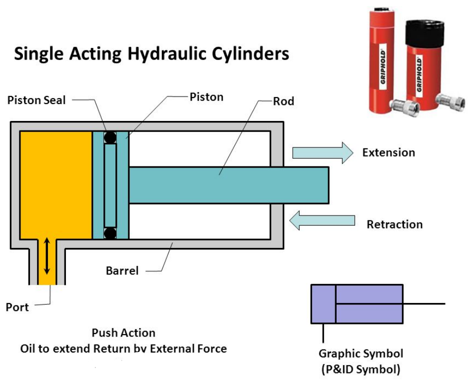


Figure 2.6: Single acting hydraulic cylinder

As shown in the figure above there are two movements of the piston rod

1. Retraction The piston rod retracts as a result of the speed bump going down when the vehicle passes over the speed bump.
2. Extension

The piston rod extends under the force of the spring.

Figure 2.7 shows the hydraulic cylinder type key. It contains information on: -

1. Special design consideration
2. Sealing material
3. Stroke distance
4. Piston diameter

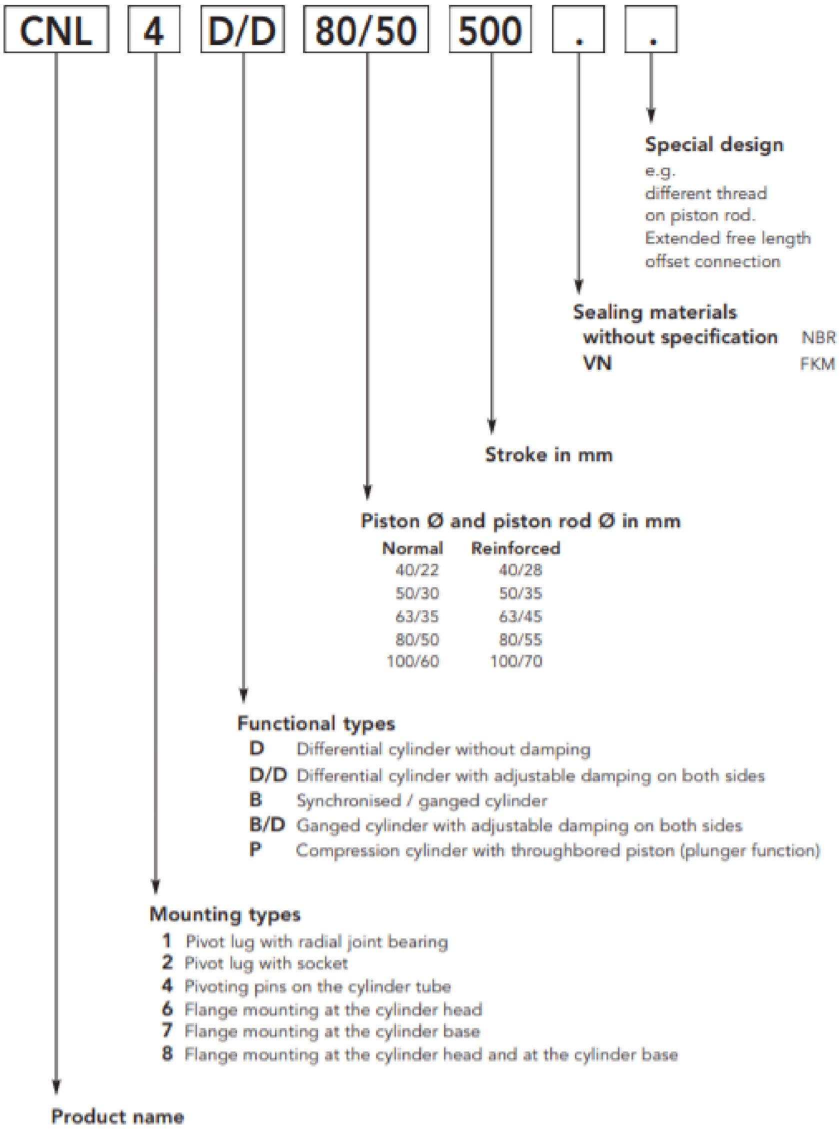


Figure 2.7: Hydraulic cylinder type key

2.2.3 Valves

1-Safety valve

A safety valve is a valve that acts as a protective measure for equipment to prevent explosions or damage and is mainly installed in pressurized vessels such as those found in chemical plants, electric power boilers and gas storage tanks. A safety valve is a type of valve that automatically actuates when the pressure of the inlet side of the valve increases to a predetermined pressure: the valve disc opens and discharges the fluid (steam or gas).

When the pressure decreases to the prescribed value, the valve disc closes again. A safety valve is a so-called final safety device that controls the pressure and discharges a certain amount of fluid by itself without any electrical power support.

A safety valve supports not only the safety of the energy industry but also the safety and security of our lives. See Figure 2.8 [10].

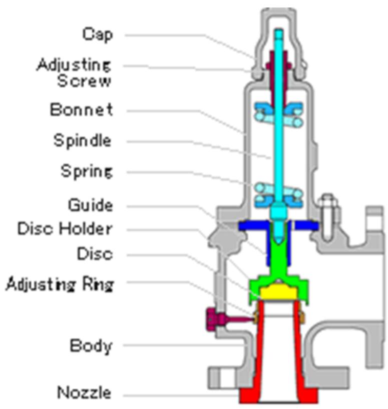


Figure 2.8: Component of the safety valve

1.1 Function of the Safety valve

1. "Nozzle" inside the Safety Valve starts to receive a higher pressure from the inlet side of the valve.
2. When the pressure becomes higher than the set pressure, "Disc" starts to lift and discharge the fluid.
3. When the pressure decreases to the predetermined pressure, the force of the spring closes the "Disc".

1.2 Safety valve parts

1. Nozzle (pressure entrance)
2. Disc (lid)
3. Spring (pressure controller)

2-One-way valve "check valve"

A check valve is a flow-monitoring device typically used in pipeline systems to allow a fluid to flow in only one direction and prevent backflow or backwash. they can be used for a variety of fluid applications such as liquids, gases, condensate or slurries.

Check valves react to flow sensitivity, which activates their opening and closing.They are primarily composed of one disc, which allows forward flow, and restricts backward flow by closing the valve when the fluid flow rate decreases, reverses or fluctuates. [11]

Figure 2.9: In line chick valve

2.2.4 Diaphragm Accumulator

Hydropneumatics accumulators have a flexible diaphragm as a separation element between the compressible gas cushion and the operating fluid. Diaphragm accumulators offer more than 30 diaphragm accumulator variants and more than 300 different fluid connections. “HYDAC” diaphragm accumulators are designed as either welded constructions or as cartridge constructions and offered in various different steels, elastomers and with different gas connections. [12] ,As seen in figure 2.11.

Essential specifications are:

1. Nominal volume: 0.075 to 4 liters.
2. Permissible operating pressure: up to 750 bars.
3. Materials for the elastomer: NBR, ECO, IIR, FKM (FPM) and more.
4. Accumulator shell materials: carbon steel, stainless steel, aluminum and more.

HYDAC diaphragm accumulators. have the following advantages:

1. Function- and weight-optimized dimensioning.
2. Any installation position possible.
3. No pressure difference between fluid side and gas side.
4. Low-maintenance and durable.

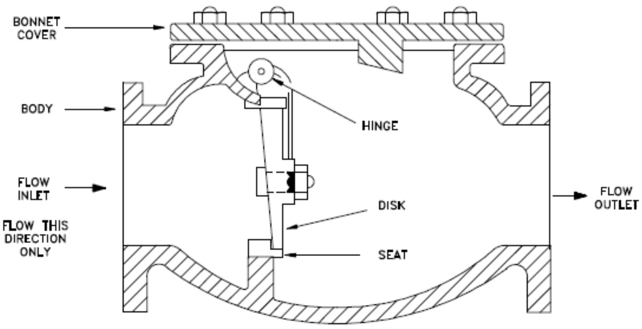


Figure 2.10: In line check valve type

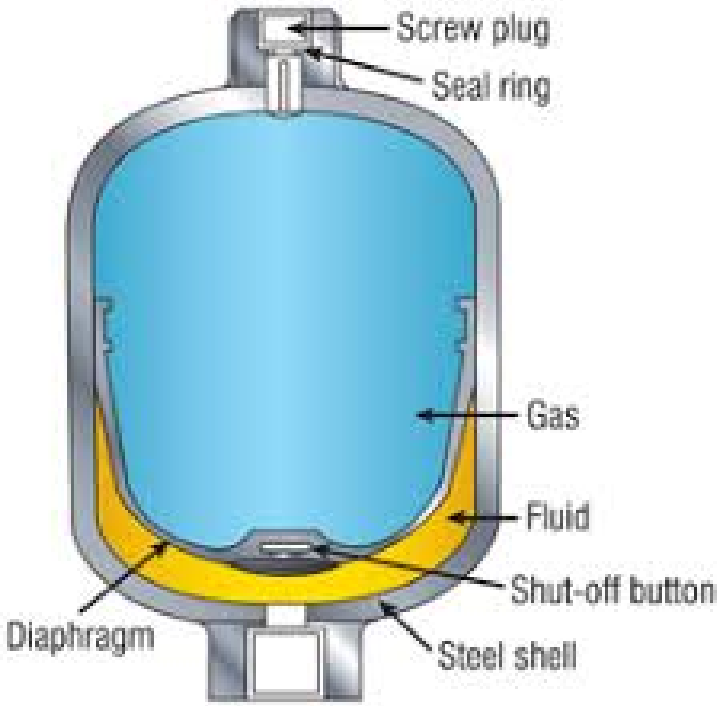


Figure 2.11: Diaphragm accumulator

2.2.5 Balance vane-type gear motor

Balance vanes will be used to convert pressurized fluid movement into rotating the shaft that is connected to the generator.
See Figure 2.12 which shows a balance vane-type gear motor component.

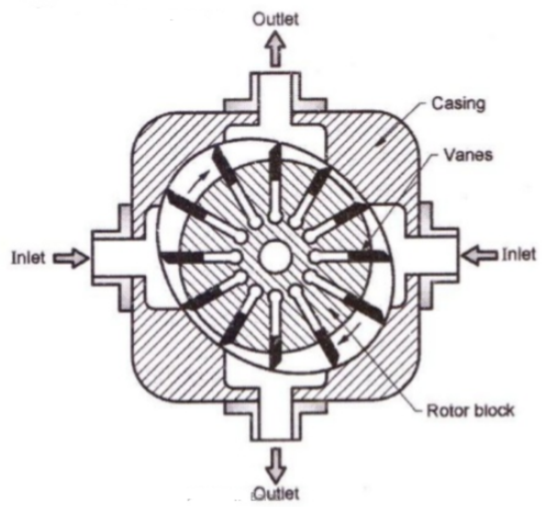


Figure 2.12: Balance vane-type motor component

The operation of the vane is based on the rotor that contains radial slots that rotate in a cam ring (housing); each slot contains a vane designed to come out from the slot as the rotor turns. During one half of the rotation the oil enters between the vane and the housing and the rotor movement moves the connected shaft.

A balanced vane casing is one that has two intakes and two outlet ports diametrically opposite each other. Inlet ports are also opposite each other [13].
Displacement vane pump characteristics:

1. Provides prime mover soft-start
2. Simple double assemblies
3. Low noise

4. Good serviceability
5. Bigger flow
6. Longer life

2.2.6 pressure switch with selector

A pressure switch is a form of switch that closes an electrical contact when a certain set fluid pressure has been reached on its input. The switch may be designed to make contact either on pressure rise or on pressure fall, see figure 2.13

Figure 2.13: pressure switch

2.2.7 Timer switch

The timer switch is considering a device controlled by timing mechanism, where the timer may switch equipment on, off, at a preset time or times after a preset interval, in this project we will use timer switch to empty the accumulator

Figure 2.14: Timer switch

2.2.8 DC generator

A DC generator is an electrical machine that converts mechanical energy into direct current electricity [14].

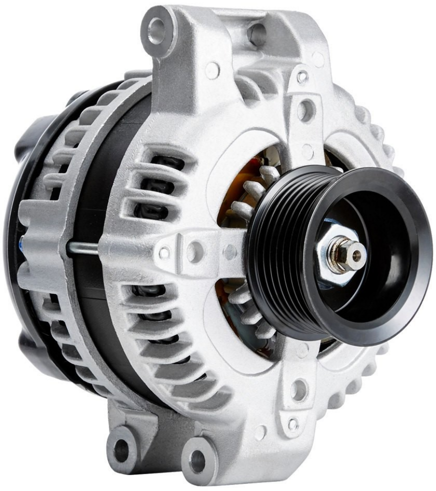


Figure 2.15: DC generator

2.2.9 Hydraulic oil container with filter

In addition, a hydraulic oil container is used to hold in reserve enough fluid to supply a hydraulic system's varying needs. It has two ports: -

1. input port to receive oil back from the motor.
2. output port to feed the hydraulic cylinder.

The container has an oil filter mounted on the intake tube which removes impurities from the system fluid [15]. See figure 2.16

Figure 2.16: Hydraulic oil container

2.2.10 Battery

A battery is a device that transforms chemical energy into electricity.

Lead-acid rechargeable batteries, which are used in cars, is the most common battery which we will use in this project, whereas the electrodes are lead and lead dioxide, with an acidic electrolyte. [16]

Every battery has two terminals, the positive cathode (lead dioxide), and the negative anode (lead). Figure 2.17 below shows the battery components.

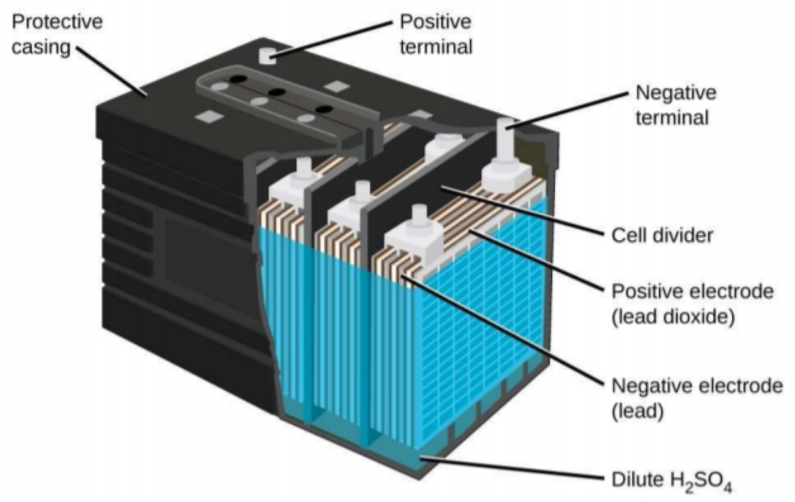


Figure 2.17: Battery components

Figure 2.18 below represents all the components of the project schematically

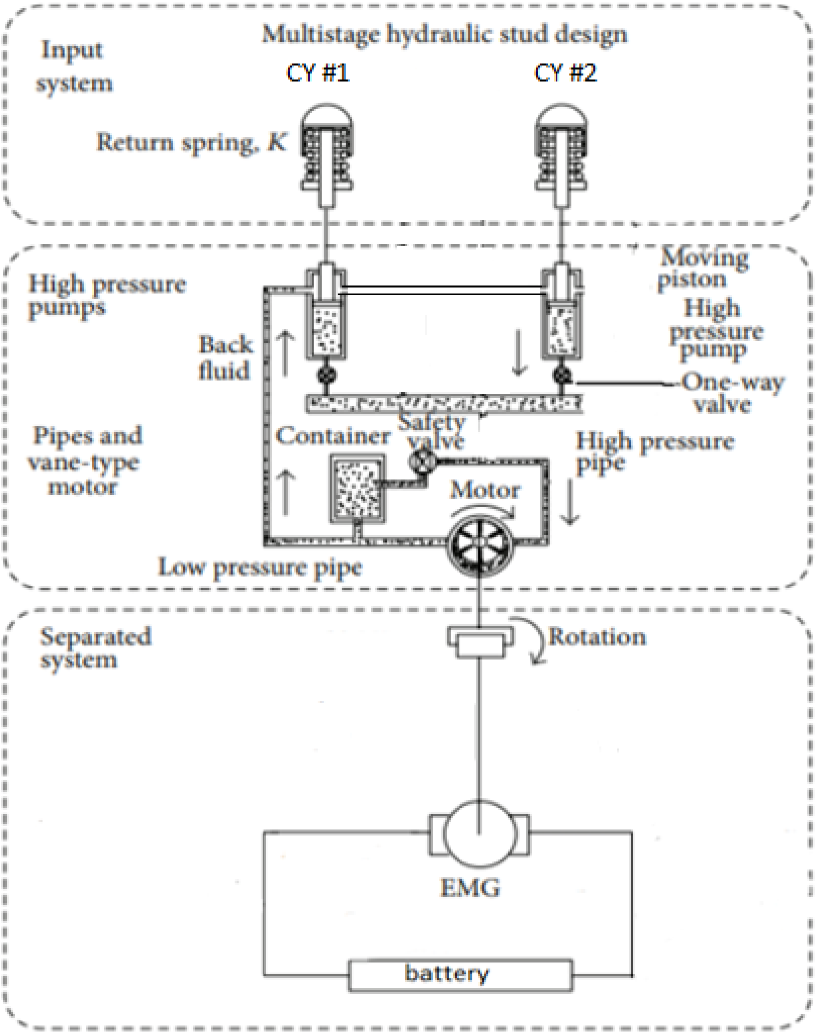


Figure 2.18: Schematic of the overall system elements

Chapter 3

Mechanical design

3.1 Introduction

When you design, you are going to formulate a plan to meet a specific need, or to solve a specific problem. If the plan results in the creation of something having a physical reality, then the product must be functional, safe, reliable, competitive, usable, manufactural, and marketable. In this section we will discuss the mechanical design of the selected mechanism, which shown in Figure 3.1, calculation of each component in term of strength, geometry, durability and material properties will be explained. Thus, these components will operate in the system without failure or defect.

The figure below shows the final view for the power generation using hydraulic speed bump project with all parts .

Figure 3.1: unit Selected for power generation using hydraulic speed bump mechanism

3.2 Design Requirement

The first step in designing any project is to define the project requirements. In other words, to define the specifications which your project supposed to do. Then you have to make many designs and choose one of them which satisfy your requirements, so the following requirements are listed for mechanical design: Enable to produce 13kw per a day. [17] the speed bump designed to work in two way .

- invest wasted kinetic energy.
- Environmental friendly “No undesirable emission”.
- Be safe for vehicle .
- Be comfortable for vehicle.
- Convenient interface.
- Easy maintenance.

3.3 CATIA Design

In this section the project completely designed and drawed parts by parts.

The word CATIA is an acronym of Computer Aided Three-dimensional Interactive Application, and it's one of the best software program used for CAD, CAE and CAM see Figure 3.2, and its able to make part design for every part of any machine or project.

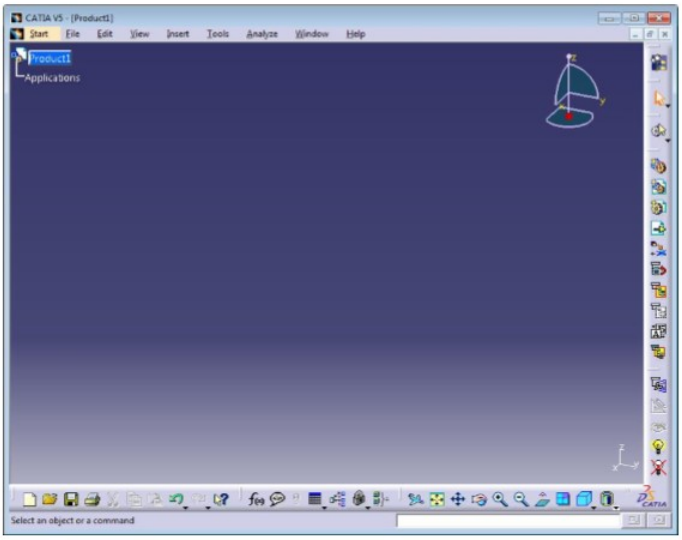


Figure 3.2: CATIA software

The mechanical components of candidate design are divided into four components. In this section we will make selection of material for each component.

3.3.1 Mechanical frame

The iron mechanical frame, forms the body of the mechanism, which carries all other parts. The iron frame must be strong enough and heavy to carry the vehicle load, and all part of the mechanism. see figure 3.3.

Figure 3.3: frame of the mechanism

In addition, the mechanical frame dimension is: -
Length = 100cm
Width = 50 cm
High = 28 cm

3.3.2 upper and lower plate

Upper plate is made by iron, which considers the first contact part between the vehicle patch and the mechanism. See figure 3.4.

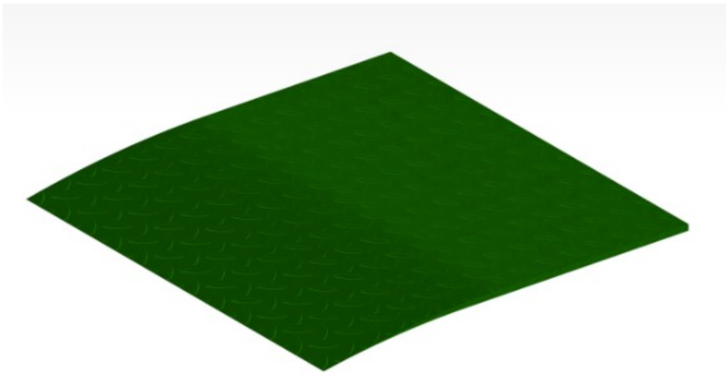


Figure 3.4: upper plate

Where lower plate is considering as the force transformer between the upper plate and the piston rod.

3.3.3 piston rod and piston

The iron piston rod moving reciprocating movement according to the upper plate movement up and down, as a result of passing the vehicle over the hydraulic speed bump upper plate. see figure 3.5 which shows (22 cm) length and (6.5cm) diameter.
Piston body makes by iron, which has contact with the frame base by welding, the piston body will cover by compression spring to extent the piston rod back, see figure 3.6

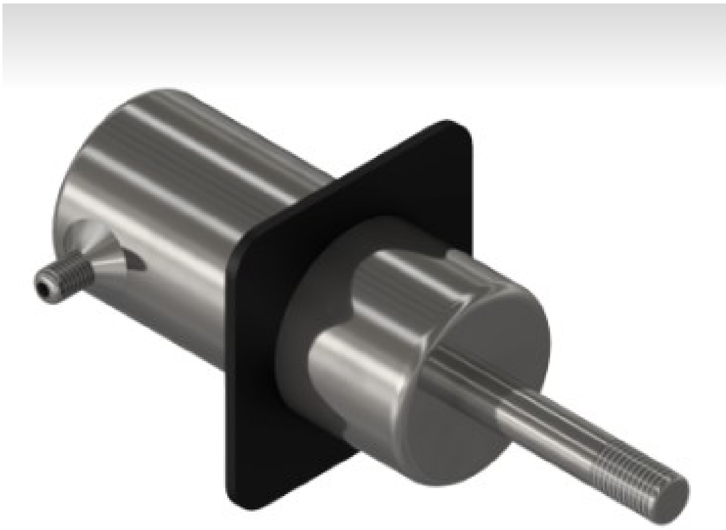


Figure 3.5: piston and piston rod

Figure 3.6: piston body covered by spring

3.3.4 male and female joint

Male and female joint used to make contact between main frame and upper, and lower plate,
This iron joint can rotate the plate around fixed point, see figure 3.7, figure 3.8.

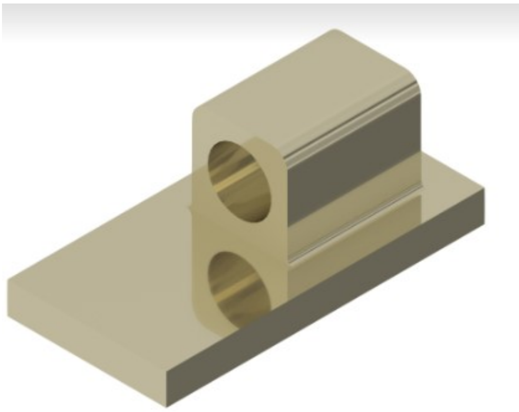


Figure 3.7: female joint

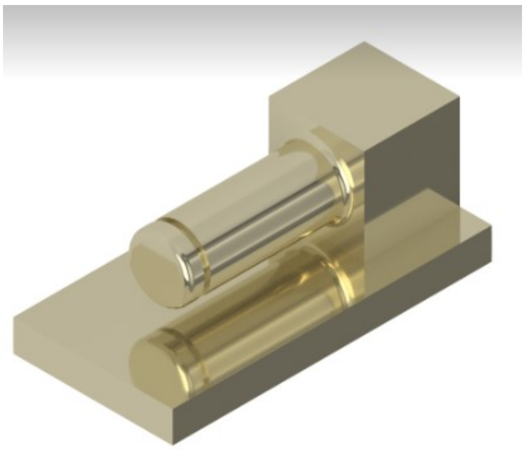


Figure 3.8: male

3.3.5 Bearing

In this project we will use roller bearing, which convert rotational motion of the bearing to reciprocating motion in the piston rod. see figure 3.9

Figure 3.9: Bearing

3.4 Fluid circuit simulation (FESTO)

Fluid SIM 5 is a comprehensive software for the creation, simulation, instruction and study of electro-pneumatic, electro-hydraulic, digital and electronic circuits. All of the program functions interact smoothly, combining different media forms and sources of knowledge in an easily accessible fashion. FluidSIM unites an intuitive circuit diagram editor with detailed descriptions of all components, component photos, sectional view animations and video sequences. As a result, FluidSIM is perfect not only for use in lessons but also for the preparation thereof and as a self-study program. [18]
The figure 3.12 below show the fluid circuit in this project.

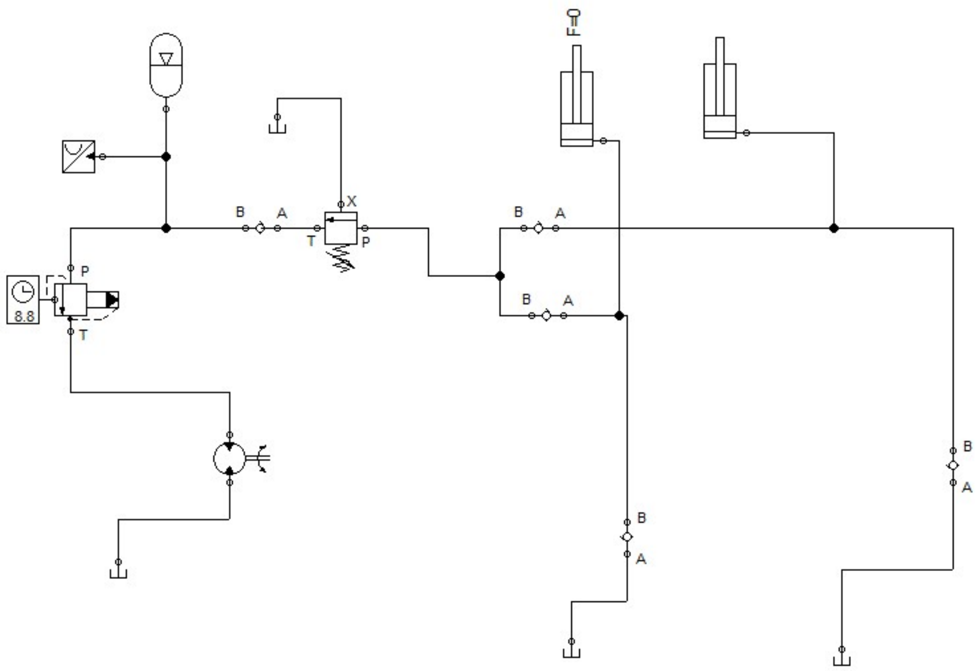


Figure 3.10: fluid circuit with all hydraulic parts

Chapter 4

Project Calculation

4.1 Power Calculation

During this section reverse engineering could be the best calculation way, where battery calculation will be the first term.

In this project we will use 12 volt, 120 Ah, and 540 A battery, Eco-tech alternator(Models: J,J-9, P and T-305-1) , Eco-tech alternator characteristics are:

1- Voltage = 14 Volts

2- 120 Ah

3- 325 A

4- High Amp at Low Rpm.

The power needed to charge the battery during two hours could be calculated by power equation, where.

$$\boldsymbol{Power}(\mathrm{p}) = \boldsymbol{Current}(\boldsymbol{I}) * \boldsymbol{Voltage}(\boldsymbol{V}) \quad \textbf{(4.1)}$$

$$\mathrm{Power(p)} = 60 * 12 = 720 \text{ watt}$$

from alternator data-sheet, we can find rpm required to produce 720 watt, and its equal to 1000 rpm.

Now, to calculate the torque required to rotate the alternator, we can use equation 4.2 .

$$\boldsymbol{T} = \frac{\boldsymbol{inpu\ power}\frac{(\mathrm{p})}{\boldsymbol{9.5488}}}{\boldsymbol{angulervelocity}(\boldsymbol{w})} \quad \textbf{(4.2)}$$

Where input power can could calculate by efficiency equation.

$$\boldsymbol{e} = \frac{\boldsymbol{output\ power}}{\boldsymbol{input\ power}} \quad \textit{\textbf{(4.3)}}$$

Where efficiency of the alternator equal 80%.

So, input power equal to,

$$\text{input power } = \frac{720}{0.8} = 900 \text{ watt}$$

From equation (4.2)

$$\mathrm{T} = \frac{900}{\frac{1000}{9.5488}} = 8.593 \text{ N.m}$$

4.2 Piston Calculation

In this project 60 bar will be the minimum accumulator pressure could be useable , with ignore the losses in pipe and all component which equal 0.000045 bar, so we should find piston area could present this pressure under the force acting, as a result of passing over the vehicle over speed bump.

this force should be found as a result of minimum vehicle mass, to earn maximum efficiency from all vehicle, where this vehicle is, Hyundai getz with a gross mass 1500 kg, where each piston will be subjected to 188 kg, and to produce 60 bar, Area consider the main variable we can change to get the required pressure. Where equ 4.4 show the relation between pressure and area.

$$\boldsymbol{pressure(p)} = \frac{\boldsymbol{mass[kg]}}{\boldsymbol{Area[cm^2]}} \tag{4.4}$$

So area can be derive from equation 4.4.

$$\text{A} = \frac{188}{60} = 3.31\text{cm}^2$$

Where diameter of the piston can determine by equation 4.5

$$\boldsymbol{D} = \sqrt{\frac{\boldsymbol{4\,A}}{\boldsymbol{\pi}}} = \boldsymbol{2cm} \tag{4.5}$$

Piston rod diameter equal to 2 cm, but as a mid range of vehicle mass which equal 8000kg on the mid of the plate and by the same way of force analysis we will choice 6.5cm as a mid-range of vehicle hit load.

Now, to find piston volume per one stroke we can use these equations.

$$\boldsymbol{Vpiston = A} * \textbf{stroke length [L]} \tag{4.6}$$

$$\text{Vpiston} = 33.1^2 * 7 = 232.16\text{cm}^3$$

there is two pistons foreach unit and each vehicle has two axles at least with right and lift wheel

$Actual\ volume = Vpiston * 2\ \{piston\} * 2\{axles\} * 2\{wheel\}$*10%{percentage of vehicle which has more than two axles}

$Actual\ vlolume = 331.66 * 8$ +(0.1*331.66) = 2043.3 cm^3

So; to fill up two-liter accumulator we need: -

$$\frac{2000\text{cm}^3}{2043.4\text{cm}^3} = 0.978\ \text{vehicle} = 1\text{vehicle}$$

4.3 Accumulator Calculation

In this project we will use accumulator with torque 10N.m. so, from equation 4.6, the volume displacement ($\boldsymbol{vD}$) of the vane can define.

$$\boldsymbol{T = \frac{p\ vD}{2\pi}} \tag{4.7}$$

So;

$$\mathrm{vD} = \frac{2\pi \mathrm{T}}{\mathrm{p}} = \frac{2\pi(10)}{60 * 10^{-5}} = 10.46\ \mathrm{cm}^3$$

it could be the highest displacement we can use, where we can use motor with lower displacement to earn more energy.

in this project we will use ($8cm^3$) motor

4.4 Pipe Calculation

In this part equation 4.7 used to determine the liquid flowrate in the pipe.

So;

$$\boldsymbol{flowrate(Q) = vD * anguler\ velocity\ (N)} \tag{4.7}$$

$$\text{flowrate(Q)} = 8 * 1000 = 8\text{l/m}$$

And now to evaluate the pipe diameter required, equ 4.8 can use.

$$\boldsymbol{flowrate(Q) = velocity * Area} \tag{4.8}$$

Where we can consider the velocity equal to 2m/s.

So;

$$A = \frac{Q}{V} = \frac{\frac{8000}{60}}{200} = 0.66\text{cm}^2$$

Where the diameter of the pipe equal to

$$D = \sqrt{\frac{4\ A}{\pi}} = 0.92\text{cm}$$

pipe diameter equal 0.92 cm.

4.5 Energy calculation

In this section the energy produced for a one working day will be measure using these equations.

Power needed to power on the motor for one hour

$$\boldsymbol{Volume\ nedded = rpm\ nedded\ for\ the\ alternator * 60 * vD} \qquad (4.9)$$

$$Vnedeed = 1000 * 60 * vD = 480000cm^3$$

Energy that we can get per one day equal to.

$$\boldsymbol{Daily\ Energy = \frac{number\ of\ vehicle\ passing\ per\ day * actual\ volume * output\ power}{Vneeded}} \qquad (4.10)$$

$$\boldsymbol{Daily\ Energy = \frac{number\ of\ vehicle\ passing\ per\ day * 2043.3[cm^3] * 0.72[kw]}{480000[cm^3]}}$$

Figure 4.1 show the relation between number of vehicle and daily energy produce for one day.

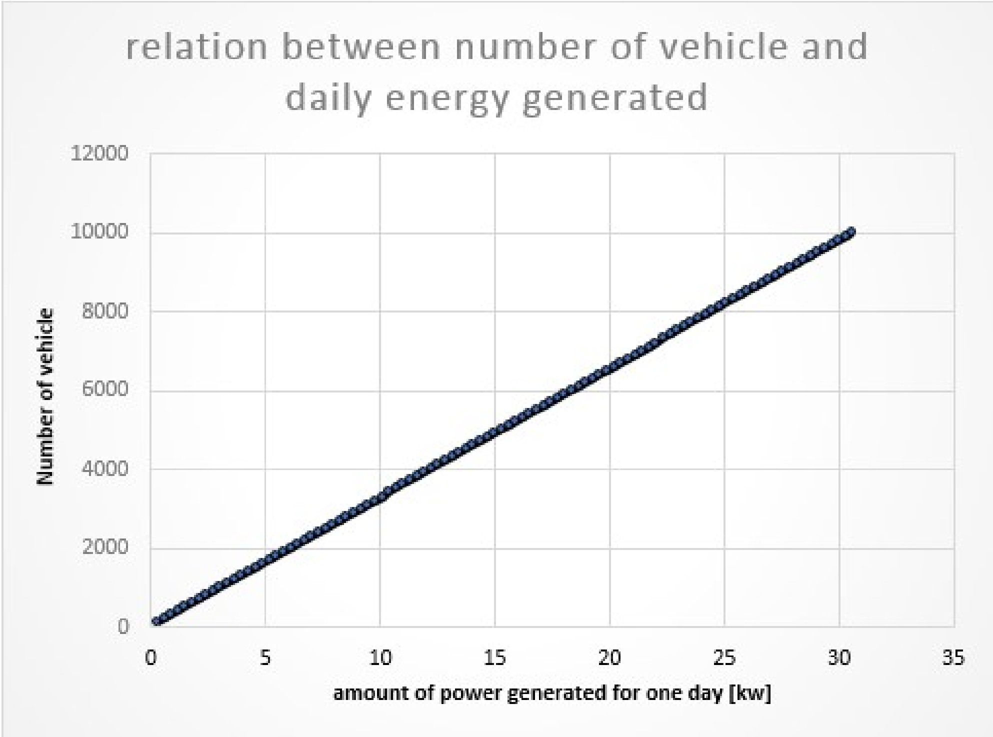


Figure 4.1 relation between number of vehicle and daily energy generated

4.6 Bearing Design

In this section we will find the best bearing could be use, where figure 4.2 show the load distribution on the speed bump plate which result from passing the tire patch of the vehicle on the speed bump plate.

the design should be under the highest load can be happen which will be 40KN on the midpoint of the plate, figure 4.1 show the load on each point should be designed.

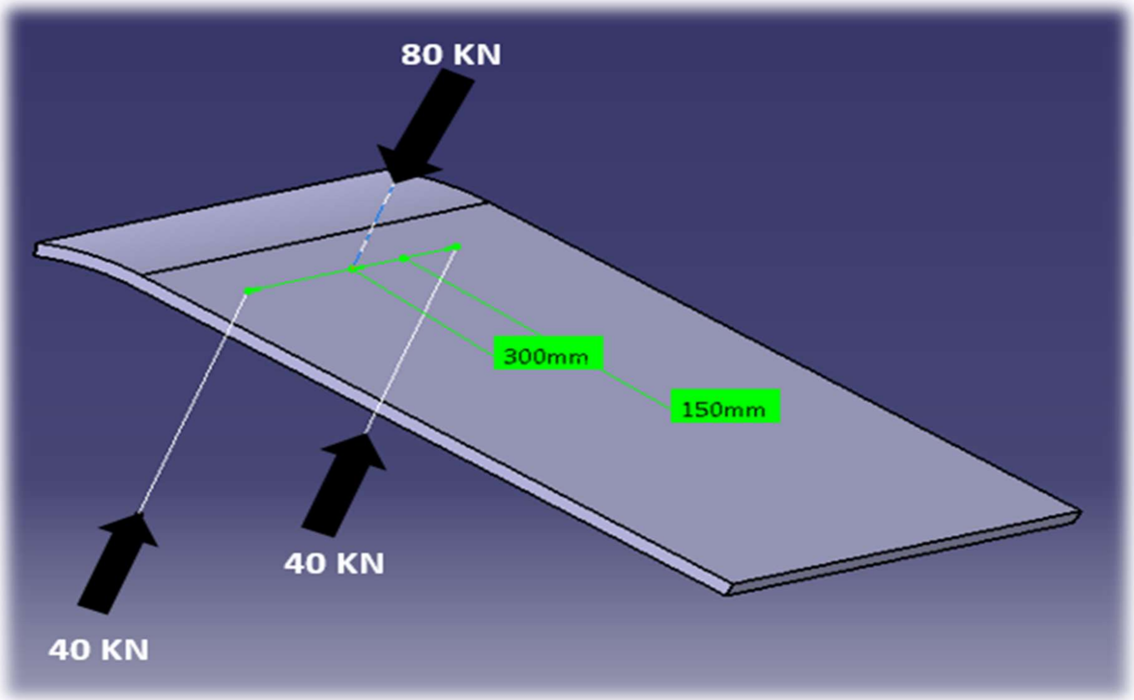


Figure 4.2 load distribution on the plate

To find the radial load acting on the bearing and spring, we can use moment and force equation.

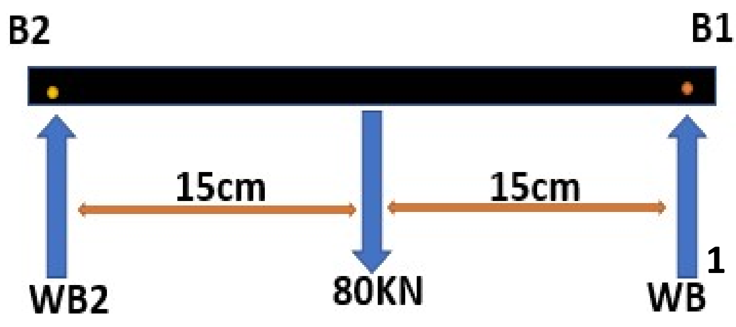


Figure 4.3 Free body diagram

From figure 4.3.

$$\sum M \text{ at } B_1=0 \qquad (4.11)$$

WB2(30)-80(15)=0

WB2=40KN

$$\sum F_y=0 \qquad (4.12)$$

WB1+WB2=80

SO;

WB1=40KN

Now we will find C_{10} for the bearing.

$$F_D = a_f * V * F_r \qquad (4.13)$$

Where

a_f= 1 [precision gearing]

V=1.2 [rotating outer ring]

F_D = 1 * 1.2 * 40 = 48 KN

L_D=L D_h * n $_D$ * 60

Where;

L D_h = 30000 hour for general industrial bearing

nD = 600rpm

LD= 30000*600*60= $1.08*10^9$rev

Now ;

$$C_{10} = F_D * \left[\frac{X_D}{X_0 + (\theta - X_0) * (1 - RD)^{1/b}}\right] \qquad \textbf{(4.14)}$$

$X_D = \frac{LD}{L10} = 1.08 * \frac{10^9}{10^6} = 1.08 * 10^3$

R = 0.9

a = 300 “Ball bearing”

FD = 48 KN

$X_0 = 0.02$

$\theta = 4.459$

b = 1.483

so;

after substitute these values in equation 4.13

$C_{10} = 507.5$

From table 4.1[19] the available $C_{10} = 539$

Table4. 1 representative catalog data for cylindrical roller bearing

	02-Series				03-Series			
Bore, mm	OD, mm	Width, mm	Load Rating, kN C_{10}	C_0	OD, mm	Width, mm	Load Rating, kN C_{10}	C_0
25	52	15	16.8	8.8	62	17	28.6	15.0
30	62	16	22.4	12.0	72	19	36.9	20.0
35	72	17	31.9	17.6	80	21	44.6	27.1
40	80	18	41.8	24.0	90	23	56.1	32.5
45	85	19	44.0	25.5	100	25	72.1	45.4
50	90	20	45.7	27.5	110	27	88.0	52.0
55	100	21	56.1	34.0	120	29	102	67.2
60	110	22	64.4	43.1	130	31	123	76.5
65	120	23	76.5	51.2	140	33	138	85.0
70	125	24	79.2	51.2	150	35	151	102
75	130	25	93.1	63.2	160	37	183	125
80	140	26	106	69.4	170	39	190	125
85	150	28	119	78.3	180	41	212	149
90	160	30	142	100	190	43	242	160
95	170	32	165	112	200	45	264	189
100	180	34	183	125	215	47	303	220
110	200	38	229	167	240	50	391	304
120	215	40	260	183	260	55	457	340
130	230	40	270	193	280	58	539	408
140	250	42	319	240	300	62	682	454
150	270	45	446	260	320	65	781	502

Bearing type is single row O-3 series, deep grove and angular contact ball bearing.

4.7 spring design

In this section, the spring will be used over rod to prevent buckling, where :-

Ls < 200mm

d rod = 80mm

F = 4000 N after being 100

End square and ground type

Y max = 220 mm

For spring design, we will use music wire A228. table 4.2[19] .

Table 4.2 Constants A and m of Sut 5 Ayd m for Estimating Minimum Tensile Strength of Common Spring Wires

Material	ASTM No.	Exponent m	Diameter, in	A, $kpsi \cdot in^m$	Diameter, mm	A, $MPa \cdot mm^m$	Relative Cost of Wire
Music wire*	A228	0.145	0.004–0.256	201	0.10–6.5	2211	2.6
OQ&T wire†	A229	0.187	0.020–0.500	147	0.5–12.7	1855	1.3
Hard-drawn wire‡	A227	0.190	0.028–0.500	140	0.7–12.7	1783	1.0
Chrome-vanadium wire§	A232	0.168	0.032–0.437	169	0.8–11.1	2005	3.1
Chrome-silicon wire‖	A401	0.108	0.063–0.375	202	1.6–9.5	1974	4.0
302 Stainless wire#	A313	0.146	0.013–0.10	169	0.3–2.5	1867	7.6–11
		0.263	0.10–0.20	128	2.5–5	2065	
		0.478	0.20–0.40	90	5–10	2911	
Phosphor-bronze wire**	B159	0	0.004–0.022	145	0.1–0.6	1000	8.0
		0.028	0.022–0.075	121	0.6–2	913	
		0.064	0.075–0.30	110	2–7.5	932	

A=2211 Mpa.mm

m = 0.145

From table 4.3

Table 4.3 Mechanical Properties of Some Spring Wires

Material	Elastic Limit, Percent of S_{ut} Tension	Torsion	Diameter d, in	E Mpsi	E GPa	G Mpsi	G GPa
Music wire A228	65–75	45–60	<0.032	29.5	203.4	12.0	82.7
			0.033–0.063	29.0	200	11.85	81.7
			0.064–0.125	28.5	196.5	11.75	81.0
			>0.125	28.0	193	11.6	80.0
HD spring A227	60–70	45–55	<0.032	28.8	198.6	11.7	80.7
			0.033–0.063	28.7	197.9	11.6	80.0
			0.064–0.125	28.6	197.2	11.5	79.3
			>0.125	28.5	196.5	11.4	78.6
Oil tempered A239	85–90	45–50		28.5	196.5	11.2	77.2
Valve spring A230	85–90	50–60		29.5	203.4	11.2	77.2
Chrome-vanadium A231	88–93	65–75		29.5	203.4	11.2	77.2
A232	88–93			29.5	203.4	11.2	77.2
Chrome-silicon A401	85–93	65–75		29.5	203.4	11.2	77.2
Stainless steel							
A313*	65–75	45–55		28	193	10	69.0
17-7PH	75–80	55–60		29.5	208.4	11	75.8
414	65–70	42–55		29	200	11.2	77.2
420	65–75	45–55		29	200	11.2	77.2
431	72–76	50–55		30	206	11.5	79.3
Phosphor-bronze B159	75–80	45–50		15	103.4	6	41.4
Beryllium-copper B197	70	50		17	117.2	6.5	44.8
	75	50–55		19	131	7.3	50.3
Inconel alloy X-750	65–70	40–45		31	213.7	11.2	77.2

E = 196.5 Gpa

G = 81 Gpa

d expected 10 mm

For safety, used design factor = $(n_s)d$ = 1.2

Robost linearity Z = 0.15

We will use as-wound spring Ssy = 0.455ut.

$$D = d_{rod} + d + d_{allowance} \quad (4.15)$$

D= 80 + 10+1

D= 91 mm

$C = \frac{91}{10} = 9.1$

$$ID = D - d \quad (4.16)$$

ID = 91– 10 = 81 mm

OD = D + d = 91 + 10= 101mm

$$N_a = \frac{G * d^4 * Y_{max}}{8 * D^3 * F_{max}} \quad (4.17)$$

$N_a = \frac{81000*220*(10)^4}{8*(91)^3*4000} = 7.3$ turn

$$Nt = Na + 2 \quad (4.18)$$

$Nt = 7.3 + 2 = 9.3$

Ls = d Nt = 10*9.3 = 90.3

Lo = Ls+1.15(220) = 343.3

$$L\,cr = 2.63\frac{D}{\alpha} \quad (4.19)$$

$$Ssy = 0.45*\frac{2211}{10^{0.145}} = 712.526 \quad (4.20)$$

$\alpha = \frac{Ssy}{n_s} = \frac{712.526}{1.2} = 593.77$

Lcr = 2.63 $(\frac{91}{0.5})$ = 478.66

$$F_{om} = -\pi^2\ d^2\ \frac{NtD}{4} \quad (4.21)$$

$F_{om} = -\pi^2\ 10^2\ \frac{9.3*91}{4} = -2086004$

Table 4.4 show the Spring properties.

Properties	Value
D	10 mm
D	91mm
C	9.1
ID	81 mm
OD	101 mm
Na	7 turn
Ls	90.3 mm
Lo	343.3 mm
Lcr	478.77 mm
Ns	1.2
Fom	-2086004

4.8 joint welding design

This section we discuss the welding design of the male joint, see figure 4.4.

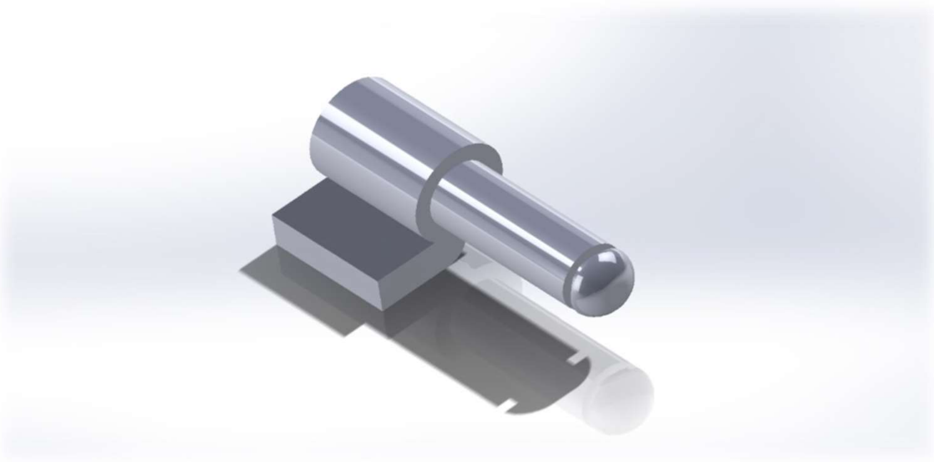


Figure 4.4 male connect joint

figure 4.5 show the material of the part which will connect.

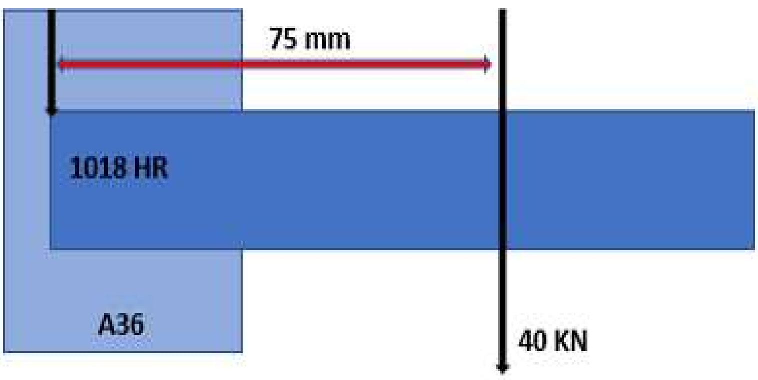


Figure 4.5 material and load subjected on the part

Figure 4.6 show half rectangular pattern of welding which could be the best pattern.

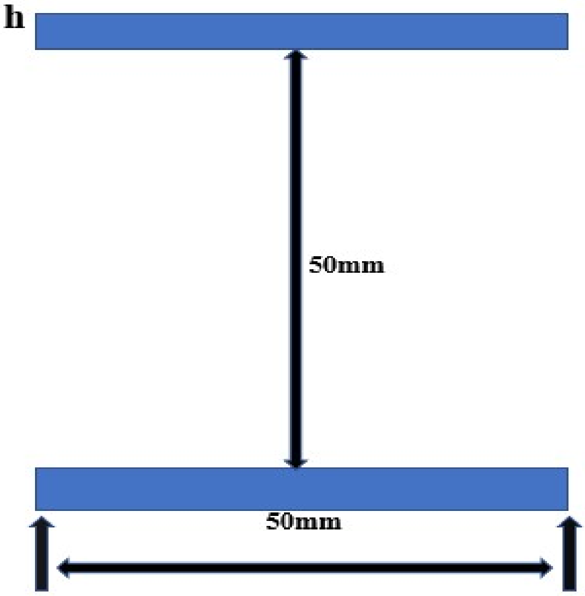
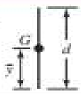
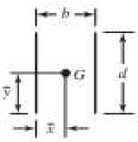
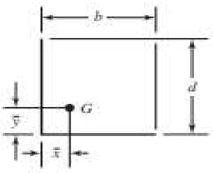
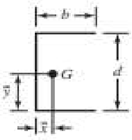


Figure 4.6 welding pattern

M=4000 * 50 = 200 KN.mm

Table 4.5 Torsional Properties of Fillet Welds

Weld	Throat Area	Location of G	Unit Second Polar Moment of Area
1. 	$A = 0.707hd$	$\bar{x} = 0$ $\bar{y} = d/2$	$J_u = d^3/12$
2. 	$A = 1.414hd$	$\bar{x} = b/2$ $\bar{y} = d/2$	$J_u = \frac{d(3b^2 + d^2)}{6}$
3. 	$A = 0.707h(b + d)$	$\bar{x} = \frac{b^2}{2(b + d)}$ $\bar{y} = \frac{d^2}{2(b + d)}$	$J_u = \frac{(b + d)^4 - 6b^2d^2}{12(b + d)}$
4. 	$A = 0.707h(2b + d)$	$\bar{x} = \frac{b^2}{2b + d}$ $\bar{y} = d/2$	$J_u = \frac{8b^3 + 6bd^2 + d^3}{12} - \frac{b^4}{2b + d}$

From table 4.5 [19].

$$A = 1.414\, hd \qquad (4.22)$$

A=1.414 h (50) = 70700 h mm^2

$$Ju = \frac{d(3b^2 + d^2)}{6} \qquad (4.23)$$

$\mathrm{Ju} = 3145833.33\mathrm{mm}^3$

By load analysis

rx = 50 mm

ry = 50 mm

Now,

$$\tau' = \frac{F}{A} = \frac{4000}{70700h} = \frac{0.0565}{h} \qquad (4.23)$$

J = 0.707 * h * Ju

J = 270427.5 h

$$\tau'' = \frac{\mathrm{Mr_y}}{\mathrm{J}} = 200000 * \frac{50}{270427\ \mathrm{h}} = \frac{36.97}{\mathrm{h}} \qquad (4.24)$$

$$\tau = \sqrt{\tau_x''^2 + (\tau_y'' + \tau_y')^2} = \frac{52.3}{h}\ Mpa \qquad (4.25)$$

Now;

Member: structural steel A36, $s_y = 248Mpa$

Attachment AISI 1018HR steel, $s_y = 220Mpa$

Allowable stress: -

Attachment: τ allowable = 0.4 s_y = 0.4(220) = 88Mpa

Member : τ allowable 0.4 s_s = 0.4(248) = 99.2Mpa

E60 xx can be used to weld it.

τ allowable for electrode = 0.3 sut=0.3*60 = 18Kpsi= 123.75

Now, for entire joint, we have

τ allowable = minimum value which equal to 88 Mpa

τ maximum = τ allowable

So; $h = \frac{52.3}{88}$ = 0.59 mm

Table 4.6 show the result of the welding properties.

Table 5.6 welding properties

Pattern	See figure 4.5
Electrode	E60 XX
Type	Fillet weld
size	H=0.59
Total length	100mm

Chapter 5

Manufacturing

5.1 Introduction

This chapter will show the prototyping manufacturing and all actual project's parts.

5.2 Frame

the frame completely made by iron. Figure 5.1 show the frame of the speed bump where all of the frame collected together by two manufacturing process.

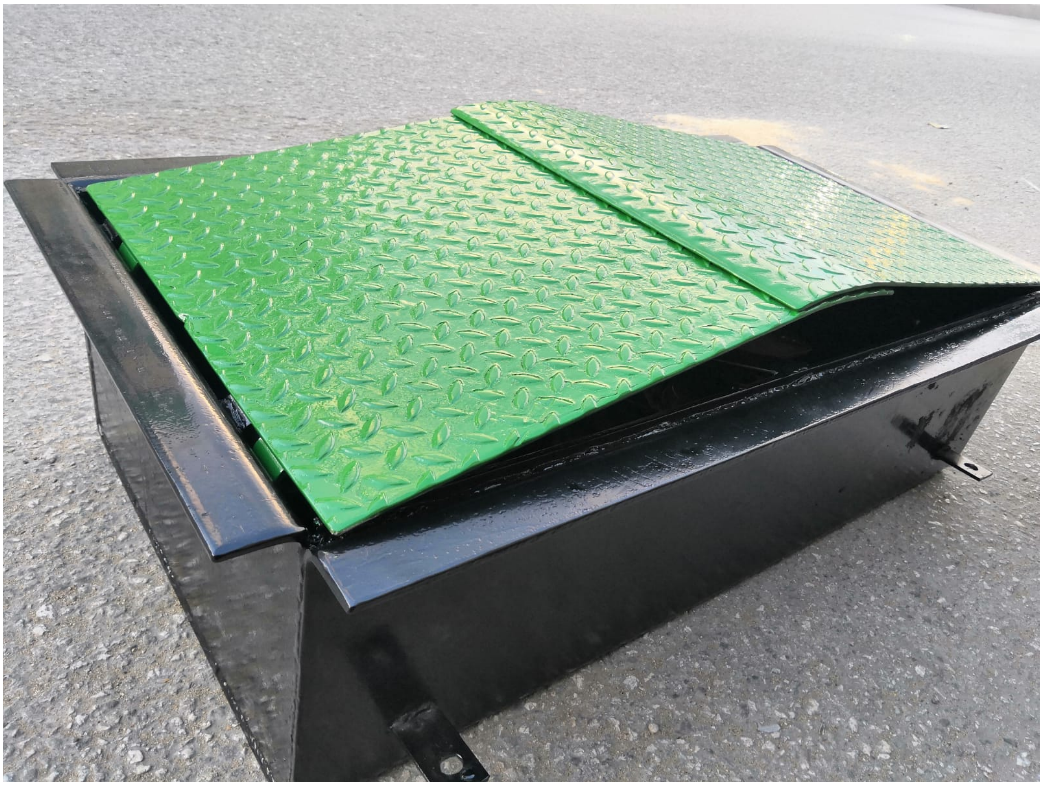


Figure 5.1: project frame

1. Bending process, which applied on the long side and top shelf of the frame.

2. Welding process, which applied to connect long and short side of the frame and also to create the oil tank inside the same frame, and to create frame support.

5.3 Dynamo

Figure 5.2 show the actual generator used which is connect to the frame using two screw. , Valeo dynamo which has these properties.

1. Maximum voltage output 13.5 v at 1700 rpm
2. Maximum Current output 90 A

Figure 5.2: Valeo dynamo

5.4 Hydraulic Motor

Danfoss hydraulic motor [OMM 8] being the best available choice, see figure 5.3 to see Danfoss motor characteristic, hydraulic motor connect o the frame using three screw and connect to the dynamo with special coupling system.

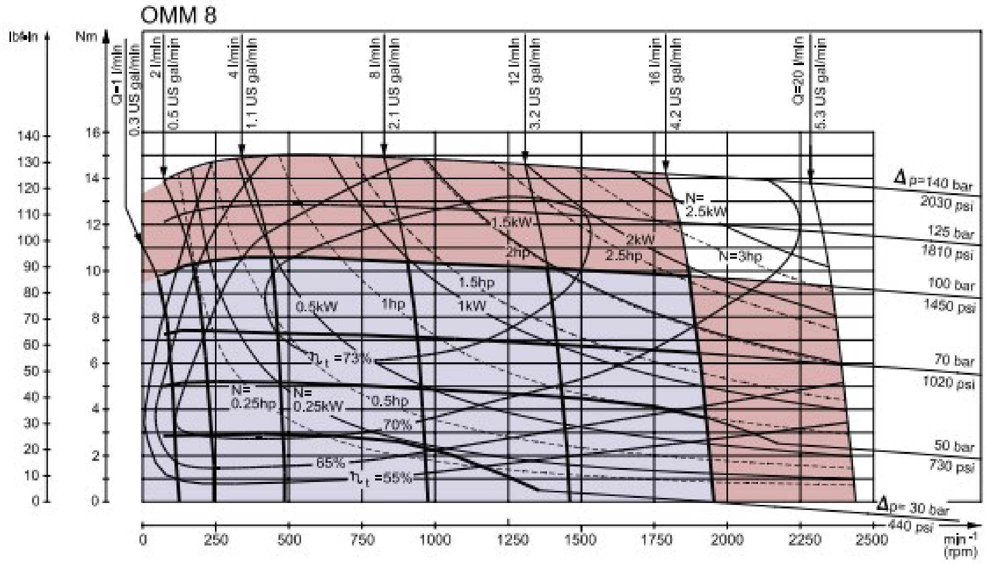


Figure 5.3: OMM 8 function diagram

Figure 5.4 show OMM 8 hydraulic motor body.

Figure 5.4: OMM 8 Danfoss hydraulic motor

5.5 accumulator

2L Hydac German accumulator with 210 bar limit shown in figure 5.5.

Hydac Diaphragm Accumulator, SB0 210-2.0 E1

Full P/N- SB0 210-2.0 E1/112A-210AK
2.0L
PB- 210BAR
TB- 20/80 Degrees C

Figure 5.5: 2L Hydac accumulator

5.6 pressure switch

Figure 5.6 show Danfoss pressure switch.

Figure 5.6: Danfoss pressure switch

See table 5.1 which show electrical specification of the pressure switch.

Table 5.1: electrical specification

Contact load (Alternating current)	0.5 A, 250 V, AC15
	12 W, 125V, DC 13
Switch	SPDT

5.7 Timer

The timer is shown in figure 5.7 has been set 8.8 second to empty the accumulator.

Figure 5.7: Timer

5.8 hydraulic solenoid

Figure 5.8 show hydraulic solenoid which will work as normally open or normally clos as result of pressure switch sign. Where hydraulic solenoid connects directly to the accumulator from input side and to the hydraulic motor from output side.

Figure 5.8: hydraulic solenoid

5.9 Hydraulic cylinder, spring and bearing

Figure 5.9 show hydraulic cylinder covered with spring and two limit part of iron., same figure show bearing which work as a load transporter between the plate which shown in figure 5.10 and the hydraulic cylinder.

Figure 5.9: hydraulic cylinder

5.10 plate

The Plate that shown in figure 5.10 consider the only shown parts from the project when it is mounted in the test location.

Figure 5.10: plate

Chapter 6

Results and Conclusion

6.1 Results

This project focuses on converting the everyday speed bump movement up and down into an energy without any type of undesirable emission , capable of using the force exerted by a vehicle passing over the speed bump to generate electricity as a new system which utilizes the inertia of passing vehicles on the hydraulic speed bump, which forces hydraulic fluid to press through a special tube, and then to rotate motor turbine that connects with an alternator then produces electricity and stores it in a battery that can be used to recharge plug-in cars, streetlights, and electric charge points for portable devices, so the results can be summarizes to:

1. The speed bump designed to work in two way, forward and backward as well.
2. The torque required to rotate the motor equal to 8.59 N.m.
3. The motor volume displacement needed equal to 8 cm2.
4. The daily energy can be calculated through equation4.10 which equal to 13kw during one day working only.

5. Spring property needed can be seen in table 4.4.
6. Welding property needed can be seen in table 4.5.

6.2 Conclusion

This environmental friendly mechanism designed to produce power and store it in the battery, which can use it again to recharge plug-in cars, streetlights, and electric charge points for portable devices.

Design and simulation of a speed bump mechanism for environmentally suitable and all year-round energy producing alternative, which is achieved firstly by reviewing literatures analysis with the theoretical background and related equations then simulating the proposed system parts using software like, CATIA V5, solid work, Festo sim. Power Generation using hydraulic speed bump, can generate about “12 kilo watt” energy per a day , this technique of power generation will help to reduce the total burden of electricity demand. The speed bump system driven by a vehicle on a road as a prime power generation source has many benefits like it does not depend on any type of fuel to run it, no waste production at any stage of the power generation process, power generation is environmental friendly, more sustainable and can be applied on large scale to produce a larger amount of energy to benefit a bigger population.

Chapter 7

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