ADVANCE VEHICLE SUSPENSION WITH ENERGY CONVERSION

Capstone

Submitted for the Degree of

Bachelor of Technology

By

ANKUR TIWARI	**11108536**
NIKUNJ SINGH	**11111388**
SHIVASHEESH SINGH	**11109317**

DEPARTMENT OF MECHANICAL ENGINEERING

LOVELY PROFESSIONAL UNIVERSITY

PHAGWARA, PUNJAB – 144402

ADVANCE VEHICLE SUSPENSION WITH ENERGY CONVERSION

Capstone

Submitted for the Degree of

Bachelor of Technology

By

ANKUR TIWARI

NIKUNJ SINGH

SHIVASHEESH SINGH

Under the Guidance of

Mr. VIVEK PARMAR

(Assistant Professor)

DEPARTMENT OF MECHANICAL ENGINEERING

LOVELY PROFESSIONAL UNIVERSITY

PHAGWARA, PUNJAB – 144402

CERTIFICATE

This is to certify that the work which is being presented in Capstone project titled "**ADVANCE VEHICLE SUSPENSION WITH ENERGY CONVERSION** " for partial fulfilment of the requirement for the award of degree of **BACHELOR OF TECHNOLOGY** and submitted in department of mechanical engineering, Lovely Professional University, Punjab is an authentic record of our own work carried during period of capstone project under the supervision of **Mr. VIVEK PARMAR,** Assistant professor, Dept. of Mechanical engineering.

The matter presented in this project is the result of our original investigation and study. No part the project proposal has ever been submitted for any other degree or diploma.

Date: ANKUR TIWARI

NIKUNJ SINGH

SHIVASHEESH SINGH

The Capstone Project proposal is fit for the submission and partial fulfilment of the conditions for the award of degree of B.Tech mechanical engineering.

Date: (Mr. Vivek Parmar)

UID - 18549

ACKNOWLEDGEMENT

We have taken efforts in this project .It would have not been possible without support of my friends and Organisation. We would like to thanks to all of them.

We are highly indebted to Mr. Vivek Parmar for their guidance and for providing necessary information regarding project.

Our thanks and appreciation also go to all our colleague who gave their best in completing the project. Also to the people who have helped us with their abilities.

.

ANKUR TIWARI

NIKUNJ SINGH

SHIVASHEESH SINGH

CERTIFICATE

This is to certify that

Ankur Tiwari 11108536

Nikunj Singh 11111388

Shivasheesh Singh 11109317

have completed objective formulation of capstone project titled **"Advanced vehicle Suspension with energy conversion"** under my guidance and supervision. To the best of my knowledge, the present work is the result of their original investigation and study. No part of the Capstone as ever been submitted for any other degree at any University.

The Capstone project is fit for submission and the partial fulfilment of the conditions for the award of B.Tech in Mechanical Engineering from Lovely Professional University, Phagwara.

Signature and Name of the Research Supervisor

Designation:

School:

Lovely Professional University

Phagwara, Punjab.

Date:

DECLARATION

We,

ANKUR TIWARI

NIKUNJ SINGH

SHIVASHEESH SINGH

Students of Mechanical Engineering under department of Lovely Faculty of Technology and Sciences of Lovely Professional University, Punjab, hereby declare that all the information furnished in this Capstone project report is based on our intensive research and is genuine.

This Capstone does not, to the best our knowledge, contain part our work which has been submitted for the award of our degree either of this University or any other University without proper citation.

Date:

ANKUR TIWARI

NIKUNJ SINGH

SHIVASHEESH SINGH

ABSTRACT

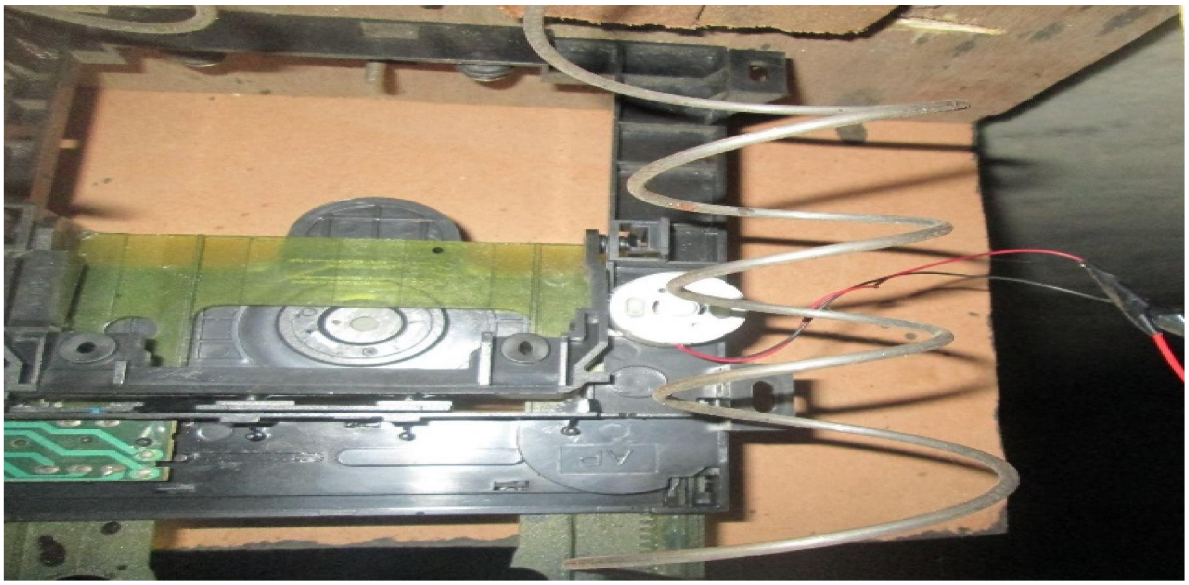
In current scenario, power is the primary need for the survival of human life. Researches shows that large amount of power is generated from non-renewable energy resources compared to that of renewable energy resources. The extensive usages of available resources in recent years created a demand for the future generation. To overcome this problem we need to utilize renewable energy sources for power generation and conservation. Therefore we have to focus more on the consumable source of energy, that are very useful and non-polluting. In this report we have focused to show the detailed survey on the mechanism for power generation from the renewable energy resources includes piston mechanism, piezoelectric mechanism, rack and pinion mechanism and the roller mechanism

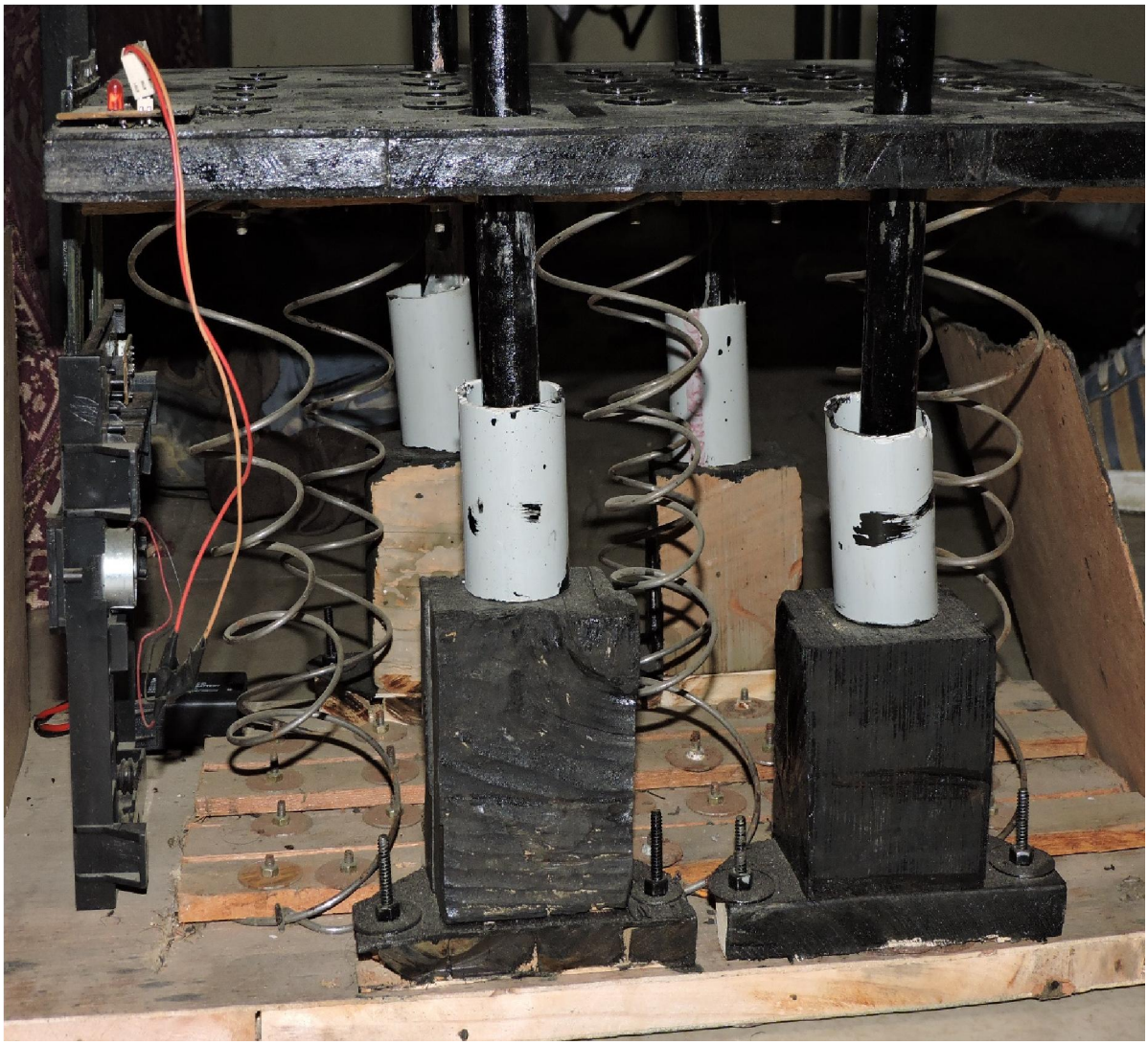
CONTENT

List of figure Page No

LIST OF SYMBOL USED

V	VELOCITY OF SHAFT
P	POWER OF SHAFT
N	NO. OF REVOLUTION
M	MASS APPLIED
G	GRAVITATIONAL FORCE
D	DIA OF GEAR
K	STIFFNESS
E	ENERGY
X	DISPLACEMENT





CHAPTER 1

INTRODUCTION

In this present era of engineering the consumption of conventional fuel is a major problem which we are facing in these days. And according to Surveys done by several organization there will be a time soon nearly 40 to 60 years when there will be no conventional fuel saved on earth if the consumption continues with this rate.

Therefore there is a need to approach the ways by which we can get useful form of energy without consumption of Petroleum product and hence less hazard to the atmosphere.

In order to get most useful form of energy that is Electrical energy there are several new ideas and ways are being find out by our scientist and engineers.

This project "Advanced Vehicle System With energy conversion And Battery Charging System" is a small but important idea to utilize the non usable form of energy which is produced by suspension system of vehicle during compression or expansion of spring into useful form of electrical energy by making some Rack and Pinion attachment to suspension system and a DC motor.

This is definitely not the way that may create a revolution in the field of energy conservation for Electric Vehicles but still it will be a bit of useful. For the utilization of non useful form of energy and also may be useful to increase the range of electrically chargeable vehicles.

This project is not exactly same as it we see or imagine in our vehicle suspension system because a normal vehicle suspension system requires minimum of 50 to 60 kg of weight or force in order to compress or expand which was practically very difficult to us therefore we just used our basic idea for generation of electricity and made a model which provides the generalized way of conversion of one form of energy into other form.

Purpose:

To utilize the mechanical energy absorbed by damper sand to convert it into electrical form for further utilization as well as for storing purpose.

Necessity of This Project:

As we all know that energy is neither can be created nor can be destroyed therefore entire study of Science and Engineering which involve the most effective and efficient use of available energy either that is in form of Chemical energy or in form of Heat energy or in term of Mechanical work output.

The entire study of Engineering is to get the best possible form of energy which we can utilize in our own way because till now we are not able to produce it. But we can transform its state .

In our world electrical energy is most useful energy which is produced from different methods and mainly from the power plants.

The main purpose for which we are working on this project is to convert the mechanical energy produced with the help of rack and pinion in to a electrical energy and where rack and pinion is attached to the suspension system of vehicle and a DC motor.

This method is also adoptable in case of conservation of this electrical energy with the help of Battery.

This Project is based on the conversion of one form of energy into one other form of energy therefore a number of setup or attachments are used and a conventional system is get modified with the help of these attachments.

For making out this project there has a set of procedures been taken place and those involves from development of idea , planning for individual contribution , exploration of views, developing a strategy, formulate the strategy, study and application prospective.

There are some terminologies or Engineering terms which plays an important role regarding the working components of project.

TERMINOLOGY

- **Energy:**

  It is a vital amount and extensive property (dependent on mass) of matter which provides any action to the particular component. Most important thing about it is that it is always conserved but changes its state of occurrence.

  eg- i) Potential Energy

  ii) Kinetic Energy

  iii) Mechanical Energy

  iv) Heat Energy etc.

- **Damping:**

  It is the resistance offered by a body to the motion of a vibratory system. The resistance may be applied by a liquid or solid internally or externally

- **Stiffness:**

  It is defined as the ability of material to resist deformation when external load is applied.

- **Modulus Of Elasticity:**

  It is the process to measure the stiffness of a body.

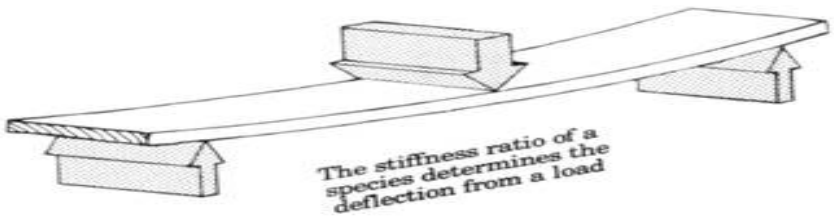


Fig. 1.1 stiffness

- **Resilience:**

  It is defined as the ability of the material to absorb energy when deformed elastically and to release it when unloaded. A resilience energy absorbs energy within elastic range without any permanent deformation. This property is essential for spring materials.

  Resilience is measured by a quantity called modulus of Resilience which is the strain energy per unit volume that is required to stress the specimen in a tension test to the elastic limit point.

  It is represented by the area under the stress strain curve from the origin to elastic limit point.

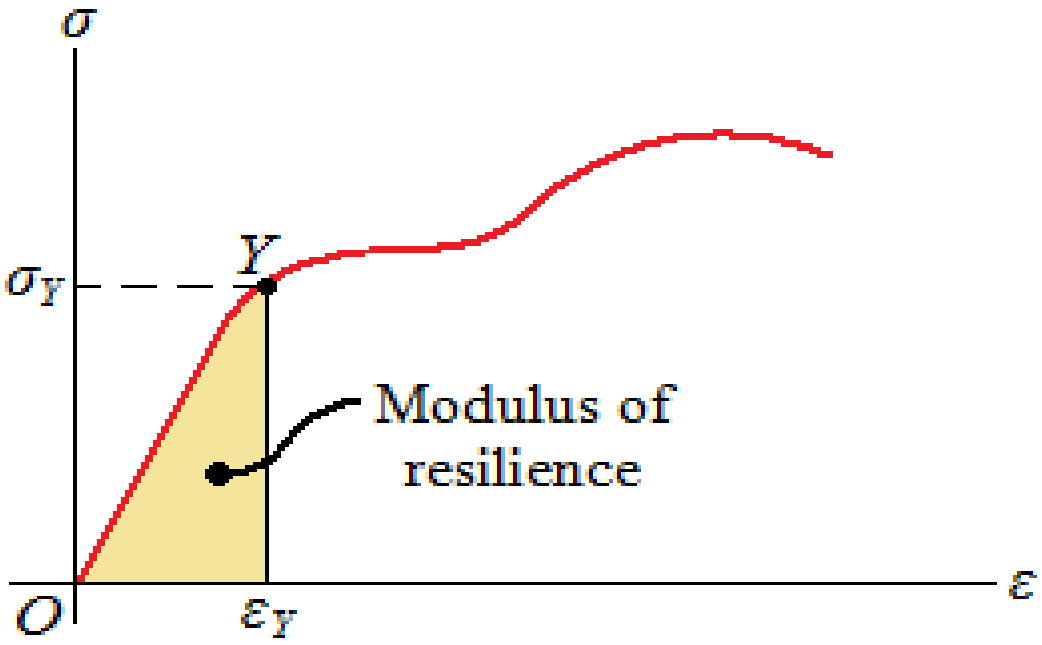


Fig. 1.2 modulus of resilience

- **Toughness:**

  Toughness is defined as the ability of material to absorb energy before fracture takes place. In other words toughness is the energy for failure by fracture . This property is essential for machine components which are required to withstand impact loads. Tough materials have ability to bend, twist and stretch before fracture takes place.

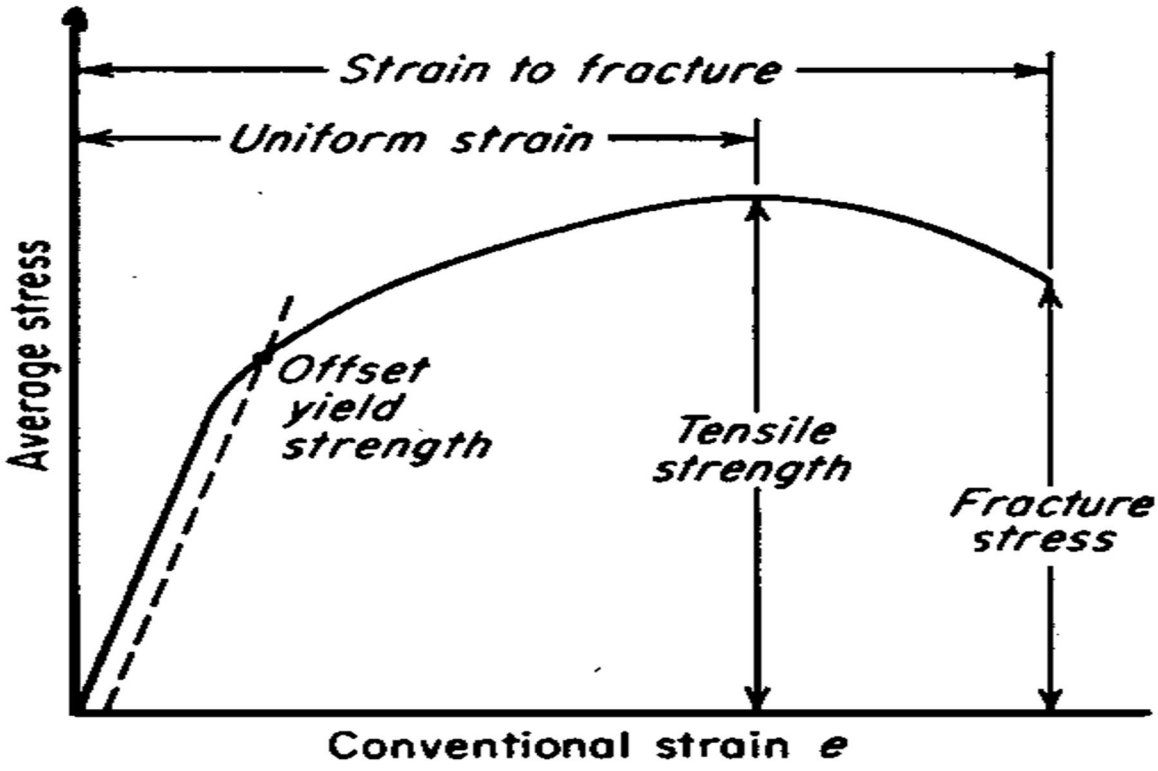


Fig. 1.3 toughness

- **Malleability:**

  It is defined as the ability of a material to a greater extent before the crack, when it is subjected to compressive force. The term malleability comes from the word meaning hammer and in a narrow sense it means the ability to be hammered out into thin sections. Malleable metal can be rolled forged or extruded because these processes involve shaping under compressive force.

Fig. 1.4 malleability

CHAPTER 2

LITERATURE REVIEW

Amod Kumar Pandey Experimented that the electrical energy is generated from the speed breakers due to the motion of the vehicle by using the rack and pinion arrangement. The roller attached with gear arrangement will rotate when a vehicle moves over it. It is found that a maximum of 15W power can be obtained from this method. If the kinetic energy of the roller is 4541 J then 5V electrical power is generated at 4 Sec and it will give the efficiency of about 40% and if 6469 J of kinetic energy will act on roller then 5.5 V electrical power is generated at 4-5 Sec. It is experimentally described that the current installed capacity of India's is 255.012 GW. The peak power shortage of our nation is 7.4%. It is derived that this mechanism will generate 1000 W electrical power when the number of rollers is increased.

Aniket Mishra Described in this paper that the kinetic energy of the moving vehicle can be converted into mechanical energy of the shaft through the rack and pinion arrangement. This method is made through rack and pinion gears, ball bearing, spur gear, flywheel, shaft and generator. The mass of the vehicle travelled through speed break is 300kg then the output power developed for one minute is 7.37 W and for one hour is 441.4 W and for one day is 10.8 W. Thus the electrical energy generated by the vehicles in one day is sufficient for running the four street lights at a time for a whole night. Now a days the conventional energies are become very low in quantity so it is the right time for focusing on the alternative sources. This process is a pollution free power generation and no any need of man power during the power generation.

Pankaj D.Jagtap Described the mechanism of rack and pinion. He observed that the best method for efficient and moderate cost of producing the electric power from speed breaker and it gives 60 – 80 % efficiency. The rack and pinion mechanism will give the efficiency of 1.5 times greater than the roller mechanism. His comment on this mechanism that it will give the efficiency of 1.5 times greater than the roller mechanism.

A.Padma Rao Tells about the mechanism of rack and pinion. He observed that the electrical energy generated by utilizing the kinetic energy of the moving vehicle. He says that the best method of generating electrical energy with the efficiency of 70 - 80 %. -Electrical energy of 2.452 W is generated by the vehicle of mass having 150 kg by one push of speed breaker. When used in an electric vehicle or hybrid electric vehicle the electricity generated by the shock absorber can be diverted to its powertrain to increase battery life. In non-electric vehicles the electricity can be used to power accessories such as air conditioning. Several different systems have been developed recently, though they are still in stages of development and not installed on production vehicles.

THE SCOPE FOR PROJECT

In our country due to increased profitable capacity, progress lifestyle and rapidly growing industrialization, the requirement & demand of transportation is increasing day- by- day. The number of vehicles revolving on the road is increasing daily. Hence chances of accidents are multiply while crossing the road especially by the children and old persons. So it became necessary to make a new speed breakers at the school building or Hospital building side road or highway. The opposing impact energy supplied by the hard speed breaker will apply massive thrust impact on the suspension system of the vehicle. This impact force can be use for power generation using regenerative method and use to charge battery and release load of alternator or dynamo from engine.

CHAPTER 3
WORKING OF THE PROJECT

In advance vehicle system of Regenerative suspension basically new concept of non-conventional energy generation. It is electro-mechanical energy generating device. This device converts reciprocating motion in to rotary motion. When we use weight on a working model then a force is applied on a modal. Due to which our mechanism on suspension, the head of rack with pinion is worked. In that (When vehicles move on speed breaker) rack will be reciprocate. The rack is attached with pinion that rotates in one direction only. The rack & pinion order convert reciprocating motion in to rotary motion. The output of free wheel is attached with flywheel which stores kinetic energy and transfer to motor (dynamo) which generate electricity with zero cost.

In that system When we applying a force on system due to the weight of a body when break aping on it then due to which a rack is moving down and because of that a pinion is attached to a motor and its rotates the motor which attached throw a motor and help of a motor it convert mechanical energy into a electrical energy it worked as a dynamo. In that case of a advance vehicle after the compression of a spring when expansion is happen in it. Motor is produced energy both side clockwise or anticlockwise so due to this a max energy is produced by a motor.

Energy is produced by a motor is stored in battery with the help of this extra energy it increased the efficiency of a vehicle.

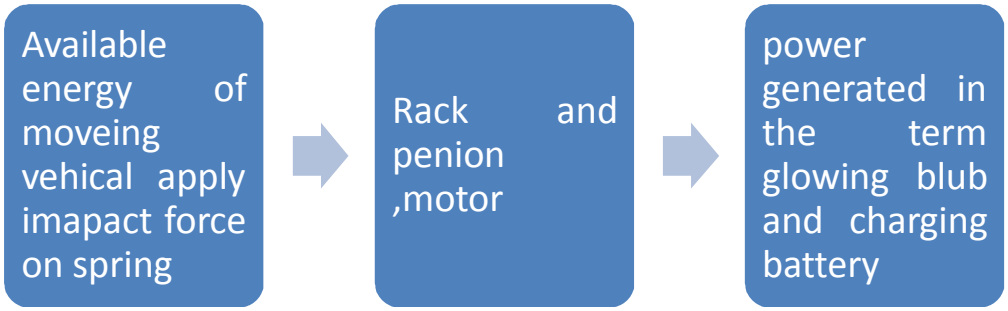


Fig. 3.1 working

Components used in a project:-

STEPPER MOTOR:-

In that stepper motor power is produced in clockwise and anticlockwise rotation of motor. A stepper motor is a special type of electric motor that moves in increments, steps, slightly than turning smoothly as a conventional motor does. In a stepper motor it produced more power than other motor.

Fig 3.2 stepper motor

SPRING:-

Spring steel is a low alloy with a very high yield strength. Because of yield strength the objects made of spring steel to return to their original shape despite significant bending or twisting.

Fig 3.3 spring

RACK:-

A rack & pinion is the working of two gear together in which pinion is the normal round gear and the rack is straight or flat. The 'rack' has teeth cut in it and they mesh with the teeth of the pinion gear.

In which pinion moved in a rack as a straight line. It can also be changes rotary motion to linear motion.

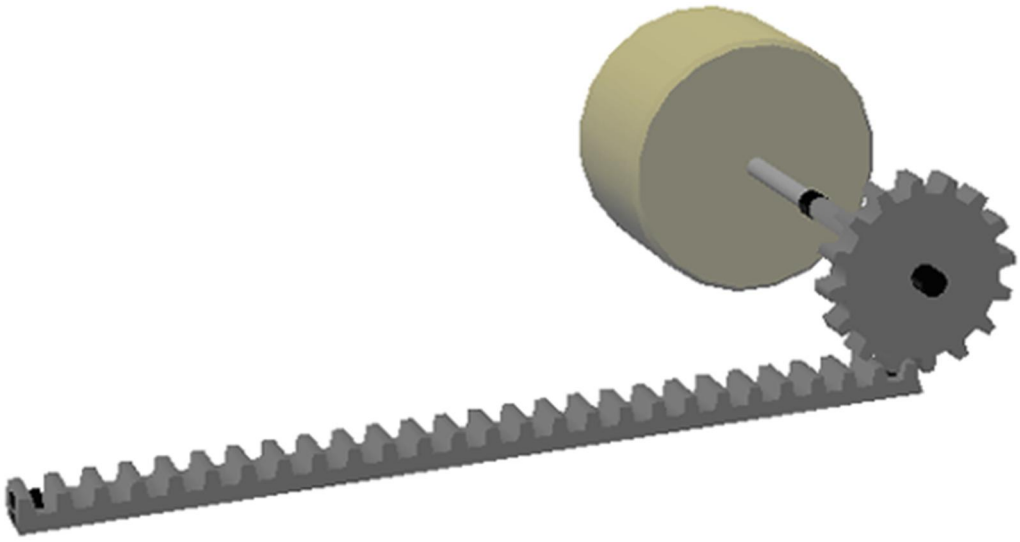


Fig 3.4 rack and pinion

DC RECHARGEABLE BATTERY:-

Mostly in that used a lead-acid, nickel cadmium, lithium ion combination are use in it. It is a dc battery which is charged by a stepper motor so it can be charge and discharge again and again.

Fig 3.5 battery

LED (light emitting diode):-

A light-emitting diode (LED) is a semiconductor device that emits visible light when an electric current passes through it. The light is not especially bright, but in many LEDs it is monochromatic, take place at a single wavelength.

LED light bulbs are a more environmentally-friendly alternative to incandescent bulbs. LED bulbs use a semiconductor apparatus that discharges visible light when an electric current passes through it.

Fig 3.6 LED

CHAPTER 4
METHODOLOGY & OBSERVATION

A system that converts kinetic energy of shock absorber to electrical energy. A setup is designed in that the whole designed are make how to produce a max electricity.It's all subcomponents are taken. Then all the subcomponents are assembled together in a repetitively manner so can its order can be fixed. After assembled the components the setup is tested for the checking whether they are correctly performing the task or not in that all the component check carefully. Under this method when applying a forced in a working model its rack moved the pinion and due to pinion a motor is moved and produced a electricity. A electricity are used for glowing blub or charging a battery

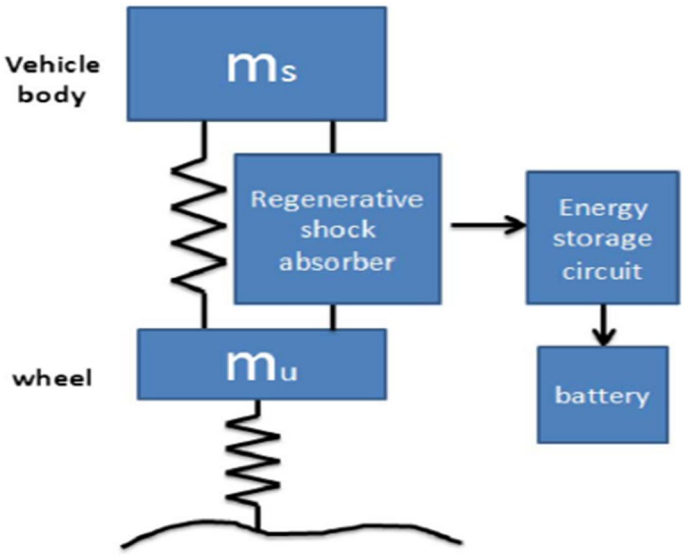


Fig 4.1 circuit diagram

MODEL CALCULATIONS:-

For a generator minimum usable amount of current can be produced with N=200rpm.

We need to develop 200rpm in shaft with the help of gearing arrangement. Hence by increasing the velocity ratio we can get power output.

Now power developed with this r.p.m.

V= Velocity of shaft.

P = Power of the shaft.

N = No. of rotation.

m = Mass applied.

g = Gravitational force.

t = Time taken.

d = Diameter.

k = Stiffness.

V = 0.05 m/s (given)

P = F * V

P = $m * g * V$

$= 0.5 * 9.81 * 0.05$

P = 0.2452 watt

$E = P * t$

$E = 0.2452 * 3600$

E = 882.9 joule

This energy is very less so therefore we need a gearing arrangement in order to increase power output.

P is directly proportional to N.

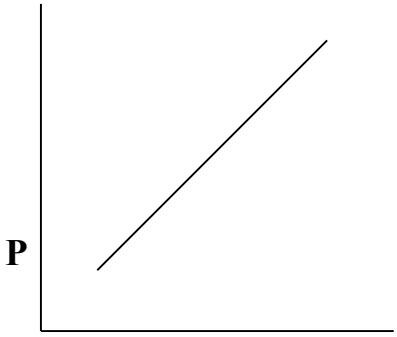


Fig 4.2

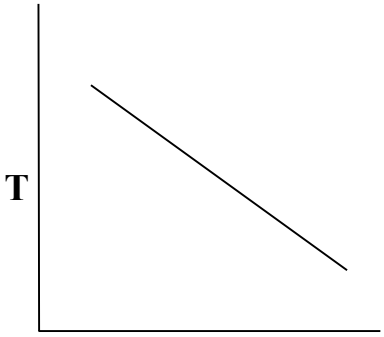


Fig 4.3

Now as we know,

m = 0.5 kg

g = 9.81 m/s

x = ± 0.025 m

For stiffness,

$k = (9.81 * 0.5)/0.025$

k = 196.2 N/m

Now for calculation of power and energy,

Deflection x = ±0.025 in 1 sec.

Therefore linear velocity of spring,

$V = 0.025 * 2$

V = 0.05 m/s

Diameter of shaft,

d = 0.01 m

For N,

$V = (\pi * d * N)/60$

$N = (0.05 * 60)/(3.14 * 0.01)$

N = 96 r.p.m

Gross vehicle weight: 1,600 kg (Passenger Car- 2 axles / 4 wheels)

Wheel load 400 kg per wheel – unsprung weight (wheel unit): 40 kg

Excitation	Damping		Chassis movement		Total yield
Wheel hub mm / metre travelled	Joule	kWh / 100 km	Hub / m	J kWh / 100 km	kWh / 100 km
± 5 mm / 10 Hz	7,1 J	0,8 kWh	± 0,5 mm	1,0 J 0,1 kWh	**0,9 kWh**
± 10 mm / 10 Hz	19,8 J	2,2 kWh	± 1,0 mm	2,0 J 0,2 kWh	**2,4 kWh**
± 25 mm / 5 Hz	63,6 J	7,1 kWh	± 2,5 mm	3,9 J 0,4 kWh	**7,5 kWh**
± 50 mm / 2 Hz	141,1 J	15,7 kWh	± 5,0 mm	9,8 J 1,1 kWh	**16,8 kWh**

Gross vehicle weight: 2,000 kg (Passenger Car- 2 axles / 4 wheels)

Wheel load 500 kg per wheel – unsprung weight (wheel unit): 40 kg

Excitation	Damping		Chassis movement		Total yield
Wheel hub mm / metre travelled	Joule	kWh / 100 km	Hub / m	J kWh / 100 km	kWh / 100 km
± 5 mm / 10 Hz	8,5 J	0,9 kWh	± 0,5 mm	1,2 J 0,1 kWh	**1,1 kWh**
± 10 mm / 10 Hz	22,6 J	2,5 kWh	± 1,0 mm	2,5 J 0,3 kWh	**2,8 kWh**
± 25 mm / 5 Hz	70,7 J	7,9 kWh	± 2,5 mm	4,9 J 0,5 kWh	**8,4 kWh**
± 50 mm / 2 Hz	155,6 J	17,3 kWh	± 5,0 mm	12,3 J 1,4 kWh	**18,6 kWh**

Gross vehicle weight: 20,000 kg (HGV- 2 axles / 4 wheels)

Wheel load 5,000 kg per wheel – unsprung weight (wheel unit): 150 kg

Excitation	Damping		Chassis movement		Total yield
Wheel hub mm / metre travelled	Joule	kWh / 100 km	Hub / m	J kWh / 100 km	kWh / 100 km
± 5 mm / 10 Hz	85,0 J	9,0 kWh	± 0,5 mm	25,0 J 3,0 kWh	**12,0 kWh**
± 10 mm / 10 Hz	226,0 J	25,0 kWh	± 1,0 mm	49,0 J 5,0 kWh	**30,0 kWh**
± 25 mm / 5 Hz	707,0 J	79,0 kWh	± 2,5 mm	123,0 J 14,0 kWh	**93,0 kWh**
± 50 mm / 2 Hz	1.556,0 J	173,0 kWh	± 5,0 mm	246,0 J 28,0 kWh	**201,0 kWh**

Gross vehicle weight: 40,000 kg (HGV- 5 axles / 10 wheels)

Wheel load 8,000 kg per wheel – unsprung weight (wheel unit): 150 kg

Excitation	**Damping**		**Chassis movement**		**Total yield**
Wheel hub mm / metre travelled	**Joule**	**kWh / 100 km**	**Hub / m**	**J**	**kWh / 100 km**	**kWh / 100 km**
± 5 mm / 10 Hz	212,5 J	22,5 kWh	± 0,5 mm	62,5 J	7,5 kWh	**30,0 kWh**
± 10 mm / 10 Hz	565,0 J	62,5 kWh	± 1,0 mm	122,5 J	12,5 kWh	**75,0 kWh**
± 25 mm / 5 Hz	1.767,5 J	197,5 kWh	± 2,5 mm	307,5 J	35,0 kWh	**232,5 kWh**
± 50 mm / 2 Hz	3.890,0 J	432,5 kWh	± 5,0 mm	615,0 J	70,0 kWh	**502,5 kWh**

CHAPTER 5

FUTURE SCOPE

Human is taking benefit of every type of energies produced, and it is increasing day by day. So in future we should also have the method to generate these energies so that lack of resources never happen.

Many research are been performing to develop different type of energies with different ways in which this process will help a lot. Regeneration of electric energy through a vehicle can help in many ways. As there are many devices and components in a vehicle which need electric energy to run so in that aspect this device will help in getting recharged every time we need.

There are many ways in which this device can show a success part for upcoming days such as:-

- **Use in electric vehicle:-** There are many electric vehicle which are manufacturing and been running on road today. These vehicle needs to be charged before use, as there is some amount of time consumed according to their charging capacity.
  But when this vehicle are used than there is only loss of energy produced so this device can help in producing some amount of continues energy so that there is less amount of energy reduce at the time of vehicle moving and some energy created when force is applied on the vehicle.
  This process can help a lot in the scope of energy saving. Continues generation of energy will be store in a battery which will provide direct power to vehicle which help to let it charge the vehicle.

- **Use in stereo system:-** In cars we us stereo system while driving and uses energy from the battery which is installed in it for many purposes but continues use of stereo system discharge battery at high amount .
  This system let battery to use the saved energy at this time because during movement of our vehicle it pass through many barriers and brakes are also applied many time which help to charge battery through our device and this saved energy can be further use to play stereo system with less loss in the power.

- **Appliances in vehicle:-** There are many appliances in vehicle such as Lights, Wipers, Automatic lock and many others. These appliances need some amount of electricity for better use which is provided by battery.

  Sometime people forget to close any of them which cause in sudden fall in energy of battery and make it totally discharge. It can also be used as a backup through which we can charge our battery easily and there will be some power to be used.

- **Saving of fuel:-** If high amount of energy can be used from the batteries then one day we can easily save fuel by making all E-vehicles. These vehicle surely will need high amount of power for better performance but as we know that today many E-vehicle are on the road but they are not used that much due to efficiency they have.

  This will easily help in increasing efficiency with some percent according to power need by the vehicles. Through these we can provide very high benefit to our environment as we know that our environment is being polluted day by day but a small part can make a big change too. And our resources which is decreasing at high speed will have a large reduce in fall.

- **Eco friendly:-** This device help to create a eco friendly nature. As we know that how E-vehicle never produces pollution or we can say make a pollution free environment so if there is more use of electrical energy instead of fuel energy less pollutant will occur.

  Installation of this device can be used for large scope if we use them at heavy vehicle more force will occur and more amount of energy will produce at a time which can be further supplied for respective uses.

  We can also store the energy for using outside the vehicle purposes. It will surely help in many other appliances as the regenerative power can be used by storing in other batteries outside the vehicle.

ADVANTAGES

- Increase overall energy efficiency of the vehicle.
- Improved performance.
- Cut down on pollution related problems.
- Increase the lifespan of battery used in vehicle.
- Store energy as much we provide it the source.
- Require no external electrical power source.
- Can be installed in any type of vehicles.
- Cheap at cost preference.

DISADVANTAGES

- Space requirement is high.
- Need maintenance.

CHAPTER 6

CONCLUSION

In this project we show how to conserve energy and use it in various process. As we know that in our world use of energy is at high level and due to which we have to suffer many losses too such as loss in energy, increase of pollution and many others. These losses should have to be decrease and we have to take some step through which we can save energy.

Use of vehicle is increasing day by day or we can say it has become a need to people and due to which every beneficiary step will lead to gain to our world. If we can conserve energy without any effort and use it for our benefit than there is only a kind of profit to self. This project lead to a big change for the development in automobile sector.

We can easily use this energy in some of our vehicle appliances which need electric power. This energy will help in increasing the battery power so with that power we can use the components more.

Using this system in our vehicle will be of no loss as this is cheap to install and giver more benefit. Through this we can easily save money also, money which we use to recharge our battery.

Performance of this system is far better as it works continuously and will give continuous energy to our vehicle.

This system will only do benefit in automobile sector.

RESULT

The power which is continuously waste during the suspension works in the vehicle does only loss and this power if calculated will come at high amount. With the help of some mathematical calculations we came to know that at different amount of weight there is different power producing.

This power can be easily save with this system. During the calculation we found that saving this energy will be more profit according to system we use in our vehicle.

REFRENCES

- Design of machine elements.
  -By V.B Bhandari.

- Strength of material
  -By S.S Rattan.

- http://www.teslamotors.com/forum/forums/electricity-suspension

- http/en.m.wikipedia.org/wiki/Active_suspension

- http://www.allaboutbatteries.com/electric_cars.html

- http://www.allaboutbatteries.com/electric_cars.html

- http://www.technologyreview.com/news/418859/electricity-generating-shock-absorbers

- http://www.ucsusa.org/clean-vehicles/electric-vehicles/how-do-battery-electric-cars-work

- http://www.interpatent.de/unsere_innovationen_strom_aus_der_federung_en.html

- http://www.scribd.com/doc/176856461/Power-Generation-Using-Suspension-System