Regenerative Shock Absorber

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Abstract - *A regenerative shock absorber has become a focal point of several researchers and industries in recent times. A regenerative shock absorber converts variable frequency, repetitive intermittent linear displacement motion to useful electrical power. The main function of regenerative shock absorber is to recover the vibration energy which can be dissipated in the form of heat as waste in conventional sock shock absorber. It is capable of converting parasitic displacement motion and vibration encountered under normal urban driving condition to a useful electrical energy for powering vehicles and accessories or charging batteries in electric and fossil fuel powered vehicles.*

Key Words: regenerative shock absorber; vibration; energy; heat; vehicle

1. INTRODUCTION

As number of vehicles over the past few decades has increased and the increase of clean energy demand, the energy dissipation of a vehicle on different parts has been investigated. Recently, regenerative shock systems caught the eye of the many researchers due to the potential to reap dissipated energy, thanks to its feasibility and accessibility.

Large amount of energy is released by the road vehicles due to the undesired vertical motion caused due to bumps, and far of that's dissipated in conventional shock absorbers as they dampen the vertical motions. A conventional automotive shock dampens suspension movement to supply a controlled action that keeps the tire firmly on the road. This is done by converting the K.E. into heat , which is then absorbed by the shock's oil.

Kinetic energy of an oscillating object is converted to electrical energy by an electric shock absorber. In a conventional mechanical shock absorber this kinetic energy is dumped in the form of thermal energy. According to the studies only 10 to 16 percent of the available fuel energy is used to drive the vehicle i.e. to overcome the air drag and road friction. Along with the engine cycle efficiency one important mechanism is the dissipation of kinetic energy due to undesirable vibrations and vertical motion of the vehicle. Through the use of a Linear Motion Electromagnetic System (LMES) the power generating shock absorbers convert the kinetic energy into electricity rather than converting it to heat. The LMES comprises of a permanent magnet stack embedded in the main piston, a rectifier, a switchable series of stator winding coils, and an electronic control system to dampen the load and mange the varying output. The magnet stack is forced to reciprocate within the annular array of stator windings by the bottom shaft of the PGSA which is mounted on the moving suspension member which generates an alternating current. The electricity generated in converted to DC current by using a full wave rectifier and stores in vehicles battery. The electricity generated by each PGSA is then combined with electricity from other power generation systems and stored in vehicles batteries.

2. CONVENTIONAL SHOCK ABSORBER

Fig: Conventional Shock Absorber

A device which is designed to dampen shock impulse and dissipate kinetic energy is known as conventional shock absorber. The dissipated energy is converted into heat energy in presence of viscous fluids. In hydraulic cylinders the heat is absorbed by hydraulic fluid where as in case of air cylinders the heated air is released to atmosphere. The shock absorbers help in reduction of rate of bounce, brake dive, roll or sway and acceleration squat as they are capable of adjusting to different road conditions. As they are velocity sensitive hydraulic damping devices they can provide more resistance when suspension is moving as quick rate because speed of the suspension and the number and size of the holes of the piston decides the resistance provided by the shock absorber.

2.1 Working of Shock Absorber

For the purpose of keeping the tire firmly on the road conventional shock absorber dampens the suspension movements due to which a controlled action is achieved. When the vehicles wheels move in up and down motion energy is contained in spring or torsion bar which is absorbed by shock absorbers to damp oscillations. Conventional shock absorbers do not support vehicle weight. They help to reduce dynamic wheel-load variations so wheels don't get off the surface but it is not possible on extremely rough roads, as a result more precise steering and braking are possible in a vehicle. The kinetic energy of

suspension motion is converted by shock absorbers into heat or thermal energy which is dissipated via hydraulic fluids.

There are various applications of shock absorbers like they play an important role in automobile and motorcycle suspensions, aircraft's landing gear and also the supports for many industrial machines. To reduce the susceptibility of structures to earthquake damage and resonance large shock absorbers have been used in field of structural engineering. They are also used to prevent railcars from damaging station platforms.

3. Types of Shock Absorber

1. Air Shock Absorber

It consists of an air chamber, an iron piston and a fluid.

2. Damper Shock Absorber

It consists of one chamber or two chambers; it should be fluid field or crammed with air. It is generally used during the linear motion of a vehicle to absorb the shock.

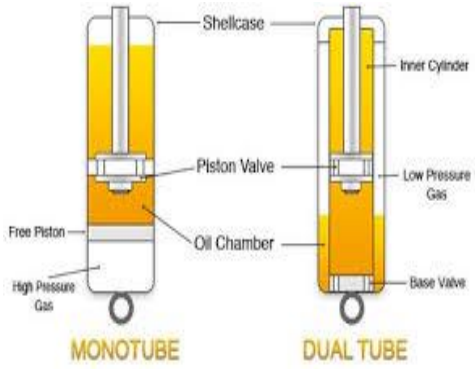

Fig : Mono tube and Dual tube shock absorber

1. **Mono Tube Shock Absorber**

It consists of single tube with two valves. It is mostly employed in larger cars and filled with oil. When there is compression of the dampener one valve gets opened and when extension of damper is taking place other valve opens while the first one is closed. The speed and nature of the bumps experienced while in motion decide the amount of the fluid to be released. A large quantity of fluid is released if low speed small bumps are received as larger vents are opened. While small vents are opened and small amount of oil is released when high speed strong bumps are experienced.

2. **Dual Tube Shock Absorber**

It consists of two nested cylindrical tubes. The tube present inside is called as working tube/pressure tube whereas outside tube is called as reserve tube .A compression valve or base valve is located at the bottom of the device on the inner side. The whole arrangement is also called as a "two-tube" shock absorber. Due to the bumps there is upward and downward motion of piston which leads to movement of fluids between different chambers through small hole or orifices within the piston and through valve. And the shock energy is converted to heat energy which is further dissipated.

4. REGENERATIVE SHOCK ABSORBER

A shock absorber which converts kinetic energy i.e. intermittent linear motion and vibration into electricity instead of heat such as in case of conventional shock absorber through the use of a Linear Motion Electromagnetic System (LMES) is known as regenerative shock absorber. It is also known as power generating shock absorber (PGSA). Battery life of electric vehicle or hybrid vehicle is increased when PGSA is used by diverting the generated electricity to powertrain of vehicle. The produced electricity can be applied to power consuming accessories like air conditioning in non-electric vehicles. The PGSA is that the same basic size and shape, and mounts within the same way, as a typical shock or strut cartridge.

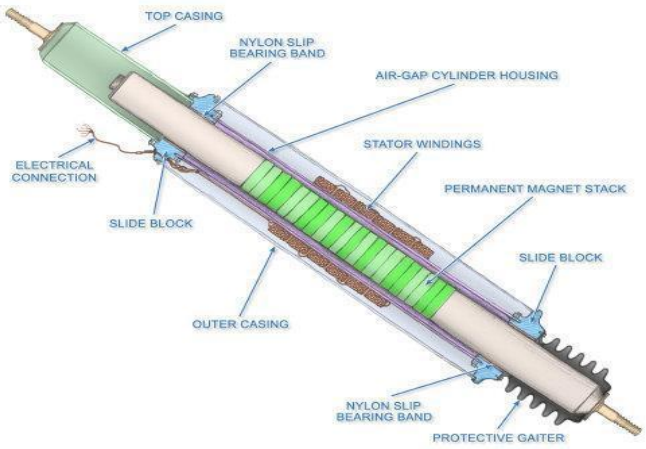

Fig : Regenerative shock absorber

Linear motor electromagnetic system has essentially a multi-phase (AC) motor that has hoad its stator "unrolled" in order that rather than producing a torque (rotation) it produces a linear force along its length. It works on the principle of Lorentz force, during which the electromagnetic force 'F' is linearly proportional to the velocity and the magnetic field ($F = qv \times B$). Where 'q' is the charge, 'v' is the coil speed with respect to magnets and 'B' is the magnetic field intensity.

The linear motors are classified into two type's viz. low acceleration and high acceleration linear motor. Low acceleration linear motors are used in applications in which ground based transportation is involved while high acceleration linear motors are very short in structure and are used to accelerate things to high speed and then release them such as in roller coasters.

Recently, the main types of regenerative shock absorbers are the following six types:

[1] Hydrostatic energy-storage type

The working principle is to convert the vibration energy consumed by the suspension system into hydraulic energy, which is stored for the use of hydraulic energy-consuming components on the suspension system.

The hydrostatic energy-storage type suspension is operated by a hydraulic system. The work of system is stable, but the energy recovery efficiency is low. Most of the vibration energy is still dissipated in the form of heat, and the system requires high sealing performance. In addition, the weight of system and the cost are required.

[2] Electromagnetic coil type

The working principle is to replace the traditional shock absorber with an electromagnetic coil device. It can convert the vibration energy dissipated by the system into electrical energy and store it in the battery. The electromagnetic coil type suspension has a simple structure with a low cost. According to the small magnetic pole gap, it may cause system damage. In addition, the copper loss increases and the efficiency become low. Therefore, the electromagnetic coil suspension structure is still in the theoretical stage at present.

[3] Ball screw type

The working principle of ball screw shock absorber is to replace the traditional shock absorber with a ball screw mechanism. When the shock absorber reciprocates with the road bump, the ball nut moves up and down, driving the screw and the electric motor in order to generate electricity for reuses. The ball-screw type shock absorber has high reliability, small size, and high transmission efficiency, but the rotational friction caused by the positive and negative rotation of the motor will reduce the durability of the entire system.

[4] Rack-pinion type

The working principle is to replace the shock absorber with a motor and a rack-pinion mechanism. The mechanism maintains engagement under the action of spring compression and transfers vibration energy to the generator for electrical energy. The generator also provides damping force through the rack-pinion structure. The rack-pinion suspension mechanism has a good fitting relationship and high regenerative efficiency. However, when the road surface excitation is too large, or when the usage time is too long, the rack and pinion will fail to response the excitation from road.

[5] Linear motor type

The permanent magnet and the coil are relatively displaced when the vehicle vibrates, so that the magnetic induction wire is cut to generate electricity. The structure converts linear motion mechanical energy into electric energy directly intermediate conversion and transmission mechanism is not required. The configuration of the linear motor type energy feeding vibration absorber is relatively simple, but the generator leakage flux is the key drawback and the electrical performance is also very low, so the power generation efficiency is generally, and the vibration damper support structure is easy to fail, and the production cost is high.

[6] Hydraulic electromagnetic type

The hydraulic cylinder piston drives the oil to flow toward the accumulator under the excitation of the external, then the oil is sent to the hydraulic motor to drive motor rotates, which will drive the generator to generate electricity. The specified design applies the coupling of the mechanism, liquid and electricity, which is flexible in arrangement higher recovery efficiency. The accumulator also provides a stable working state, but there are still some difficulties in the real-vehicle installation and application for there are many structural elements.

Table : Performance comparison of shock absorbers

Structure Type	Efficiency	Cost	Reliability
Hydrostatic energystorage	Low	High	High
Electromagnetic coil	Low	Medium	Low
Ball screw	High	Medium	High
Rack-pinion	Medium	Medium	Medium
Linear motor	Medium	High	Low
Hydraulic electromagnetic	High	Low	High

As shown in the above table, the main structures of the current shock absorbers are integrated. It is found that the hydrostatic energy-storage type and the electromagnetic coil type shock absorber capture a part of the energy losses by suspension, and most of the vibration energy dissipated in the form of heat, so the efficiency is low. In contrast, the electromagnetic structure has high efficiency and reliable structural design, especially the structure of the hydraulic electromagnetic structure is excellent, which has great development potential.

4.1 WORKING OF REGENERATIVE SHOCK ABSORBER

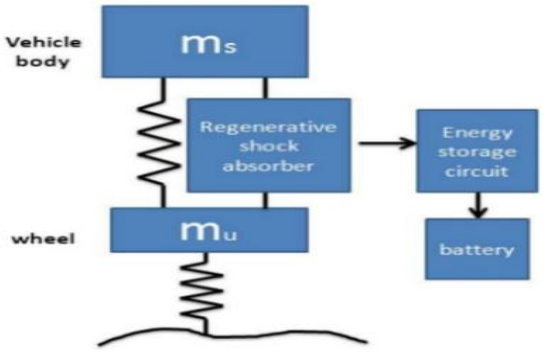

Fig: Working of regenerative shock absorber

The vibrations due to road roughness are suppressed by installing shock absorbers between chassis and wheels to ensure vehicle's handling and comfort. Generally the design consists of mainly a coil winding array and permanent magnets. The permanent magnets are concentrically placed on a metallic rod which is of high magnetic reluctance. Regenerative shock absorbers utilize the relative motion between magnetic field and coils to directly produce electricity according to Faraday's law of electromagnetic induction. This principle state's that if there is relative motion between the conductor and the magnetic field, across the ends of conductor a voltage will be produced in a magnetic field. Coil windings array and the permanent magnet have relative motion in PGSA .Voltage developed at the ends of a single conductor coil depends on the relative velocity 'v', between the coil and the magnet array, the magnetic field 'B' and the length of the conductor coil 'l'. Equation gives us this particular relation V=Bv*l*, as a result electricity is generated in this mechanism in alternate current form. A full-wave rectifier is used to convert generated electricity into direct current which is further stored in batteries of vehicle.

The shock absorber consists of two cylinders. One having larger diameter and other having smaller diameter. Smaller diameter cylinder moves inside the cylinder having larger diameter while suspension movement takes place. So, because of repeated movement of cylinders over coils a magnetic field is produced. Further electrical motor produces electricity from this magnetic effect which is to be stored in battery.

4.2 ADVANTAGES OF REGENERATIVE SHOCK ABSORBER

- It is highly efficient and energy saving.
- It produces less noise during operation.
- It has wide range for operation.
- It has low operating cost.
- It is highly reliable due to low failure rate and robust structure.
- The "electricity generating suspension system" has a much higher energy yield than other known options available in market.

4.3 DISADVANTAGES OF REGENERATIVE SHOCK ABSORBER

- The main drawback of the system is the cost. It is costlier than other suspension system available due to the neodymium magnets which are costly to manufacture.
- Complexity of system
- Problem occurred in collecting materials.
- There may be problems like rubbing in (LWV) light weight vehicles during operation.
- As whole system consists electric wiring so there may occur short circuit of system.
- Requires high precision machinery and skilled workers for manufacturing.
- It is very difficult and costly to repair the system in case of failure.

5. APPLICATIONS

- Regenerative shock absorber can be used in vehicles which have movable suspension technology and uses electricity for performing some kind of operation.
- It is successfully tested on electric vehicles. The system performs best on heavy, off-road vehicles moving quickly over rough terrain, so the companies are targeting military applications.
- This system can be used in commercial trucking industry as they carry heavy loads and small amount of movement in shock absorbers may generate useful amount of electricity.
- The power controller in the system gets information from accelerometers and sensors which is processed to improve vehicle handling by changing resistance of dampers. So, suspension becomes stiff or soft.
- Regenerative shock absorbers can be used along with other techniques such as regenerative braking system to improve efficiency by converting waste heat into useful electricity.

6. CONCLUSIONS

A considerable amount of natural resources are wasted as vehicle's vibrational energy is dissipated in form of heat by conventional shock absorber. This wasted energy can be recycled with the help of power generating shock absorber. The potential in converting vibration energy into electrical energy through the shock absorber is promising and rewarding and can make the vehicle more sustainable by consuming less amount of fuel.

- Depending upon the vehicle and driving conditions it is possible to obtain fuel saving upto 1.5% to 6%. Moreover, the researchers say that this system can improve the stability of the vehicle.
- Power can be harvested in continuous way with the help of regenerative shock absorber. On the smooth highway road, system can improve the fuel efficiency by 2%, and on bumpy roads up to 10% increase can be expected.
- Regenerative shock absorbers are low cost and high performance systems that meet the environmental requirements. They are also reliable and flexible in operation. So, they can be considered for other power generating application.

REFERENCES

[1] Kirpal Singh, Automobile Engineering Volume 1, Suspention

[2] Horst Bauer (ed)., Automotive Handbook 4th Edition, robert Bosch GmbH 1996, ISBN 0-8376-0333

[3] Mitcheson, P., et al., Transduction mechanisms and power density for MEMS inertial energy scavengers. Power MEMS, 2006. 6: p. 275-278

[4] Xu L. Research on automotive electric and electric energy- absorbing shock absorber [D]. Wuhan University of Technology, 2011

[5] Fang Z, Guo X, Zuo L. Energy Suspension Potential Research and Sensitivity Analysis[J]. Journal of Jiangsu University (Natural Science Edition), 2013, 34(4): 373-377

[6] Xie, L., J. Li, and M. Cai, Design of a Hybrid Energy-Harvesting Shock Absorber. 2015

[7] Kawamoto, Y., et al., Electro-mechanical suspension system considering energy consumption and vehicle manoeuvre. Vehicle System Dynamics, 2008. 46(S1): p. 1053-1063