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Electrical Power Generation using Shock Absorber

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Synopsis
During the everyday usage of an automobile, only 10–16% of the fuel energy is used to drive the car—to overcome the resistance from road friction and air drag. A conventional automotive shock absorber dampens suspension movement to produce a controlled action that keeps the tire firmly on the road. This is done by converting the kinetic energy into heat energy, which is then absorbed by the shock's oil. This is the important loss is the dissipation of vibration energy by shock absorbers in the vehicle suspension under the excitation of road irregularity and vehicle acceleration or deceleration. In this paper we study the concepts of power generating shock absorber which can efficiently recover the vibration energy in a compact space.
Power generating shock absorber absorber is a device that converts the kinetic energy of an oscillating object into electric energy. This kinetic energy is normally dumped in a form of thermal energy in a conventional, mechanical shock absorber. It consists of a permanent magnet linear synchronous generator (PMLSG), a spring, and an electric energy accumulator. The major goal of the project is to design and analyze the operation of an electric shock absorber. It is successfully tested on electric vehicles. The system performs best on heavy, off-road vehicles moving quickly over rough terrain.The shock absorbers are connected to a power management system that can interface with other sources of power, such as regenerative braking systems, thermoelectric devices that can convert waste heat into electricity

I.INTRODUCTION

Road vehicles can expend a significant amount of energy in undesirable vertical motions that are induced by road bumps, and much of that is dissipated in conventional shock absorbers as they dampen the vertical motions. A conventional automotive shock absorber dampens suspension movement to produce a controlled action that keeps the tire firmly on the road. This is done by converting the kinetic energy into heat energy, which is then absorbed by the shock's oil. The Power-Generating Shock Absorber (PGSA) converts this kinetic energy into electricity instead of heat through the use of a Linear Motion Electromagnetic System (LMES). The LMES uses a dense permanent magnet stack embedded in the main piston, a switchable series of stator coil windings, a rectifier, and an electronic control system to manage the varying electrical output and dampening load. The bottom shaft of the PGSA mounts to the moving suspension member and forces the magnet stack to reciprocate within the annular array of stator windings, producing alternating current electricity. That electricity is then converted into direct current through a full-wave rectifier and stored in the vehicle's batteries. The electricity generated by each PGSA can then be combined with electricity from other power generation systems (e.g. regenerative braking) and stored in the vehicle's batteries.

The electric shock absorber is a device that converts the kinetic energy of an oscillating object into electric energy. This kinetic energy is normally dumped in a form of thermal energy in a conventional, mechanical shock absorber. However, only 10–16% of the available fuel energy is used t o drive the vehicle, i .e. to overcome the resistance from road friction and air drag. Besides engine cycle efficiency, one important mechanism of energy loss in automobiles is the dissipation of kinetic energy during vehicle vibration and motion.Goldner did some preliminary studies on the energy recovery in vehicles by using a simple regenerative shock absorber composed of a single magnet and coils. They estimated the recoverable energy for a 2500lb vehicle with an average speed of 20 m/s (45 m/h) is about 20% - 70% of the power that is needed for such a vehicle to travel on a typical highway at 45 mph. Goldner patent for an electromagnetic linear generator and shock absorber design was able to recover energy at a significant efficiency, however, its weight of 70 kg (154lbs) may not be appropriate for a passenger vehicle.

Oly Paz conducted a study of different configurations of linear induction generators forvehicle suspension. The author presented a design method for one configuration of a magnet and conductor set -up, which was calculated to have a theoretical efficiency of 46%: however, a prototype was not fabricated . Finite element analysis on this design would suggest that the actual efficiency would be significantly less than predicted as a result of its ineffective use of high magnetically permeable materials for certain components.

Abhijeet Gupta designed electromagnetic shock absorbers provide means for recoveringthe energy dissipated in shock absorbers. Two electromagnetic shock absorbers for potential use in vehicles are fabricated and tested them in a small all-terrain vehicle (125 kg). Their experiment indicated that the

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rotary configuration regenerated power at a much higher efficiency (21%) than the linear configuration: however, its bulky des ign makes it incompatible with a passenger car. To further magnify the motion and increase efficiency, regenerative absorbers composed of ball screw and rotational electric motors have been developed by a number of researchers.
Lie Zuo design characterize and test a retro fit regenerative shock absorber which canefficiently recover the vibration energy in a compact space. Rare-earth permanent magnets and high permeable magnetic loops are used to configure a four-phase linear generator with increased efficiency and reduced weight. The finite element method is used to analyze t he magnetic field and guide the design optimization .Presented in this paper are some of the results of a study aimed at determining the effectiveness of efficiently transforming that energy into electrical power by using optimally designed regenerative shock absorbers. In turn, the electrical power can be used to recharge batteries or other efficient energy storage devices (e.g., flywheels) rather than be dissipated. The results of the study are encouraging - they suggest that a significant amount of the vertical motion energy can be recovered and stored. This can also be plugged to power management device that can also manage power from other sources, such as regenerative braking systems. Thermoelectric devices in shock absorber converts waste heat into electricity, or conformal solar panels, The power is then fed into the car's electrical system to reduce the amount of load on the alternator.

II. CONVENTIONAL SHOCK ABSORBERS

In this section we will first give an overview about the conventional types of shock absorbers, working of conventional shock absorbers and their applications.

2.1 Conventional Shock Absorbers

Fig 2.1 Conventional Shock Absorber

A Conventional Shock Absorber is a mechanical device designed to smooth out or damp shock impulse, and dissipate kinetic energy. You would be think that as shock absorbers dissipate energy then where tat energy goes...?

- In most dashpots, energy is converted to heat inside the viscous fluid. In hydraulic cylinders, the hydraulic fluid heats up
- In air cylinders, the hot air is usually exhausted to the atmosphere.
- In electromagnetic types dashpots, the dissipated energy can be stored and used later.

The amount of resistance a shock absorber develops depends on the speed of the suspension and the number and size of the holes of the piston. All modern shock absorbers are velocity sensitive hydraulic damping devices. This means that the faster the suspension moves the more resistance the shock absorber provides. Because of this feature, shock absorbers adjust themselves to road conditions.

As a result, shock absorbers reduce the rate of:

- Bounce, Roll or sway
- Brake dive and acceleration squat

2.2Working of Shock Absorbers

A conventional automotive shock absorber dampens suspension movement to produce a controlled action that keeps the tire firmly on the road. Shocks absorbers are used to damp oscillations by absorbing the energy contained in the springs or torsion bars when the wheels of an automobile move up and down. Conventional shock absorbers do not support vehicle weight. They reduce the dynamic wheel-load variations and prevent the wheels from lifting off the road surface except on extremely rough surfaces and making possible much more precise steering and braking. The shock absorbers turn the kinetic energy of suspension motion into thermal energy, or heat energy, to be dissipated through the hydraulic fluid.

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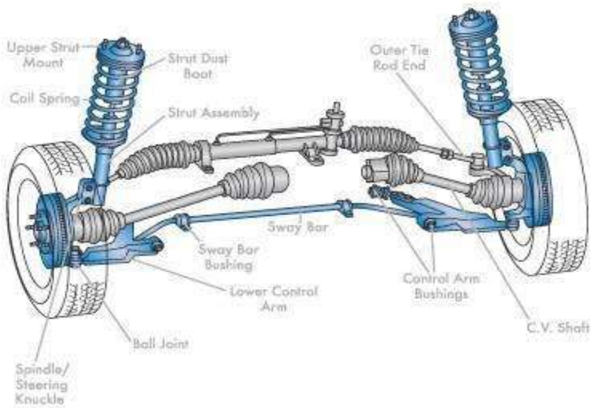

2.3 Applications of Shock Absorbers

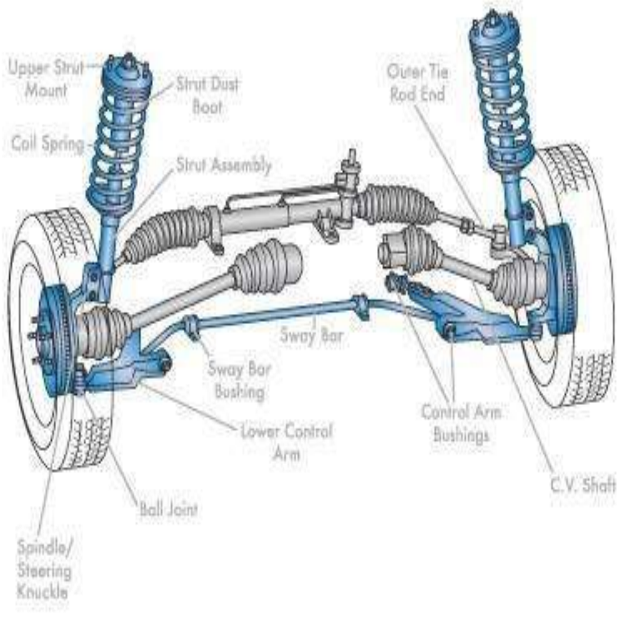

Fig 2.3 Application of Shock Absorbers

- Shock absorbers are an important part of automobile and motorcycle suspensions, aircraft landing gear, and the supports for many industrial machines.

- Large shock absorbers have also been used in structural engineering to reduce the susceptibility of structures to earthquake damage and resonance.

- Inrail cars and rapid transit systems because they prevent railcars from damaging station platforms.

The bottom shaft of the PGSA mounts to the moving suspension member and forces the magnet stack to reciprocate within the annular array of stator windings, producing alternating current electricity. That electricity is then converted into direct current through a full-wave rectifier and stored in the vehicle's batteries. The PGSA is the same basic size and shape, and mounts in the same way, as a standard shock absorber or strut cartridge.

3.2 ADJUSTABLE DAMPENING

An electronic control system monitors the requirements of each individual road wheel's suspension and varies the dampening by quickly switching on or off individual stator coil rings. With all stator coil rings switched on the PGSA produces a strong dampening force which can then be varied for disparate road conditions by switching coils on and off as needed. This provides an added level of benefits in allowing the shock to be very soft in cruising situations (small, high-frequency movements) and instantly change to a sport shock in aggressive cornering situations (longer, lower-frequency movements). Further, the rebound and compression strokes can have different dampening values and application curves depending on performance requirements.

This application could conceivably produce over twenty watts per wheel in normal operation. City driving, with its varying road surface characteristics, as well as stop and go traffic's font-to-back loading, will generate more power than driving on smooth roads at consistent speeds.

III. POWER GENERATING SHOCK ABSORBERS

Electric shock absorber is also known as Power-Generating Shock Absorber (PGSA). The Power-Generating Shock Absorber (PGSA) converts this kinetic energy into electricity instead of heat through the use of a Linear Motion Electromagnetic System (LMES).

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3.1 Working of Power Generating Shock Absorbers

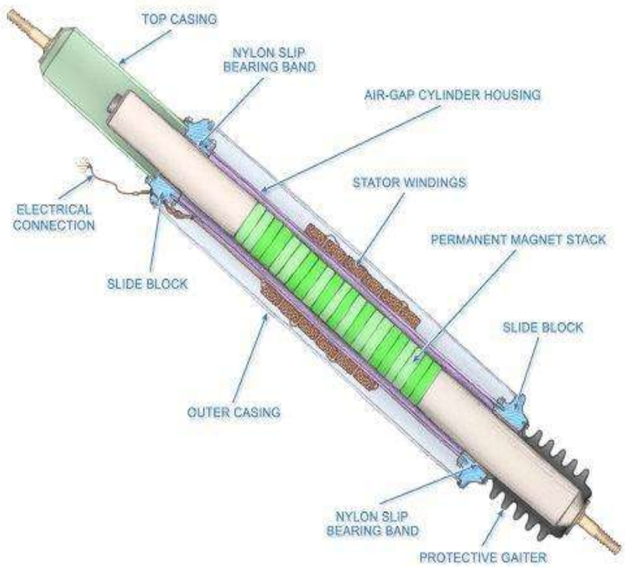

Fig 3.1 Power Generating Shock Absorber

The Power-Generating Shock Absorber (PGSA) converts this kinetic energy into electricity instead of heat waste through the use of a Linear Motion Electromagnetic System (LMES). The LMES uses a dense permanent magnet stack embedded in the main piston, a switchable series of stator coil windings, a rectifier, and an electronic control system to manage the varying electrical output and dampening load.

3.3 MANUFACTURING CONSIDERATIONS

Manufacture of the Power-Generating Shock Absorber will require a machined main shaft with embedded permanent magnet stack, a strong air-gap cylinder housing, high quality stator windings, and robust slide bearings. The magnet assembly consists of an inner magnet stack surrounded concentrically by a larger diameter outer magnet stack. Each stack consists of three axially magnetized ring magnets separated by two iron-pole rings and two additional pole rings located at the ends of the stack. Other systems, such as microprocessor-controlled voltage, current, and dampening regulation, external casing, protective bellows, etc. will also need to be designed and tested. The magnetic finite element method is then used for the design optimization to increase the power density, and finally a refined model of the energy harvesting is presented.

IV. PERFORMANCE OF PGSA

- A prototype of a shock absorber for vehicles which can harness and generate electricity back into the vehicle is made by the team of researchers. The team claims that their

prototype increases a vehicle's fuel-efficiency by up to 10 percent by using a "hydraulic system that forces fluid through a turbine attached to a generator."

- The system performs best on heavy, off-road vehicles moving quickly over rough terrain.

- Currently, only 10-16% of a vehicle’s fuel energy is used to drive the vehicle, i.e. to overcome the resistance from road friction and air drag. The rest is lost due to braking,

vibrational energy dissipation, and other forms of loss.

- Prof. Lie Zuo estimated that for a middle-size vehicle, 100W, 400W, and 1600W of average power is available for harvesting from the regenerative shock absorbers while

driving on Class B (good), C (average), and D (poor) highways at 60 mph, which is comparable with car alternators (500-600W). And the energy potential for trucks, rail cars, and off-road vehicles is on the order of 1kW-10kW.

- This represents a potential of 2-3% fuel efficiency increase in conventional cars, up to 6% in military vehicles and up to 8% for hybrid vehicles.

- ―The power regeneration is proportional to the square of the magnetic flux across the coils,‖ Lie Zuo said.

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Fig 4.1 Levant Technologies Electric Shock Absorber

V. APPLICATION OF PGSA

- This technology can be applied to any type of vehicle that employs movable suspension technology and uses electricity in some form as its fuel.

- It is successfully tested on electric vehicles. The system performs best on heavy, off-road vehicles moving quickly over rough terrain, so the company is targeting military applications.

- It also is sensible that having onboard power generation could be a real advantage in military situations where troops are moving in remote areas without readily available

fuel sources. Conserving fuel in those scenarios, especially during combat, could be the difference between life and death.

- What comes to mind quickly for non-military applications Is the commercial trucking industry. While they typically run trucks over roadways, their payloads of tens of

thousands of pounds couple even with small, constant movements might generate a fair amount of electricity with shock absorber generators.

- To improve vehicle handling, the power controller uses information from accelerometers and other sensors to change the resistance from the generators, which stiffens or softens the suspension.

- For example, if the sensors detect the car starting a turn, the power controller can increase the resistance from the shock absorbers on the outer wheels, improving cornering,

- The shock absorbers are connected to a power management system that can interface with other sources of power, such as regenerative braking systems, thermoelectric devices that can convert waste heat into electricity.

VI. COST FACTOR

- The most important factor that comes in our mind is COST. What is the use of new system if it costs more? The new system should be relatively low cost then only it can serve the purpose.

- The companies has emphasized using off-the-shelf parts, where possible, to keep down costs. Diamond (Owner of Levant Power) notes that active shock absorbers have failed commercially in the past because they were too expensive.

- What distinguishes the new system is, its relatively low cost and ability to generate electricity.

- In order to contain costs as much as possible, the shock absorbers are built using mostly components already available on the market. They want, therefore, to avoid repeating

the failure experienced time ago by the active suspensions, which were practically discarded because of their costs too high for conventional vehicles.

- The shock absorbers and control electronics will cost slightly more than conventional shock absorbers, but the recoup time for cost of installation in trucks and services vehicles is 1-2 years, and 3-4 years for typical passenger vehicles. And that is for existing vehicles. Hopefully in the near future they will be in all new cars too..

VII. FUTURE OF THIS TECHNOLOGY

- In the future, the researchers are planning to increase the energy density and efficiency of the system by further increasing the magnetic field intensity and improving the harvesting electrical circuit.

- Wireless sensors and actuators will be used in future. For example, if the sensors detect the car starting a turn, the power controller can increase the resistance from the shock absorbers on the outer wheels, improving cornering.

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- There is still room for improvement in the overall design of the regenerative system, and researchers are working on such improvement.

- Stony Brook University, Tufts University and General motors are developing systems of their own that use no fluids, only electromagnetic resistance. They says one of the biggest challenges in designing such systems is making them small enough to fit into existing vehicles, yet ensuring they are still capable of converting a useful amount of electricity.

- There is some discussion taking place about the potential of adding their technology to the Humvee's replacement, the Joint Light Tactical Vehicle and military vehicles.

VIII. CONCLUSION

- A larger magnetic field will be necessary if more power needs to be generated.

- Conversion of energy produced by a vehicle shock absorbers movements into electrical energy, allows a significant fuel savings.

- It is possible to obtain a fuel saving between 1.5 and 6%, depending on the vehicle and on the driving conditions. Moreover, the researchers say that this system can improve the stability of the vehicle.

- ―Regenerative braking harvests large amount of power in a very short time, in an intermittent manner,‖ Lie Zuo said. ―However, the regenerative shock absorbers can

harvest the power in a continuous way. On the smooth highway road, The electric shock absorbers can improve the fuel efficiency by 2%, and on bumpy roads up to 10% increase can be expected.‖

- More researchers are going on to extend the tests involving other types of vehicles such as trucks, buses and other automotive vehicles.