

Design, Fabrication and Testing of a Regenerative Strut

Pragadish Nandakumar
KCG College of Technology

ABSTRACT

The fuel prices are increasing every day and so are the pollution caused by vehicles using fossil fuels. Moreover, in a car with an internal combustion engine, we get on average 25% efficiency, the other 75% is wasted, mostly through friction and heat. One 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 design, manufacture and test a regenerative coil-over strut that is compact, simple in design and more economical. Since our strut is a modification of an existing strut design, it would be much more feasible to implement. We tested our prototype strut using a TATA Indica car under city road conditions. The damping characteristics and output voltage of the strut were recorded and compared with a normal coil over strut. Based on the test data, it was found that the strut was able to recover about 8-10 watts of electricity at 20kmph.

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INTRODUCTION

In a vehicle, shock absorbers reduce the effect of traveling over rough ground, leading to improved ride quality and increase in comfort. It is well known that automobiles are inefficient, wasting over 74% of energy stored in fuel as heat. Though regenerative braking technique has been developed to recover energy due to braking, it does not supply power on a continuous basis.

Regenerative shock absorbers currently available in the market are bulky and costly. Therefore, we developed a regenerative strut by modifying the existing strut design thereby making it cheaper and more compact. The electricity produced by the strut can be used to power auxiliary equipments thereby reducing the load on the alternator.

LITERATURE SURVEY

Over the past 12 years, a lot of research has taken place in the field of regenerative shock absorbers. Lei Zuo, et al. [1] have worked on a prototype design of Electromagnetic energy harvester for vehicle suspension. In this paper they have designed, characterized and tested a prototype retrofit regenerative shock absorber. They fabricated two prototypes of regenerative electromagnetic shock absorber: a linear device (called as Mark 1) and a rotary device (called as Mark 2) and installed them in vehicle to study energy recovery. Gupta et al, [2], (2003) has studied the available energy from shock absorbers as cars and trucks are driven over various types of

roads. Goldner, et al. (2001) [3] have carried out a proof-of-concept - to evaluate the feasibility of obtaining significant energy savings by using regenerative magnetic shock absorber in vehicles. They proposed electromagnetic (EM) shock absorbers to transform the energy dissipated in shock absorbers into electrical power. P. Zhang et al. [4] have presented comprehensive assessment of the power that is available for harvesting in the vehicle suspension system and the trade-off among energy harvesting, ride comfort, and road handling with analysis, simulations and experiments. Zhen Longxin and Wei Xiaogang [5] have modeled the structure and dimensions of a regenerative electromagnetic shock absorber in CAD software package. S. Mirzaei. et al [6] introduced a passive suspension system for ground vehicles based on a flexible Electromagnetic Shock Absorber (EMSA). They designed and provided a model of passive suspension. Bart Gysen et al., [7] have studied design aspects of an active electromagnetic suspension system for automotive applications which combines a brushless tubular permanent-magnet actuator with a passive spring. N. Bianchi et al [8] have described the design criteria of a tubular linear motor, with interior permanent magnets. They derived key equations for the analysis of the motor, considering both slotted and slot less topology. Babak Ebrahimi et al., [9] presented the feasibility study of an electromagnetic damper, as sensor/actuator, for vehicle suspension application. They have optimized geometry of shock absorber to achieve higher electromagnetic forces and magnetic flux induced in the system.

DESIGN

The Regenerative strut has a linear generator at its center. The mechanism converts the kinetic energy of suspension vibration between the wheel and a sprung mass into useful electrical power. The linear generator consists mainly of a magnet assembly and a coil assembly.

The magnet assembly is made of ring-shaped permanent magnets and ring-shaped high magnetically permeable spacers stacked alternatively. The magnets are arranged with like-poles of adjacent magnets facing each other to redirect the magnetic flux in the radial direction. Neodymium Ferrite Boron (NdFeB) magnets are used for their high flux density of 1.5 T. Diameter of magnet is 24mm and height is 30mm.

A concentric outer cylinder made of high magnetically permeable material like AISI 4130 is used to reduce the reluctance of magnetic loops, to further increase magnetic flux density in the coils.

A total of five prototypes were developed each with different designs. All of them were tested for standard deflections in a shock absorber. The prototype with the best output was selected and incorporated into the strut design.

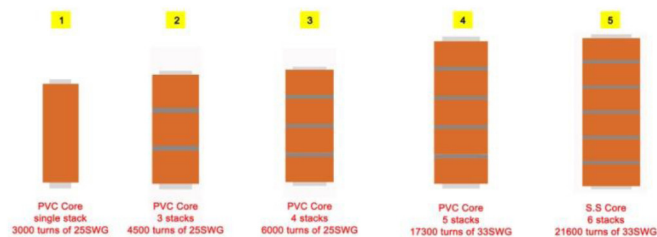


Figure 1. Prototypes developed

Prototype 1

In the first prototype, 3000 turns of copper wire of 25 SWG were wound on a 1 inch diameter PVC pipe and the maximum output obtained was 3 volts.

Prototype 2

In the second prototype, 4500 turns of copper wire of 25 SWG were wound on a 1 inch diameter PVC pipe in the form of 3 stacks each of 50mm width. The maximum output obtained in it was 5 volts.

Prototype 3

In the third prototype, 6000 turns of copper wire of 25 SWG were wound on a 1 inch diameter PVC pipe in the form of 4 stacks each of 50mm width. The maximum output obtained in it was 9 volts.

Prototype 4

In the fourth prototype, 17300 turns of copper wire of 33 SWG were wound on a 1 inch diameter PVC pipe in the form of 5 stacks each of 30mm width. The maximum output obtained in it was 20 volts.

Prototype 5

Copper coil of 33 SWG is used for this coil assembly. The coils are wound in the form of stacks of 25mm width. Each stack consists of 3600 turns of copper wire. The winding is done in an alternate direction for every consecutive stack. Six such stacks are wound with 5mm space between each stack. The maximum output obtained in it was 30 volts. Hence this design was incorporated into the final prototype.

The ends of the coil are connected to a rectifier set-up. As the copper coils move inside the magnetic field, a voltage will be generated.



Figure 2. Coil assembly design

Final Assembly

An existing strut of a TATA Indica car is taken and the damper arrangement in the center is removed. The coil assembly is fixed to the lower strut by means of MiG welding. The magnet assembly is fixed to a piston rod which is bolted to the upper strut. When the strut undergoes a deflection, the coil assembly moves relative to the magnet.

According to faraday's law, any change in the magnetic environment of a coil of wire will cause a voltage (EMF) to be "induced" in the coil. When the shock-absorber undergoes a deflection, the coil assembly undergoes a relative movement with respect to the magnet assembly. Due to this, the flux lines of the magnet are disturbed which produces an EMF in the copper coil.