ISSN 2395-1621

Design & Development of a Device to Harness Vibrational Energy to Generate Electrical Output

#1 K.M.Afzal, #2 A.P.Tadamalle

[1]kmafz02@hotmail.com
[2]aptadmalle.scoe@sinhgad.edu

#1 M.E. Mechanical (Mechatronics) Department of Mechanical Engineering, Savitribai Phule Pune University

#2 Associate Professor, Department of Mechanical Engineering Sinhgad College of Engineering Pune, Maharashtra, India

ABSTRACT

Vibrations can be accumulated and converted to power in various forms. It is abundantly available in nature. Researchers have been working on tapping its potential majorly as it could solve major energy concerns .They can be captured and harnessed from ambient vibrational sources such as vehicular motion, railway tracks etc. Once harnessed, a variety of applications be it industrial on the large scale or general household on the small scale can be run. Regenerative electromagnetic harvesters implemented on automobiles is one such concept of obtaining electrical output on the large scale, by decreasing the reliance over the existing battery and hence powering up the peripherals by incorporating appropriate changes. Also in turn the overall efficiency of the automobile is increased. Much work has been done on a regenerative electromagnetic shock absorber based on standard data obtained from four wheelers. This paper attempts to obtain an electrical output through a shock absorber using the electromagnetic principle for two wheelers. Measurement data of the hydraulic shock absorber fitted on a two wheeler is obtained and later with the help of digital accelerometers and a microcontroller, road data can be obtained which helps in understanding various parameters subjected to the shock absorber. Analytical calculations are done to give an idea about the electrical output based on the design. Design of the regenerative shock absorber is done on CATIA software. Static magnetic field analysis is carried out at an equilibrium position and the results are plotted. The analytical calculations were later compared with the plot results of the static magnetic analysis.

***Keywords*— Electromagnetics, Energy Recovery, Regenerative shock absorber, Vibrational Energy**.

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. Introduction

The percentage of fuel energy in an automobile required to overcome the air drag and resistance due to road friction is only about 10%-16%. Rest of the energy is wasted through various losses such as driveline losses, air drag, rolling resistance, engine losses, braking losses, idling losses. Of all these braking losses contribute about 5.8% of energy lost. Braking loss is considered as the loss of kinetic energy into waste heat due to vibrational motion of the suspension system. In the past hundred years or so, the automobile industry has designed optimal suspension and braking systems such as anti-lock braking systems and active suspensions in order to lessen the amount of waste heat dissipated. Also, regenerative braking has caught the eye of major researchers in the last few decades and its most important application is the braking system on electric trains and vehicles. The main drawback of the regenerative braking principle is that it is not a continuous energy recovery system. Looking at the suspension system to continuously recover energy while in motion is an objective of many researchers provided all factors such as weight ,damping output etc. are considered thoroughly. Work on such precision actuators is on the primitive scale as such continuous regenerative systems have not come into practice yet. The conventional shock absorber working in tandem with the suspension spring is merely an energy dissipating device. By changing the internal structure of the shock absorber based on the principle of electromagnetic induction could lead to obtaining an electrical output. In short, a part of the braking loss can be recovered in an electrical form. If harnessed, running of peripheral systems such as air conditioning systems, the radio, headlights, tail lamps, etc could become much easier as this energy recovered would be able to run such applications while also charging the battery simultaneously due to constant motion of the vehicle. The shock absorbers on two wheelers can also be used for energy recovery and the energy recovered can run the aforementioned applications.

II. LITERATURE REVIEW

Lei Zuo et al. designed an electromagnetic vibrational energy harvester specifically for taking the railway track deflections/ vibrations as their input. It is designed with a patented multiple motion rectifier which basically converts the bidirectional motion to a unidirectional output motion. The preliminary design is made to make sure it runs the high power track side applications such as warning signals, switches and monitoring systems which require at least 10 W of power to run. Moreover power generated is DC as implementation of a flywheel is used[1].Lei Zuo et al. also designed and fabricated a 1: 2 model of a linear generator based electromagnetic shock absorber was done. Finite element method was utilized to analyze the magnetic field and guide the optimization of the design. Experimental tests conducted on the harvester show that the available energy that can be harnessed is between 16 – 64 W at a suspension velocity of 0.25 – 0.5 m/s.[2]Longzin zhen et al. discussed and analyzed the structure and principle of a regenerative electromagnetic shock absorber were analyzed in detail. The design consists of two coil winding arrays as well as two magnet arrays to generate a larger electrical output. Electric power can be re-obtained from the battery and it is produced due to the relative motion of the coil assembly and the permanent magnet. Magnetic flux density was obtained by utilizing the ANSYS software and accordingly performance parameters were obtained.[3]R.A.Oprea et al. provided the theoretical framework for the design of a linear electromagnetic shock absorber that converts the vibrational energy dissipated into electricity is discussed. Also, damping effects due to the design are also taken into consideration. Finite Element analysis is used to obtain the optimum size and configuration including the material to be used . Electro-mechanic and Thermal characteristics are numerically and experimentally investigated.[4]I. Martins et al. compared the design of the electromagnetic shock absorber with the hydraulic active suspension to highlight its commercial usage in the near future. Since active suspensions are too expensive, developments in the power electronics department and the permanent magnet material properties could be tapped so as to achieve better results at an affordable price. The analysis done and the experimental results show that the force values produced by the actuator are suitable and the actuator is oil free. Utilization of such an electrical system allows easier operation and guarantees regeneration of energy in the near future.[5] Lei Zuo et al. also employed the mixed motion rectifier patented technology to the conventional shock absorber by changing the internal structure of the shock absorber with a rack and pinion configuration. Experimental setup done proved to obtain 15 W of power while driving at a speed of 15mph on a B class road.[6].

III.CONCEPT & DESIGN ANALYSIS

In this section, at first the concept or working principle of the shock absorber is put forward followed by its design in CAD software. Lastly static magnetic analysis and its results are highlighted and compared with the analytical parameters.

A. Working Principle of the Regenerative shock absorber

The regenerative shock absorber converts suspension vibration between the wheel and the sprung mass into electrical power. The design consists of mainly a coil windings array and a permanent magnet array. The permanent magnet array is concentrically placed on a metallic rod which is of high magnetic reluctance. Along with the permanent magnets the, magnetic permeable spacers are stacked concentrically on the rod and they are placed in between permanent magnets. The permanent magnets are axisymmetrically magnetized and their orientation takes the form of N-S-S-N. This orientation allows the like poles to repel each other and the magnetic flux to move radially from the north to south of the permanent magnet. The coil windings array is basically a plastic tube on which the coils are wound. Plastic tube is considered due to its high electrical resistivity and less weight. An outer cylinder of magnetic permeable material is used to encase the permanent magnets array and also to reduce the reluctance of magnetic loops and thereby increase magnetic flux through the coils.

The electromagnetic induction principle states that there will be a development of voltage across the ends of a conductor in a magnetic field provided there exists relative motion between the conductor and the magnetic field. In this case, the relative motion is in between the coil windings array and the permanent magnet array. The voltage developed at the ends of a single conductor coil depends on the relative velocity V_Z, between the coil and the magnet array, the remanent magnetic field $B$and the length of the conductor coil, $l.$. Equation (1) gives us this particular relation.

$$V = BV_Z l \quad (1)$$

Equation (2) gives us the current produced due to the above emf set up in the coil depends on the electrical conductivity of the coil σ, the radial magnetic field of the permanent magnet B_r, the relative velocity V_z and the area of cross-section of the wire A_w.

$$I = \sigma B_r V_z A_w \quad (2)$$

The magnetic field developed in the conductor coil in order to oppose the current's creation in the first place is given by equation (3) Equation (3)follows lenz's law.

$$B_l = \mu n I \quad (3)$$

The magnetic field induced depends on the turn density, current and the relative permeability of the conductor material.The length of the coil is given by equation (4).

$$l = \pi D_c N \quad (4)$$

Where N is the number of turns of the coil and D_c is the average coil diameter.

Measurements from a conventional hydraulic shock absorber are taken. The outer cylinder OD is found out to be 30mm and the ID is found to be 27mm. The axial rod diameter is found out to be 10mm. The axial rod length is 19cm and the extended length and collapsed length of the shock absorber are both 36cm and 30cm. By keeping the axial length of axial rod same and changing the OD to 35mm and ID of 32mm of the outer cylinder of the design proposed and employing the industrial standard N35 grade NdFeB permanent magnet of size 20mmx10mmx10mm, static magnetic analysis was done. The OD and ID of the permanent magnets and magnetic permeable spacers is the same. Mild steel spacers are used due to their high magnetic permeability.The height of the spacers is taken to be 8mm. A copper coil of 30 AWG (American wire gauge) is considered with 250 - 300 turns for being the conductor. The length of the coil is taken as half of the length of the permanent magnet and magnetic spacer combined that results to 9mm. The coils are made to align with the permanent magnet array. The distance between respective coils is kept as 0.1mm. The coils are positioned such that they are 90° out of phase with each other. The coils adjacent to the permanent magnets at an equilibrium position will always give an output voltage of 0. Whereas the coils adjacent to the magnetic spacers will give positive and negative peak to peak values of the voltage generated.

B.Static Magnetic Analysis

Magnetic field analysis was carried out to confirm with the analytical calculations and to optimize the solution. FEMM 4.2 software was used to showcase the radial magnetic field acting on the coils .Value of radial magnetic field acing on the copper coil was found out to be 0.157T analytically. The initial simulation case with no outer cylinder and axial rod material as stainless steel gave us a value of 0.154T. By changing the axial rod material to Aluminium we obtain a value of 0.202T. This is because Aluminium has high magnetic reluctance and hence the magnetic field is pushed towards the coils. By applying an outer casing of mild steel due to its high magnetic permeability gives us a range of 0.290T.This says that there is more power that can be extracted from this device due to optimizing the design. Fig 1 –Fig 3 shows the magnetic flux distribution within the regenerative shock absorber. The outer tube of mild steel helps in keeping the magnetic flux well within the casing and pushes all the flux through the coils.

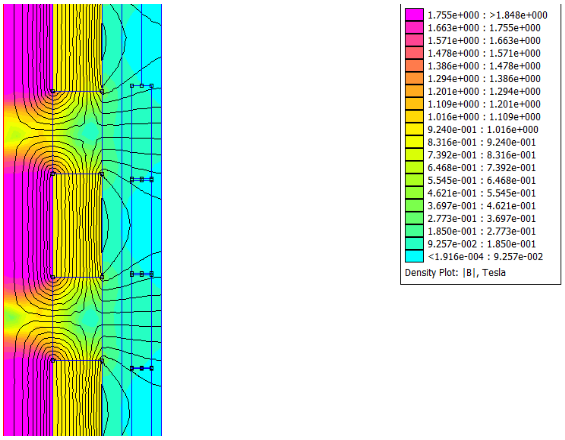

Fig 1. Magnetic field distribution with Stainless steel axial rod

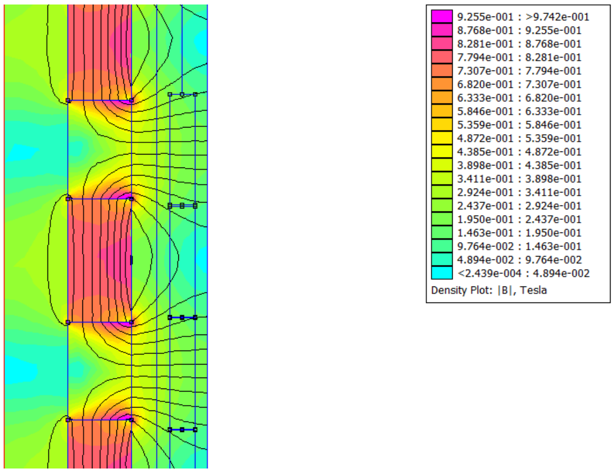

Fig 2. Magnetic field distribution with Aluminium axial rod.

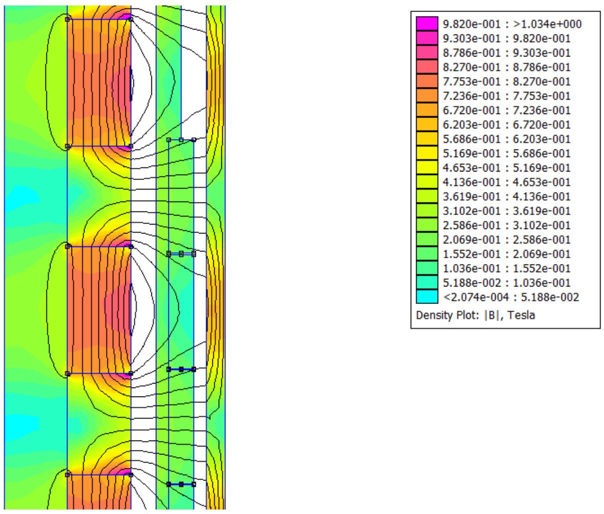

Fig 3. Magnetic field distribution with Aluminium axial rod and Mild steel outer casing.

C. Obtaining acceleration data

A circuit was built by utilizing a microcontroller, two digital accelerometers and pull ups resistors. The program code for obtaining acceleration inputs was written and burnt on the microcontroller. The circuit once implemented will give the acceleration faced by the conventional shock absorber during motion at a specific velocity. The acceleration data will be obtained by the accelerometers which are positioned separately, one at the top eyering of the shock absorber and the other at the bottom eyering.

C.1 Hardware Implementation

A circuit was constructed with the help of an Arduino ATMEGA 328 microcontroller and two ADXL345 digital accelerometers in order to obtain real time acceleration inputs resulting on the conventional shock absorber. Four 4k7 pullup resistors were utilized in order to aid the communication process as the operating voltage for the ADXL345 is 3.3 V and the operating voltage for the Arduino ATMEGA328 microcontroller is 5 V. Fig 4. Shows the connections and the various components of the circuit.

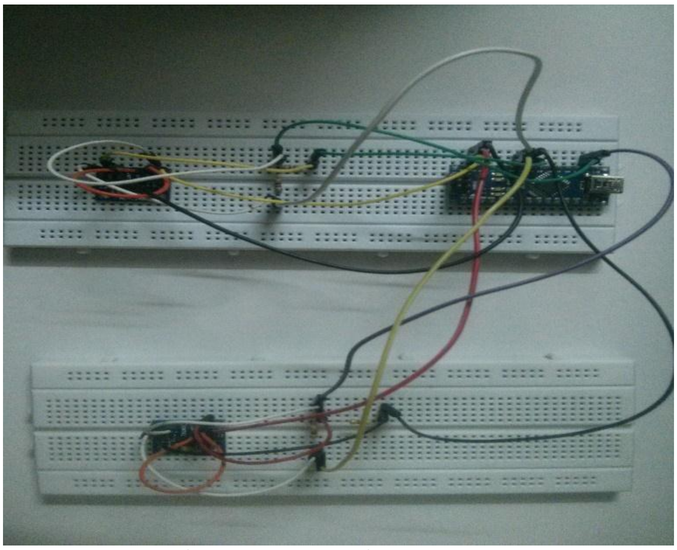

Fig 4. Circuit for data acquisition of real time acceleration inputs.

C.2 Software Implementation

The software part consists of the program code written on the IDE platform of the Arduino microcontroller. The coding language is basic C++. Once the code was written it was tested by normal motions of the accelerometers to check if the ciruit built was adhering to the program code written and was giving output values of accelerations. The transfer protocol utilized for communication is the I2C protocol

IV. CONCLUSION

This paper talks about the choice of materials required for the construction of the regenerative shock absorber. Moreover, the magnetic field analysis done and the analytical calculations prove that the scheme for this model is viable.

The circuit building along with program coding for obtaining real time acceleration inputs has been completed.

V. FUTURE WORK

The next step is to validate the model by building a prototype of the said model and testing it for various amplitudes and frequencies.

The designed circuit will be applied on a shock absorber and the acceleration inputs for a specific velocity shall be analysed and plotte**d**

ACKNOWLEDGMENT

The author sincerely thanks all his colleagues who made this work reach this particular stage possible. Also thanks to the family for their constant support and their belief.

REFERENCES

[1] John J. Wang, G.P. Penamalli , Lei Zhou, “Electromagnetic Energy Harvesting from Train Induced Railway Track Vibrations” Proceedings of the IEEE/ASME International Conference on Mechatronics and Embedded Systems Applications (MESA) 2012, pp. 29-34.

[2] L. Zuo, B. Scully, J. Shestani, Y. Zhou, “ Desing and characterization of an electromagnetic energy harvester for vehicle suspensions” Journal of Smart Materials and Structures, 2009, Vol 19, pp. 1- 10.

[3] Longxin Zhen, Xiaogang Wei, “Structure and Magnetic field analysis of Regenerative Electromagnetic Shock Absorber”, Proceedings of the IEEE, WASE International Conference on Information Engineering, 2010.Vol 3, pp. 152 – 155.

[4] R.A Oprea, M. Mihailescu, A.I. Chirila, I.D. Deaconu, “Design and Efficiency of Linear Electromagnetic Shock Absorber”IEEE, Proceedings of the IEEE 13th International Conference on Optimization of electrical and electronic equipment(OPTIM), 2012pp. 630 -634.

[5] I. Martins, J. Esteves, GD Marques, et al.“ Permanent magnets linear actuator applicability in automobile active suspensions”, IEEE transactions on Vehicular Technology, 2006, vol.55(1), pp. 86 – 95.

[6] Zhongie Li, Lei Zuo, George Luhrs et al. “ Electromagnetic energy harvesting shock absorbers. Design, Modelling & Road tests”, IEEE transactions on Vehicular Technology, 2013, vol.62(3), pp. 1065-1074.