Design and Simulation of Regenerative Suspension using Piezoelectric Transducer

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Abstract - *The standard vehicle suspension dissipates the mechanical vibration energy within the form of heat which wastes considerable energy. Over the last decade, green manufacturing has attracted a good deal of attention worldwide. Achieving clean energy may well be attained through scavenging the waste energy from the ambient environment and converting it into useful energy. The regenerative suspensions have attracted much attention in recent years for the development of the ability to remove energy are discussed, then the research and development of regenerative suspension is reviewed, and therefore the energy harvesting schemes and their characteristics regarding the performance and reduction of energy dissipation are discussed. Above all, the quantity of energy dissipation and also the potential of energy regenerate summarized and remarked. Only by combining vibration reducing performance and energy harvesting efficiency we can have a promising prospect in regenerative suspensions. The evaluation of the electrical harvesting circuits and different storage devices for the harvested power has also been discussed. The paper also will shed light on the range of potential applications of the harvested energy.*

Key Words: **Regenerative suspension, Green manufacturing, Clean Energy, Harvested energy, Vibrations.**

1. INTRODUCTION

The piezoelectric effect is a molecular phenomenon that was perceived at the macroscopic level as a change in voltage that's created when a piezoelectric substance is deformed. This was first observed by Carl Linnaeus and Franz Aepinus within the mid-1800s, but it had been not truly understood until it had been demonstrated by two French physicists, Jacques and Pierre Curie in 1880. Certain natural materials like quartz, salt, and even sugar would generate a voltage when placed under stress. These materials all had characteristic crystal structures formed from a lattice of molecules with asymmetric dipole moments that may reply to mechanical pressure. Later it absolutely was found that alternatively, the crystals would vibrate when a current was applied to them. Within the early 1900s, the converse of this was utilized in the primary submarine sonars. Scientists created piezoelectric transducers from quartz crystals placed between the steel plates. A current seasoned one transducer emitted a high-frequency ping which might bounce off objects and so be picked up by another transducer sensitive enough to exactly convert the echo. Evidently, companies like AT&T Bell Laboratories, GE, Federal Telegraph Company, and Westinghouse scrambled to file patents and compete for the market share within the new technological market. This competition spawned the primary large private research and development firms. Up to the present point, the sole piezoelectric material used was quartz, both because it had been inexpensive and it had been common. Whereas, research began into alternatives and more practical manufacturing methods, but despite the invention of things like piezo ceramics and piezoelectric igniters, the technology was largely overshadowed by the invention of radiation and vacuum tubes. Even with a piezoelectric component in nearly every radio and TV, it remained obscure well into the top of the 20th century. In times, the foremost common use has remained in audio equipment. Guitar pickups and barbeque grill igniters are common examples where piezoelectric crystals are a staple, but they need also found a distinct segment in vibrational analysis in fluids and heavy machinery. Another modern applications in which piezo is used are as time standards in watches, piezoelectric motors, vibration dampeners, and inkjet ejectors. The qualities that make this technology unique in these fields make them extraordinary. Since the energy-saving idea was introduced within the 20th century, energy efficiency has gained attention within the industry.

2. OBJECTIVES

The need to extract energy from wasted ambient energy is growing day by day because of scarcity of energy. The majority of low-power electronics, have embedded devices and remote sensors, are powered by batteries. However, even when it involves long-lasting batteries, they have a limited existence and has to get replaced every few years. The replacements can end up to be extremely costly as there are many sensors in remote locations. Whereas, energy harvesting technologies supply unlimited operating life of low-power equipment and even remove the requirement to switch batteries where it's costly, unfeasible, or unsafe. Most of the energy harvesting applications are made to be self-sustaining, cost- effective, and also require minimum or no servicing for several years. On addition the power is used as closest to the source, which completely eliminates transmission losses and long cables. When the energy is enough to power the device directly, the appliance or device powered by the energy can operate without batteries.

3. METHODOLOGY

3.1 Plan of Work

In this paper we will be harvesting vibration energy using piezoelectric crystals, performing on piezoelectric effect. That is, when there is no pressure applied on the crystals, the centers of the negative when and positive charges concur on each other. The dipole effect is nullified and thus that material is neutral. After pressure is exerted on the piezoelectric crystals, they force to change the internal structure and now +ve and –ve charges do not coincides, as a result of which dipoles are generated which further results in polarized molecules. This polarized material generates an electric field whose amount depends on the amount of polarization which depends on the quantity of vibrations occurring. This electric field transforms mechanical energy into electrical energy. This a.c voltage is converted into d.c voltage using rectifiers. A huge number of vehicles suspensions produces vibrations which can be further used to generate electrical energy. And this redeems our electricity to a great extent. Piezoelectric transducer are a vibration energy harvester, which converts mechanical energy into electrical energy with piezoelectric materials through piezoelectric phenomenon. Piezoelectric devices are used in many applications like power harvesting shoes, Piezoelectric fans etc. In electric cars vibration energy produced with their running can also be converted into electricity by piezoelectric vibration energy harvesters. This electricity can be stored in batteries. Unlike other electric cars that depend upon special charging stations or an electric cable plugged into an outlet at home, the electric car charged by the vibration energy relies on piezoelectric devices to charge the car's battery when it moves.

3.2 Working

When an automobile goes through a bump or is moving the vibrational energy is being absorbed by the suspension.We will be using cantilever mounted piezoelectric transducers which are placed above the valve assembly in the shock absorber piston cylinder assembly, the pushing force or the pressure of compressing damper oil is applied on the transducer, because of which the crystal lattice of the transducer is deformed and it converts the pressure or force into AC voltage across the electrodes. When a piezoelectric crystal is compressed or expanded, AC voltage is generated in thecrystal. The output that is generated is AC voltage, the AC voltage is then rectified by using diodes, after rectification the voltage can be decreased by using buck converter or to increase buck boost converter can be used. Then the voltage is stored in the capacitor and after that it is distributed to the loads.

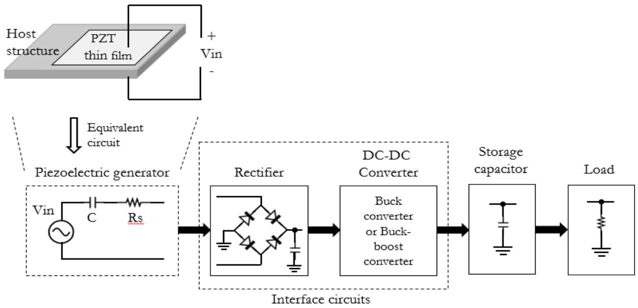

Figure-1: Energy Harvesting

3.3 Flow of Work

The vehicle speed considered will be less than 10 km/h when passing over a bump, with a minimum of 0.127 m for the suspension travel distance, and therefore the road handling of the relative distance between the road and also the tires must be within the range of 0.05 m. We derived the equations of motion of the complete car model and studied the suspension system when subjected to different disturbances. Pulse and impulse disturbances got to the right front wheel. For the case of the pulse input, the most oscillations affected the front axle with little effect on the rear axle. However, for the impulse disturbance, the utmost oscillations undergone by the front axle were much on top of the pulse disturbance. The proposed system showed 1 / 4 car model (2 DOF) with a piezoelectric harvester placed in parallel to the suspension springs. For study purpose, the quarter car model was excited by a sinusoidal input with a 1 g (9.8 m/s2) amplitude. The peak output voltage and power from the piezoelectric element were recorded as 88V and 61.4W respectively. The harvested voltage and power were pretentious by the suspension parameters like tire stiffness, suspension stiffness, and damping coefficients. The proposed theoretical analysis was validated experimentally by modelling the sprung and unsprung masses as aluminum blocks with four springs and one piezoelectric element in between. The setup was subjected to a sine wave with an acceleration of 1.5 m/s2 and amplitude of 0.1m. The utmost output voltage was 0.88 V for one cycle of the shock absorber.

4. DESIGN

This section will explore design of a damper, based on loadings and performance characteristics identified in previous chapters. General design considerations are considered first, followed by actual component designs. To make accurate conclusions on the feasibility of the production of a personalized set of dampers, certain design issues must first be taken under consideration. The factors which require consideration include manufacturability, cost, durability, thermal dissipation, assembly and disassembly procedures and sealing. Only the most important components are going to be discussed. Due to concerns about the accuracy of the numerical model, the damper components will remain within the concept stage, without final dimensions.

4.1 Components

The suggested design of the piston for the damper. The piston has been designed specified the valve stack doesn't impede the oil flow when the piston is within the opposite 1/2 its stroke. The Piezoelectric Transducer is to be placed above the valve stack assembly, also which does not impede the motion of the oil flow. Piston cylinder diameter and rod diameter is taken as 50mm and 20mm respectively. Cylindrical ports of diameter 3mm were speculated by the model. The dimension of the cylinder and piston have a tolerance of 0.02mm. Strut Mounting with Cylinder chamber. It contains the proposed design for the cylinder and mounting points. Most of the parameters in this model have been taken as assumptions. The mounting bolts are of 10mm on the underside portion of the model with a four bolt mounting. The total height of the cylinder model is taken as 450mm with inner diameter as 25mm and outer diameter as 28mm. Spring seat of the damper is taken to possess a diameter of 140mm on which the spring are mounted.

5. CALCULATION

5.1 Weight Distribution

Available data:

(model calculations done for Hyundai Grand i10)

Gross weight = 1025kg

Kerb weight = 935kg

Wheel base = 2425mm = 2.425m

a=distance from front wheel to CG.

b=distance from rear wheel to CG.

a=1.286; b=1.139

W1: Force on the front axle.

W1 = Gross Weight.g.b/Wheel Base

=1025x9.81x1.139/2.425= 4,722.85N

Quarter Car Weight = W1/2= 4722.85/2

= 2361.42 N

5.2 Force of Damper

(Considering incompressible flow ,cavitational free operation and minimum frictional losses)

F=Force exerted by quarter part of the vehicle (N) = 2361.42

m=Unsprung mass of the quarter part vehicle (kg) =240.7

u=Initial velocity (m/s) = 0.0
v=Final velocity (m/s) =1.38
t=Rise time of the suspension (s) =0.5
k=Spring rate/Spring constant (N/m)
=F/x
x=Vertical displacement (m) =0.1
k=F/x=2361.42/0.1
k=23614.2 N/m.

$F=m(v-u)t+F + k\int tv$
F_{damper}= 2361.42-240.7(1.38-0.0)/0.5- 23614.2*0.125
F_{damper} = -1254.69 N… (-ve sign implies the direction is reversed)

5.3 Voltage Output

(model calculation for a PZT-5A Transducer)

F_{damper}: Shock Absorber Cylinder Force (N)=1254.69

d33: Piezoelectric charge constant parallel to y-axis (C/N) =$390*10^{-12}$

Ɛo: Permittivity of free space (F/m) = $8.854*10^{-12}$

Ɛr: Permittivity of piezoelectric material (F/m)=1700
t : Distance between electrodes (m)=$1*10^{-3}$
A: Surface area of piezoelectric material (m^2)= $40.3*10^{-3}$
Voc: Open circuit Voltage (v)

Voc=dFt/ƐoƐrA
$Voc=390*10^{-12}.(1254.69).1*10^{-3}/ 8.85410^{-12}.(1700).(40.3*10^{-3})$

Voc=0.88 v …….*(voltage for one cycle of one transducer)*

5.4 Power Output

ρ: Resistivity (m) =1010
t: Transducer thickness (m) $=1*10^{-3}$
A: Surface area of the transducer (m^2) $=40.3*10^{-3}$
Voltage (v) =0.88
R: Resistance of Transducer(Ω)
P: Power (W)

$R=\rho*t/A=1010*1*10^{-3}/40.3*10^{-3}$
R=25.06
$P=V^2/R=0.88^2/25.06$
P=0.034 W

6. SIMULATION

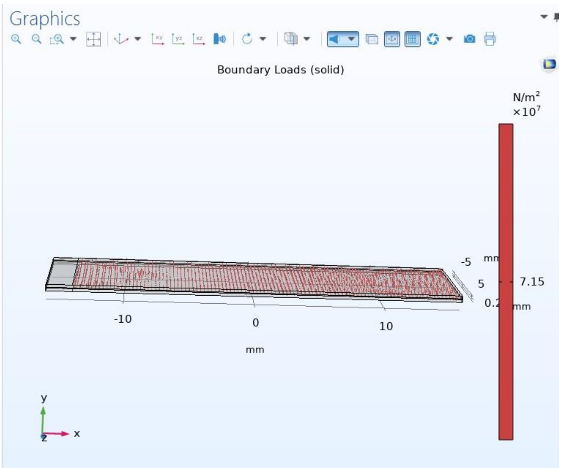

Figure-2: Boundary Loads

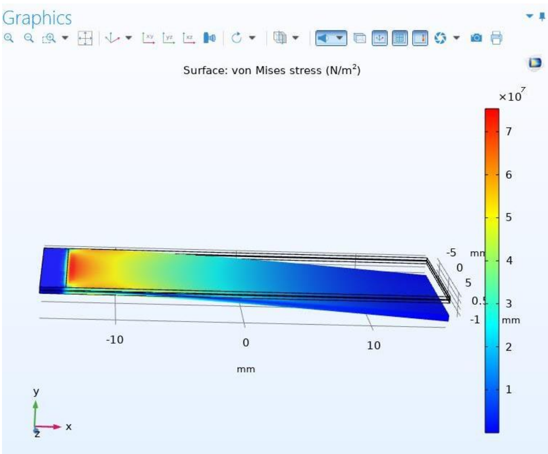

Figure-3: von Mises Stress

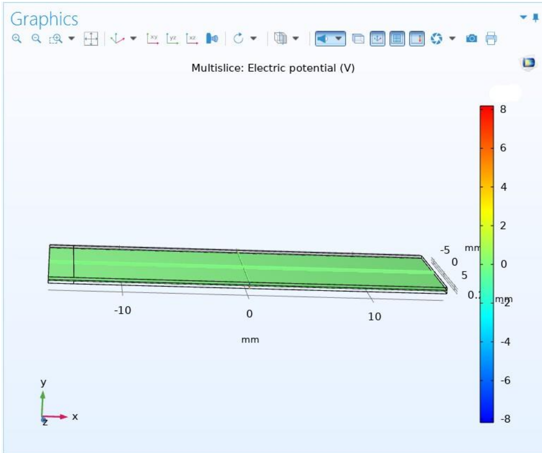

Figure-4: Electric potential

7. RESULT

From this report we are trying to give attention to the new ways with advanced technologies present in front of us for generating electrical energy. Since electrical energy is non-renewable, there is a great need to save electrical energy efficiently. Thus, by collaborating this vibration energy with electric cars can save an enormous amount of electricity and that saved electricity can be used to light up many lives. In this concept the piezoelectric materials play a very important role. The Piezoelectric materials have the ability to transform mechanical energy into electrical energy. The amount of energy generated depends on the number of transducers in vehicles and the number of disturbances on the road. Then this received energy is stored in batteries. This review illustrates that, regardless of the technique used in energy harvesting from a car suspension system, the outcome is, however, still limited (from 0.034 W to 3.4W) when compared with the available dissipated energy. Different methods may be suggested here so as to maximize the harvested power.

Iteration for 'n' number of cycles:

N	Voltage (V)	Power (Watts)
1	0.88	0.034
10	8.8	0.34
50	44	1.75
100	88	3.4

Table-1: Voltage and Power Outputs

8. CONCLUSION

The scope and contribution of current work was investigation of the kinematics and dynamics of the proposed regenerative shock absorber. Producing tailored piezoelectric elements with improved material characteristics for converting most of the mechanical vibrations from cars into electrical power is one of the possible ways. Most of the work mentioned during this review makes use of electric battery as a storage device. Moreover, automobile manufacturers are encouraged to provide vehicles that are equipped with multiple energy harvesters to create the dissipated energy available for utilization. This definitely have a direct effect on the fuel used and, on the economy, as well. Different methods may be suggested here so as to maximize the harvested power.

9. ACKNOWLEDGEMENT

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