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Design and Analysis of Power Generation using Piezoelectric Material in Electric Cars

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Abstract

Energy is employed by each and every organism in the macrocosm for its survival. As in this presto moving world, the population is adding day by day and the conventional energy sources are lessening. The expansive operation of energy has redounded in an energy extremity over the many times. Thus, to overcome this problem we need to apply the ways of optimal application of conventional sources for conservation of energy. Generating the electricity in the suspense system of the machine and store the energy in the battery or alternator as conventional system by simply driving the vehicle. Current sports bikes are typically without kicks and this power generation system can be used to charge the battery within short span of time. Many of the power generation styles in the vehicle suspense system is bandied. These climates are generated when vehicle passes over a road bump. The kinetic energy generated from the suspense system is converted into electrical power by using colourful mechanisms. This report is substantially concentrated on many power generated medium in vehicle suspense system. The entourages are the motifs considered to be reviewed in power generation styles.

I. INTRODUCTION

Dependency of mankind on technology has been increasing exponentially since the time out of mind. Electricity is an essential part of this technology. Therefore, the demand for electricity has been increasing exponentially. And to fulfil this demand nearly every known source has been exhausted and other people are now seeking new sources. One of those resources is piezoelectric materials. Piezoelectric power generation isn't a replacement concept. Power

generation from shoe sole and stair case are a number of the examples. When certain materials are applied with load, they generate current. This phenomenon is understood as piezoelectricity and therefore the materials possessing this property are referred to as piezoelectric materials. Since these materials require some amount of load to work, they're placed within the suspension of the vehicle since it's always under load even when the vehicle is at rest.

Piezoelectric ceramics belongs to the group of ferroelectric materials. Ferroelectric materials are crystals which are polar with none field being applied. The piezoelectricity is common in piezoceramics like PbTiO3, PbZrO3, PVDF and PZT elements. One of the defining traits of a ferroelectric material is that the molecular structure is oriented such the fabric exhibits an area charge separation, referred to as an electrical dipole.[1]

Throughout the synthetic piezoelectric material composition, the electrical dipoles are orientated randomly, but when a really strong field is applied, the electrical dipoles reorient themselves relative to the electrical field; this process is termed poling. Once the electrical field is extinguished, the dipoles maintain their orientation and therefore the material is then said to be poled.

II. LITURATURE SURVEY

1. **M. E. H. Jamadar, B. S. Manjunath, T. Student, M. Engineering, and K. L. E. Msscet** [1]

designed a vibration harvesting system with multilayers of piezoelectric material. The aim here was to use the vibrational energy from the suspension system of the vehicle, amplify it and use in to generated electricity using piezoelectric materials. The experiment turned out to be successful with 2 to 5 volts of average voltage generated.

2. **Kiran Boby from MACE, Kothamangalam in 2014** [2]

Proposed a design to generate piezoelectric power from shoe sole. The experiment turned out to be successful and they were able to produce about 40V of energy promising a bright future in piezoelectric power generation. Inspired form the above literature reviews this paper makes an attempt to introduce the concept of generating power from leaf springs via piezoelectric materials.

3. **Piezoelectric Energy Harvesting In Automobile Wheels,' Ayan Bhattacharya Volume 5, Issue 11, July-2018**[3]

Humans have always being depended upon the fossil fuels as the source of energy for their daily needs. With the exponential growth in population, the dependence on these conventional sources for the daily energy requirements has led to the depletion of the same and adverse ill-effects on the environment. To lessen the burden and if possible minimize to zero, energy harvesting has become the need of the hour and the development of the different energy harvesting technologies has been the prime area of research

4. **Efficiency Improvement of Regenerative Energy for an EV - World Electric Journal**
[Takuya Yabe, Kan Akatsu, Nobunori Okui, Tetsuya Niikuni, Terunao Kawai] [4]

The regenerative brake of EVs, HEVs are limited because of the motor capacity and the current limit of the battery. As a result, not only the regenerative electric brake but also the mechanical brake must be used. To increase the regenerative energy, the motor capacity and the battery capacity are requested to be large, however, it is very difficult because of the cost and the limit of the inverter capacity. Therefore, in this paper, regenerative energy is increased by improving a breaking method without changing the power train system. In this paper, the reason why the regenerative energy is limited is firstly shown, and an improved method to absorb the regenerative energy is proposed.

5. **Research on Electric Vehicle Regenerative Braking System and Energy Recovery - International Journal of Hybrid Information Technology**
[GouYanan College of Mechanical and Electrical Engineering, Zaozhuang University- 2016][5]

In this paper, the design of the electric vehicle energy recovery system converts the braking energy into electric energy which charges for the battery. The specific workflow for the electric vehicle energy recovery system is that the controller controls the permanent magnet motor together with a three-phase controlled bridge rectifier filter circuit working through wire connection, the rectifier filter circuit converts the three-phase alternating current produced by the permanent magnet motor to direct current, and then the direct current is delivered to the inverter

6. **Development of a regenerative braking control strategy for hybridized solar vehicle – IFAC**

[M. Grandone, M. Naddeo, D. Marra, G. Rizzo – 2015][6]

In this, we found that a solar-hybridized vehicle has been developed at the University of Salerno through the installation of an additional battery (Lithium-Ion) and two electrically driven in-wheel motors on the rear wheels on a conventional vehicle. Moreover, solar cells on the vehicle bonnet and roof have been installed so that it is possible to charge the battery pack taking advantage of solar energy. In that way, the vehicle can operate in pure electric mode (when ICE is switched off or disconnected by the front wheels) or in hybrid mode (when the ICE drives the front wheels and the rear in-wheel motors operate in traction mode or generation mode, corresponding to a positive or negative torque). The battery can be recharged by both rear wheels when operating in generation mode, and photovoltaic panels.

7. **DESIGN AND ANALYSIS OF REGENERATIVE BRAKING SYSTEM OF ALL-TERRAIN VEHICLE [R. Vignesh, Mr. S.R. Benin – 2018]**[7]

This Project can help to increase the efficiency and performance of vehicles through braking. This requires a Regenerative Braking System (RBS). This system gets the kinetic energy of the vehicle from the wheels and converts it into useful energy. This is done by the motor converting the kinetic energy into electricity. This energy is

boosted and stored in the battery. Again, when the accelerator is pressed this energy is re-used to provide acceleration to the vehicle. Further, this mechanism reduces the tear on the friction brakes making it long-lasting. The literature search focused mainly on topics related to electric vehicles (EV), hybrid electric vehicles (HEV) and fuel cell-powered hybrid electric vehicles (FCHEV).

III. PROPOSED WORK

i. Experimental set up

It was noted from trials that voltage from PZT units connected in series connection is good but current attained is poor, whereas from PZT units connected in parallel, the current attained is good but the voltage is poor. Developing a piezoelectric energy harvesting system is grueling because of their poor source characteristics (high voltage, low current, high impedance). So, then we use 4 heaps of piezoelectric systems equidistant to each other attached to a indirect strip arranged in between the inner subcaste of tyre and external face of wheel hem.[8]

FIG 1- Layout of arrangement of piezo discs in the tyre

Each PZT unit is connected with other two PZT unit in series connection. So each row has 3 piezoelectric units connected in series like shown in the figure (1). These rows of PZT units connected in series are connected to the therapy circuit (collectively) in a resemblant connection. So, arranging the piezoelectric system in a series resemblant connection produces good affair voltage and current, needed for proper energy harvesting. The affair of the system isn't a steady bone. So, a full surge ground therapy is used to convert this variable voltage into a direct bone. The therapy circuit is also used to convert the AC affair of a piezoelectric system into DC voltage. The amending circuit consists of 4 diodes.

ii. HARDWARE REQUIREMENTS

Due to the climate, a piezoelectric demitasse generates the electrical power. The produced affair voltage is in the form of ac. Also it can be converted to dc by passing it through therapy circuit. The converted dc voltage can be fed into boost.

A) Piezoelectric Materials

1) PZT (Lead zirconate titanate)
2) PVDF (Polivinylideneflouride)
3) Quartz

B) Tyre

1) 215/60 R15 tyre

C) Electric Circuit Parts

1. Diodes
2. Transducers
3. Wires
4. Battery
5. Multimeter

iii. WORKING

In our proposed system, for conversion of mechanical energy into electrical energy we used several piezoelectric transducers. For filtering, storing and help this ac voltage a 1 farad of5.5 volt super capacitor has used. All super capacitors used in resemblant to the piezoelectric material. The super capacitor is also known as Electrical Double Subcaste Capacitor (EDLC). Super capacitors are differing from other general capacitors. It can bridge the gap between capacitors and batteries with its high capacitance value. Super capacitors needed short time to charged, that's why available mechanical energy can be fluently stored as electrical . energy. But it needs much longer time to discharge. So, the stored electrical energy can be hold for longer time than other capacitors. When one of the piezoelectric unit (4 different units placed at right angles to each other) comes in contact to the road face (the contact patch area), at any case an electric voltage is produced in each of the piezoelectric unit. This AC affair is converted into usable DC voltage using the therapy circuit. This electrical voltage is fed to the capacitor bank for storehouse. A battery is also connected as shown in the circuit illustration which cuts off from the circuit as soon as the battery gets full charged. The battery is also ready for operation. The generated DC voltage can also be used to run onboard electrical bias or other detectors in the auto. This working process is applicable for each of the 4 bus of an machine fitted with piezoelectric modules.

iv. NUMERICAL ANALYSIS

1. Standard Specifications And Data For Calculations

For computations of the affair voltage certain data indicated in Table 1 is needed. The mechanical stress source is principally from the cargo on the tire which is generally the perpendicular cargo.

Table 1: Assumed data of working environment for calculations

Parameter	Value
Weight of the vehicle (4-wheeler/ 5passengers)	1600kg
Weight distribution	50:50
Wheel Diameter	668mm
Wheel Width	215mm
Tire Air Pressure	36psi
Dimension of PZT module	28mm dia, Thickness 2mm
d33	350x10-12 C/m2
g33	16.6x10-3Vm/N
Electromechanical coupling coefficient	0.69

Since, the vehicle is weighing 1600kg and 50:50 weight distributed, the load on each tire is calculated out to be 400kg(4000x9.81=3924N). The modules are to be arranged such that 4mm gap is maintained between two successive modules.

Number of modules mounted on each wheel =

(Circumference of the wheel) / (radius of wheel +gap between two modules)

$=\pi$ x 668/(4+334) = 6 (approx)

Therefore, the total number of modules in each wheel is 6.

Contact patch area = Load on the wheel/Air pressure in tire = (400x9.81) /0.1724 N/ 2)

=**17755.65 mmsq**.

For the width of the contact area to be 215mm, the length of the contact area (assuming that the region is almost a rectangular one) is mm. Therefore, the contact area almost indulges 6 PZT modules which will be 170 mm under stress once entering to the contact area zone.

Assuming that the load is distributed uniformly in the contact patch area, the mechanical stress induced in each module will be:

Mechanical Stress induced in each module = (Force on each module / area of application of load) = (400 X 9.81)/ (π X 0.028*0.028) = 1593173.46 N/mm2

Open Circuit Voltage (OCV) = g33 x σ x t

where, σ = induced mechanical stress in the module, t = thickness of the module

Therefore, **O.C.V = 16.6 x 10-3 x 1593173.46x 0.002 = 90V (approx)**

Charge Density = d33 x σ = 350 x 10-12 x 1593173.46 N/mm2

Charge on each module = charge density * π * 0.01775565 = 2.14 µA (for 1sec)

Thus,

Power Output =VI =90 X 2.14 = 192.6 µW

Maximum voltage that can be generated in each piezo module = 90 V

$$\text{Output power in one unit} = 44 \text{ x} 2.14 = \mathbf{192.6\,\mu W}$$

$$\text{Output power in one strip} = 3 \text{ x } 192.6 = \mathbf{577.8\,\mu W}$$

As there are total of 4 piezo stacks (4x24=96 total units) , For one complete rotation of the wheel, the number of times the same power output is obtained is equal to 96

Therefore, $\mathbf{Amount\ of\ power\ generated\ in\ total = 577.8\,\mu W \times 96}$

$$= \mathbf{55.8mW\ (approx)}$$

$$\text{Output power in 4 wheels} = 4 \text{ x } 55.8 = \mathbf{221875mW}$$

Assuming that the vehicle is running at a speed of 45 km/hr (12.5 m/s),

$$\mathbf{The\ no.\ of\ wheel\ rotations\ per\ second\ is\ given\ by} =$$

$$\text{velocity } /(\text{radius of wheel X } 2\pi)$$

$$= [12.5/(334\text{x}2\text{x}\pi)] \text{ x } 1000$$

$$= 6 \text{ rotations / sec}$$

Power output per wheel per second (car is in running condition)

$$= 6 \times 221{,}875.2 = \mathbf{1331251.2mW}$$

Therefore, Power output for 4 wheels of the car /second = 5,325,004.8 X 4 = **5325004.8mW (approx.)**

If the vehicle runs for 1hour (3600 seconds),The amount of energy that can be stored = (0.0247 x 3600) J

$$= \mathbf{1917001.3\ Joules\ (each\ wheel)}$$

Total Energy that can be stored from all the wheels

$$= 19{,}170{,}01.3 \text{ X } 4$$

$$= \mathbf{766805.2\ Joules}$$

= 766.80 KJ = 2.1kwh

IV. RESULT AND DISCUSSIONS

It can be seen that the quantum of energy that can be stored from an hour of driving with the present design of the system is enough for feeding the power force requirements of colorful electronic circuits of the vehicle. Proper

designing and trials can lead to better results. Although the effectiveness of similar systems is around 30-40, use of better quality PZT accoutrements can yield better results.

V. CONCLUSION

Piezoelectric materials have the ability to transform mechanical strain energy into electrical charge. The amount of energy generated depends on the speed of the vehicle and the number of piezoelectric elements on the tires. In this paper a theoretical model for energy harvesting system using piezoelectric materials have been presented. It is evident that harnessing energy through piezoelectric materials provider a cleaner way of powering lighting systems and other equipment. It is a new approach to lead the world into implementing greener technologies that are aimed at protecting the environment. Piezoelectric energy harvesting systems are a onetime installment and they require very less maintenance, making them cost efficient. One of the limitations of this technology is that its implementation is not feasible in sparsely populated areas as the foot traffic is very low in such areas.

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