ENERGY HARVESTING VIA ROAD TRANSPORT PRESSURE

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Abstract

The formation of acquiring the energy surrounding a system and covering it into usable electrical energy is termed power producing.Producing electricity using transportation pressure utilizing the speed breaker and piezoelectric effect is very innovative and useful.Electricity is the basic part of nature and it is one of our widely used forms of energy.We get electricity,which is a secondary energy source,from the conversion of other sources of energy,like coal,natural gas,oil,nuclear power and other natural sources,which are called primary sources.This paper emphasises on the idea that the mechanical energy can be converted to the electrical energy by the help of speed breaker and piezoelectric effect.We know that massive amounts of mechanical energy go waste when millions of vehicles move on the road.The speed breaker and the piezoelectric generators harvest that energy and save them in road side batteries that can be used by people.In this paper we discuss the research that has been performed in the area of power producing and especially we discuss about piezoelectricity.

Index Terms**—Piezoelectric,Speed breaker,Non-conventional energy,Electro-mechanical energy,Alternating current.**

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I. INTRODUCTION

Energy is an important input in all the sectors of any countries economy.The day-to-day increasing population and ecreasing conventional sources for power generation, provides a need to think on non-conventional energy resources.In this paper we are looking forward to conserve the kinetic energy that gone wasted, while the vehicles move.The number of road transports are increasing day by day.**B**eneath speed breaker, setting up an electro-mechanical unit known to be pressure leaver and beneath the road setting up piezoelectric generators could help us conserving the energy and use it for power generation.The generators will supply the clean energy to rechargeable batteries.We can supply this energy to street lights,traffic lights,and nearby areas,and thus helps in country's economy.

II. LITERATURE REVIEW

The energy catastrophe is any great bottleneck in the stock of energy resources to an economy.The studies to sort out the energy catastrophe led to the idea of generating power using speed breaker and piezoelectric generators.Firstly South African electrical crisis has made them implemented this method to light up small villages of the highway.The idea of basic physics to convert the kinetic energy into electrical energy that gone wasted when the vehicle run over the speed breaker and the piezoelectric generators beneath the road.Since then,a lot has been done in this field.The idea caught our working team and decides to develop the research that will produce more energy and store it for use at night time as it proves to be a boon to the economy of the country.

III. PROPOSED SYSTEM AND OPERATION

A. SYSTEM DESIGN AND CONFIGURATION FOR SPEED BREAKER

While moving, the vehicles possess some kinetic energy and it is being wasted. This kinetic energy can be utilized to produce power by using a special arrangement called pressure leaver.

Running Vehicle

↓

Creating pressure on the pressure leaver & piezoelectric generator

↓

Result: Moving of fly wheels in the P.Leaver and Compression on the Piezoelectric Generator's impact cap

↓

Produce electricity by Generator

↓

Storing energy in rechargeable battery

↓

Power convert to AC If required

↓

.. Using the energy when need

Fig. 1. Flowchart of the whole system operation

As a result flywheel will rotate and this rotation of the flywheel will cause the DC generator to produce electricity.This electricity can be stored by a rechargeable battery by charging the battery.

B. DRAWING OF THE PRESSURE LEAVER AND DC GENERATOR MECHANISM

When enforcing pressure on the pressure lever the mechanical gears will rotate, and boost the shaft RPM from shaft 01 to Shaft 05 because these shaft are mechanically coupled with each other. Flywheel and DC Generator are coupled with shaft 05 so flywheel rotates and stores mechanical kinetic energy. This helps to rotate the generator in desired RPM.

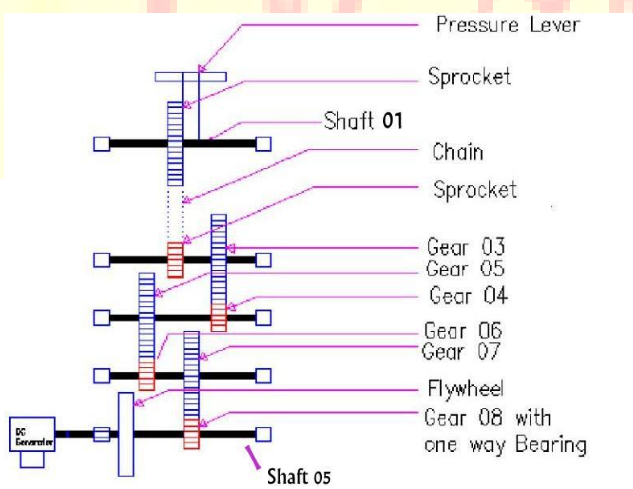

Fig. 2. Pressure Leaver

C. SPEED BREAKER PROJECT'S ELECTRICAL CIRCUIT DIAGRAM

Switches that can be turned to different positions to make a connection with the contacts in that particular position.A rechargeable battery,storage battery,or accumulator is a type of electrical battery.It comprises one or more electrochemical cells,and is a type of energy accumulator.It is known as a secondary cell because its electrochemical reactions are electrically reversible.chargeable batteries come in many different shapes and sizes,ranging from button cells to megawatt systems connected to stabilize an electrical distribution network.Several different combinations of chemicals are commonly used,including: lead–acid, nickel cadmium (NiCad),nickel metal hydride (NiMH),lithium ion (Li-ion),and lithium ion polymer (Li-ion polymer).When electricity is produced in DC generator, current passes through the rectifier and rechargeable battery is charged.When power is needed during the night time,selector switch is on and rechargeable battery supplies desired power.

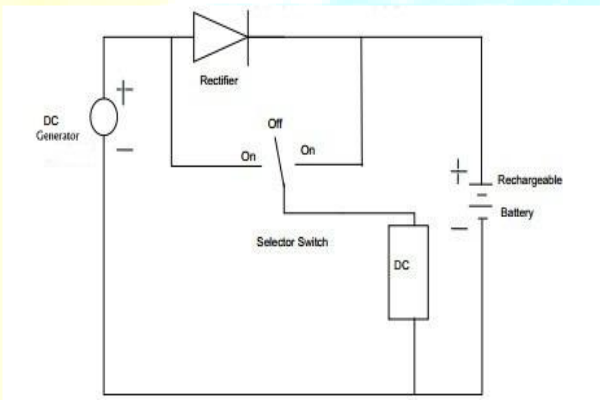

Fig. 3. Speed breaker project's electrical circuit diagram

D. MODEL OF THE SPEED BREAKER PROJECT

When pressure lever is pressed the flywheel will rotate by chine sprocket gear mechanism,it will force to rotate the DC generator because DC generator and flywheel are in same shaft.DC generator will produce electricity by the rotation of armature coil and generated electricity will be stored in a rechargeable battery.This electricity can be used later for people's use.

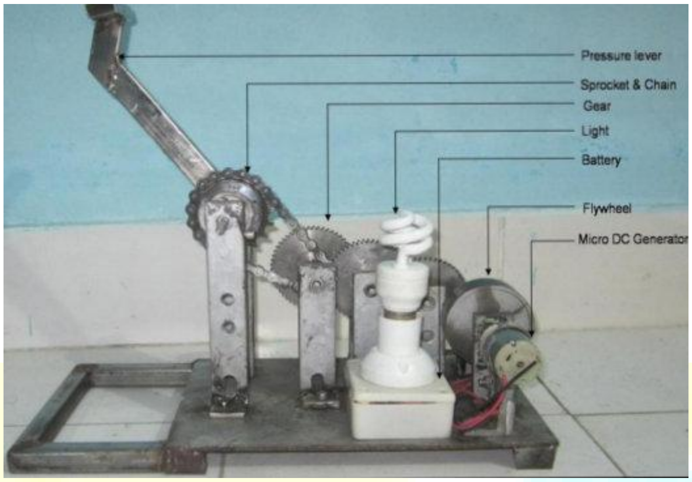

Fig. 4. Model of the designed Speed breaker project

E. PIEZOELECTRIC GENERATOR MECHANISM

Piezoelectric generators are embedded under the asphalt, minimizing potential energy waste. Potential energy is stored in the piezoelectric generators and used to produce electricity. The storage system consists of electronic components which transfer the energy from the piezoelectric generators to the storage device. The harvested energy can be transferred back to the grid, or used for infrastructure such as street lighting.While imposing pressure on the piezoelectric generator the impact cap goes down and put a pressure on preload stud inside the housing chamber.Using the piezoelectric effect the compression process runs and the generator produces electricity through the quartz element plate.

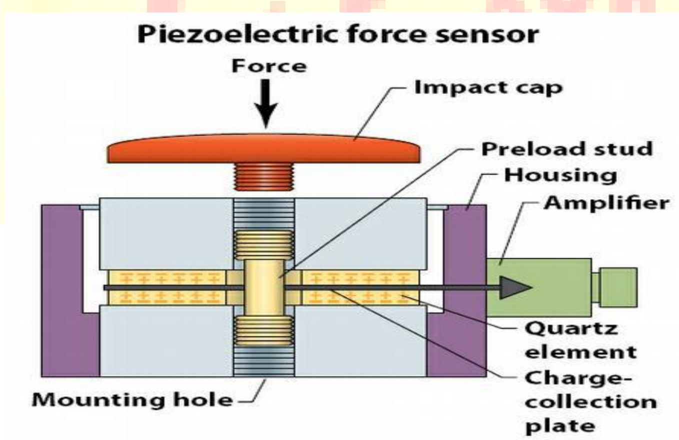

Fig. 5. Piezoelectric generator

E. EFFECTIVITY OF PIEZOELECTRIC EFFECT

We propose that when the effect applied to roads,the system works optimally when car and truck traffic is at least 600 vehicles per hour.The system can produce up to 500 killowatt-hours (kWh) from a 1 km stretch of dual carriage way which is enough energy to power 600 to 800 homes. As vehicle pass over the piezoelectric generator which is beneath the road layer,the vibration generates electricity that travels to a larger transformer which then distributes the energy.The generators can be as thin as afew centimeters or can cover large expansive surfaces,and can be easily adapted for a variety of different transit systems including roadways,railways and even airplane run ways.

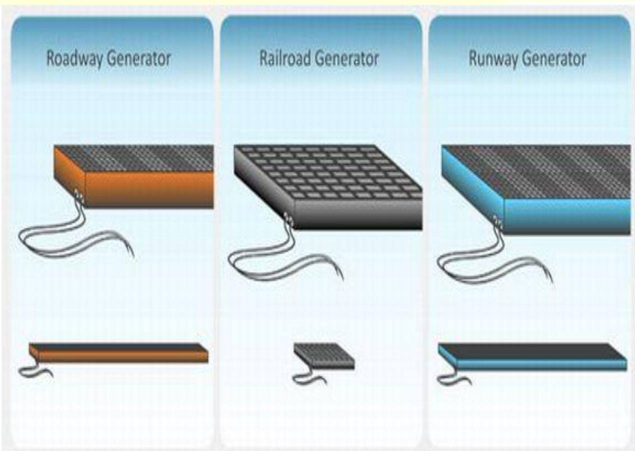

Fig. 6. Piezoelectric generator for roadway,railway & runway

F. Power Generation Circuit

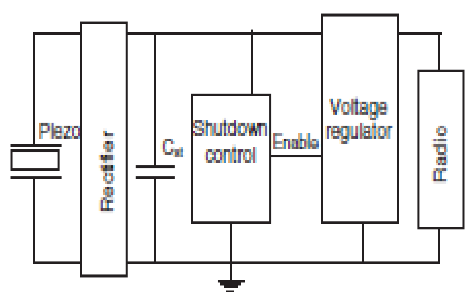

Fig. 7. A Schematic Diagram of the Power Generation Circuit

IV. NEW TECHNOLOGY AND RESULTS

Energy harvesting systems based in Israel specializes in the development of custom piezoelectric generators for specific purposes such as harvesting mechanical energy imparted to roadways from passing vehicles.We have also developed an efficient storage system to collect and store the electricity produced by these generators.The accumulated energy can be used to power traffic lights and or street lamps and in the future could be routed into the grid.IPEGs (Innowattech piezoelectric generators) are piezoelectric crystals that can harvest mechanical energy created by changes in weigh, motion, vibration and temperature, and convert it to electrical current.The energy harvested was stored in the electric capacitors of the storage system.IPEGs have some benefits, such as these are easy and inexpensive to install. Embedden between a road's layers, they are mounted with electronic cards to store traffic generated energy. The system is usually converted with a layer of asphalt, but concrete or composite concrete and asphalt can also be used. Because systems can be installed when new roads are laid or when regular maintenance work in performed or existing surfaces, installation costs are substantially less than those incurred with either wind or solar systems. One truck can generate 200 volts. Our result shows that this system capable of producing significant amounts of electricity,about 400KWh from a 1 km stretch of generators along the dual carriageway (assuming 600 vehicles go through the road segment in an hour), enough energy to power 600-800 houses.

Table 1: Compare the effectiveness of piezoelectricity harvesting with other options & also decision analysis

Factors	Piezoelectricity harvesting	Solar	Wind	Coal	Oil & Coal
Payback/ year	4-8 years (depending on volume of traffic)	20-30	12-30	15-20	10-13
Clean	yes	yes	yes	no	no
Mature Tech.	no (improving day by day)	yes	yes	yes	yes
Implementation in Town areas	yes	yes	no	no	no
Low maintenance	yes	no	no	no	no
Preserves environment in original state	yes	yes	no	no	no

The Innowattech roadway system has been quoted to cost $550,000 for the installation of one km of roadway,which generates 100 kWh.This corresponds to an overnight capital cost of $5,500/kWh.On the other hand solar photovoltaics cost between US$2200/kWh. In certain locations hydro resources can produce electricity at US$250/MWh.In comparison, electricity from coal costs US$70 /MWh.Peizoelectric might have a high production cost per kWh but it this can compensate for the power grid lines required for conventional power plants. Moreover,it is environment free,not releasing poisonous fumes into the air.

V. A PIEZOELECTRIC POWER HARVESTING MODEL

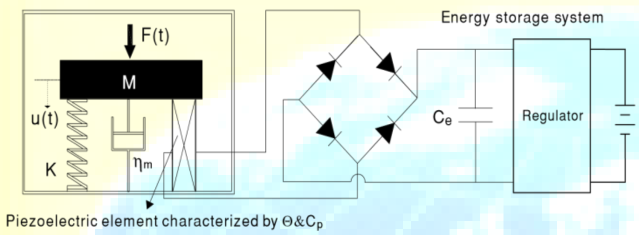

Fig. 8. An equivalent model for a piezoelectric vibration energy harvesting

If the structure is vibrating at around its resonance frequency, we may model the power generator as a mass+spring+damper+piezo structure, as shown in figure 8.

F(t): forcing function applied to the system

M: effective mass bounded on a spring

K : effective stiffness

η_m: a damper of coefficient

C_p : capacitance.

u : *d*isplacement of the mass *M*

V_p : voltage across the piezoelectric element.

I(t):The current flowing into the specified circuit.

$$M\ddot{u}(t) + \eta_m \dot{u}(t) + K u(t) + \Theta V_p(t) = F(t), \quad (1)$$

$$-\Theta \dot{u}(t) + C_p \dot{V}_p(t) = -I(t), \quad (2)$$

The vibrating generator is assumed to be driven at around resonance by the harmonic excitation $F(t) = F_0 \sin(\omega t)$, (3) where F_0 is the constant magnitude and ω is the angular frequency of vibration.

An ac–dc rectifier followed by a filtering capacitance C_e is added to smooth the dc voltage, as shown in figure 8. The common approach to having the stable output dc voltage is to assume that the filter capacitor C_e is large enough so that the rectified voltage V_c is essentially constant .

Specifically,

$V_c(t) = \langle V_c(t)\rangle + V_{\text{ripple}}$, where $\langle V_c(t)\rangle$ and

V_{ripple} are the average and ripple of $V_c(t)$, respectively.

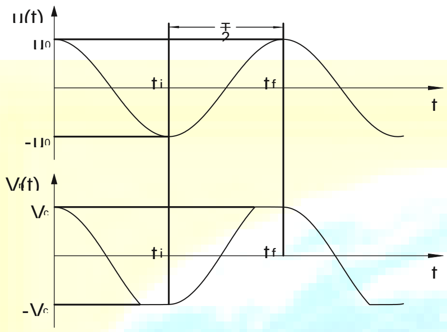

Fig. 9. Typical waveforms of displacement u(t) and piezo voltage $V_p(t)$ for an ac–dc power harvesting circuit.

From figure 9, the steady-state solution of u(t) is assumed to take the following form:

$$u(t) = u_0 \sin(\omega t - \theta) \qquad (4)$$

whereu_0: constant magnitude.

Let $T = \frac{2\pi}{w}$ be the period of vibration, and t_i and t_f be two time instants $(t_f - t_i = \frac{T}{2})$ such that the displacement u undergoes from the minimum $-u_0$ to the maximum u_0, as illustrated in figure 3. Assume that $\dot{V}_p \geqslant 0$ during the semi-period from t_i to t_f. It follows that $\int_{t_i}^{t_f} \dot{V}_p(t)\,\mathrm{d}t = V_c - (-V_c) = 2V_c$.

Note that

$C_e\dot{V}_c(t) + \frac{V_c}{R} = 0$ for $t_i < t < t^*$ during which the piezo

Voltage $|V_p| < V_c$ and $I(t) = C_e\dot{V}_c(t) + \frac{V_c}{R}$ for $t^* \leqslant t < t_f$ during which the rectifier conducts. This gives

$$-\int_{t_i}^{t_f} I(t)\,\mathrm{d}t = -\frac{T}{2}\frac{V_c}{R}$$

since the average current flowing through the capacitance C_e is zero, i.e., $\int_{t_i}^{t_f} C_e\dot{V}_c(t)\,\mathrm{d}t = 0$ at the steady-state operation.

The integration of (2) from time t_i to t_f is therefore

$$-2\Theta u_0 + 2C_p V_c = -\frac{T}{2}\frac{V_c}{R},$$

or

$$V_c = \frac{w\Theta R}{wC_pR + \frac{\pi}{2}}u_0. \qquad (5)$$

We next need to find out u_0 to determine V_c.

The equation of the energy balance

$$\int_{t_i}^{t_f} F(t)\dot{u}(t)\,dt = \int_{t_i}^{t_f} \eta_m \dot{u}^2(t)\,dt + \int_{t_i}^{t_f} V_p(t)I(t)\,dt, \quad (6)$$

where

$$\int_{t_i}^{t_f} F(t)\dot{u}(t)\,dt = \frac{\pi}{2}F_0 u_0 \sin\theta,$$

$$\int_{t_i}^{t_f} \eta_m \dot{u}^2(t)\,dt = \frac{\pi}{2}\eta_m w u_0^2,$$

$$\int_{t_i}^{t_f} V_p(t)I(t)\,dt = \frac{\pi}{w}\frac{V_c^2}{R}. \quad (7)$$

Differentiating (1) with respect to time t and using (2), we have:

$$M\frac{d}{dt}\ddot{u}(t) + \eta_m \frac{d}{dt}\dot{u}(t) + \left(K + \frac{\Theta^2}{C_p}\right)\frac{d}{dt}u(t) - \frac{\Theta}{C_p}I(t) = \frac{d}{dt}F(t). \quad (8)$$

Integrating (8) with respect to time t from t_i to t_f and using (4) provides the third equation

$$\left(K - Mw^2 + \frac{\Theta^2}{C_p}\right)u_0 - \frac{\pi\Theta}{2C_p wR}V_c = F_0\cos\theta. \quad (9)$$

Thus, the unknown variable θ can be eliminated from (7) and (9). This gives

$$\left\{\eta_m w u_0 + \frac{2}{wR}\frac{V_c^2}{u_0}\right\}^2 + \left\{\left(K - Mw^2 + \frac{\Theta^2}{C_p}\right)u_0 - \frac{\pi\Theta}{2C_p wR}V_c\right\}^2 = F_0^2. \quad (10)$$

As u_0 is related with the rectified voltage V_c by (5), the above equation (10) can be further simplified to find u_0. The result is

$$u_0 = \frac{0}{\left\{\left(\eta_m w + \frac{2w\Theta^2 R}{(C_p wR + \frac{\pi}{2})^2}\right)^2 + \left(K - w^2 M + \frac{w\Theta^2 R}{C_p wR + \frac{\pi}{2}}\right)^2\right\}^{\frac{1}{2}}}.$$

The average harvested power can also be obtained once u_0 is determined since

$$P = \frac{V_c^2}{R} = \frac{w^2\Theta^2 R}{\left(wC_p R + \frac{\pi}{2}\right)^2}u_0^2. \quad (11)$$

To summarize, the normalized displacement u_0, rectified voltage V_c and average harvested power P can be expressed by

$$\bar{u} = \frac{u_0}{\frac{F_0}{K}}$$

$$= \frac{1}{\left\{\left(2\zeta_m + \frac{2k_e^2 r}{(r\Omega+\frac{\pi}{2})^2}\right)^2\Omega^2 + \left(1-\Omega^2+\frac{\Omega k_e^2 r}{r\Omega+\frac{\pi}{2}}\right)^2\right\}^{\frac{1}{2}}},$$

$$= \frac{\frac{\pi}{w}\frac{V_c^2}{R}}{\frac{\pi}{2}\eta_m w u_0^2 + \frac{\pi}{w}\frac{V_c^2}{R}}$$

$$= \frac{2\left(\frac{V_c}{u_0}\right)^2}{\eta_m w^2 R + 2\left(\frac{V_c}{u_0}\right)^2}$$

$$= \frac{2\Theta^2 R^2 w^2}{\eta_m w^2 R\left(wC_p R + \frac{\pi}{2}\right)^2 + 2\Theta^2 R^2 w^2}$$

— V_c $r\Omega$ (12)

$$V_c = \frac{F_0}{\Theta} = \left(\frac{}{r\Omega + \frac{\pi}{2}}\right) \times \frac{k_e^2}{\left\{\left(2\zeta_m + \frac{2k_e^2 r}{(r\Omega+\frac{\pi}{2})^2}\right)^2\Omega^2 + \left(1-\Omega^2+\frac{\Omega k_e^2 r}{r\Omega+\frac{\pi}{2}}\right)^2\right\}^{\frac{1}{2}}}, \quad (13)$$

$$\overline{P} = \frac{P}{\frac{F_0^2}{wM}} = \frac{1}{r + \frac{\pi}{2}} \times \frac{k_e^2 \;{}^2 r}{2\zeta_m + \frac{2k_e^2 r}{(r+\frac{\pi}{2})^2}\;{}^2\;{}^2 + 1 - {}^2 + \frac{k_e^2 r}{r+\frac{\pi}{2}}\;{}^2}, \quad (14)$$

Where several non-dimensionless variables are introduced by

sc

$$k_e^2 = \frac{\Theta^2}{KC_p}, \qquad \zeta_m = \frac{\eta_m}{2\sqrt{KM}}, \qquad w_{sc} = \sqrt{\frac{K}{M}}, \quad (15)$$

$$\Omega = \frac{w}{\quad}, \qquad r = C \; w_{sc} R.$$

pw_{sc}

Above k_e^2 is the alternative electromechanical coupling coefficient[1], ζ_m the mechanical damping ratio, w_{sc} the natural frequency of the short circuit, and r the normalized frequency and electric resistance. Note that there are two resonances for the system and are defined by:

$$\Omega_{sc} = 1, \qquad \Omega_{oc} = \sqrt{1+k_e^2}, \quad (16)$$

where $_{sc}$ and $_{oc}$ are the frequency ratios of the short circuit and the open circuit, respectively.

Using (14), F_0 = MA, where A is the magnitude of acceleration of the exciting basere, the harvested average power per unit mass is described by

$$\frac{P}{M} = \frac{A^2}{w} \cdot \overline{P}\; r,, k_e^2, \zeta_m \qquad sc$$

Efficiency

$$= \frac{W^e}{W^{in}}, \qquad W$$

Where the $\oint \cdots dt$ denotes average over time [26, 33]. Above W^e is the time-averaged power dissipated across the load resistor R and W^{in} is the time-averaged power done by the external force. The balance of energy in (6) gives

$$W^{in} = W^m + W^e, \qquad W^m = \oint \eta_m \dot{u}^2 \, dt,$$

where$W^m$is the time-averaged power dissipated due to the structural damping. From (7)
efficiency

due to (5) it can also be written in terms of the non dimensionless parameters defined in

(15) by efficieny $= \frac{r\frac{k_e^2}{\zeta_m}}{\left(r\Omega + \frac{\pi}{2}\right)^2 + r\frac{k_e^2}{\zeta_m}}$ ff. (19)

The total damping ratio of the system can be decomposed as

Z tot= $\zeta m + \zeta e$,

where ζ_e is the electrically induced damping ratio due to the removal of mechanical energy from the vibrating system. Using (19),the induced damping ζ_e for an ac–dc piezoelectric power harvesting system. Indeed, the efficiency of the energy conversion can be re-defined by

efficiency $= \frac{\zeta_e}{\zeta_m + \zeta_e}$ (20)

From (19) and (20), the induced damping added to the system can be found to be

$$\zeta_e = \frac{rk_e^2}{\left(r\Omega + \frac{\pi}{2}\right)^2}. \qquad (21)$$

V. ADVANTAGES

This technology provide genuine environmental benefits where parasitic mechanical energy on roads, highways, railways and airport runaways,are harvested and transferred back,in a process by which the energy is captured,stored and reused.Both the DC and Piezoelectric generator's contruction are simple.The technology we use here is very matured and maintenance is easy.There is no consumption of any fossil fuel which is non-renewable source of energy.In this process there is no fuel transportation required and no external source is needed for power generation.Using the speed breaker and piezoelectric effect for harvesting we can harvest energy all the year round.This technology has developed a very efficient storage system to collect and store the electricity produced by these generators.The accumulated energy can be used for local power needs or routed into the grid.

VI. FUTURE WORK

In the future,this technology can serve to gather information creating “Smart Roads.” In addition to energy production,real-time data on the weight,frequency and distances between passing vehicles can be generated.

VII. CONCLUSION

In coming days, this will prove a great boon to the world,since it will save a lot of electricity of power plants that gets wasted in illuminating the street lights. As the conventional sources are depleting very fast, then its time to think of alternatives.We got to save the power gained from the conventional sources for efficient use.So this idea not only provides alternative but also adds to the economy of the country.Now,vehicular traffic in big cities is more,causing a problem to human being. But this vehicular traffic can be utilized for power generation by using the speed breaker and piezoelectric effect.It has advantage that it does not utilize any external source.Now the time has come to put forte these types of innovative ideas,and researches should be done to upgrade their implication.By implementing some modification of the designed project, the efficiency of the whole system can be increased by increasing the capacity of the generators and applying more weight.

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