Power Generation From Vibrations on the Sleepers beneath Railwaytracks for Railway Stations

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Abstract

A railway track undergoes mechanical vibrations when a train passes. The weight of a train rake is around 40 – 240 tons depending on the type of the train. Assuming the general weight of the train as 80 tons then it is sure that the mechanical vibrations produced are high. So, if we convert these mechanical vibrations into other forms of energy, a lot of energy would be created. Here we can use piezoelectric crystals which will be able to convert these mechanical vibrations into equivalent electrical energy. But the stress directly on the tracks is too large to be made useful for conversion by the use of the piezoelectric crystals because the maximum load that piezoelectric crystals can take is 25000 psi (available in the market). Hence, we are trying to generate electricity using the vibrations on the sleepers beneath the railway tracks because the vibrations, there are reduced and can fall in the range of the available piezoelectric crystals. The electricity thus generated will be in the form of sudden bursts as the pressure is experienced only when the train rake will pass over the plates. A continuous supply of electricity can be obtained by storing these sudden bursts of electricity in batteries and can be utilized as and when required. The frequency of train in Mumbai region is one every three minutes. There are other places with similar high frequency of trains. Such places will be highly benefitted by this concept. Massive wastage of power takes place at railway stations due to continuous and sometimes unnecessary usage of electrical appliances. The power thus generated can be used at nearby railway stations thereby saving precious energy, eliminating transmission losses and saving money as the power is now generated at a cheaper rate. This power generated by this concept can also be used at farms near railway tracks. The power thus generated is pollution free. The future scope of the concept is that we can implement helical coil springs in between the Crystals to generate double the amount of power as previous.
Keywords: Batteries, Power generation, Piezoelectric Crystals, Railway Sleepers, Vibration

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I. INTRODUCTION

A lot of energy is been used for various purposes and no one actually has a count of how it is wasted. One such huge form of energy is Electricity. Electricity is generated from various sources and is been used for various activities. There is no regulatory body which is concerned about the wastage of Electricity. There are many places which use electricity and thus those places are responsible for not proper usage of electricity.

Railway stations are one of such places which need electricity for the working of various appliances. The appliances are in working conditions always even if there is use or no usage. So here we are trying to implement our concept which will be able generate electricity from Railway tracks using the vibrations from sleepers beneath the railway tracks. The power generated will be very much useful for the nearby railway stations thus eliminating the stations depend on the other sources. The entire electricity used by a railway station will be thus generated by the nearby tracks with this concept.

We are using the principle of piezoelectric which converts the mechanical vibrations in equivalent electrical energy which can be stored in batteries and used whenever and wherever required. As we know the vibrations produced on the tracks are very high and thus it is difficult to convert those mechanical vibrations into equivalent electrical energy. Thus we are trying to convert the vibrations which we get on the sleepers beneath the railway tracks which are quite less than that produced on the tracks.

II. SLEEPERS

The Rectangular shape like objects held below the railway tracks are called as sleepers. Generally in India, sleepers are made up of concrete, but there are sleepers made up of wood, plastic, iron, etc.

A. Types :-

1) *Wooden*

Timber sleepers are usually of a variety of hardwoods, oak being a popular material. Some lines use softwoods, sometimes due to material necessity; while they have the advantage of accepting treatment more readily, they are more susceptible to wear.

Problems with wooden sleepers include rot, splitting, insect infestation, plate-cutting (abrasive damage to the tie caused by lateral motion of the tie plate) and spike-pull (where the spike is gradually worked out and loosened from the tie).

2) *Concrete*

Concrete sleepers have become more common mainly due to greater economy and better support of the rails under high speed and heavy traffic than wooden sleepers. In early railway history, wood was the only material used for making sleepers.

In those days, occasional shortages and increasing cost of wood posed problems. This induced engineers to seek alternatives to wooden sleepers. As concrete technology developed in the 19th century, concrete established its place as a versatile building material and could be adapted to meet the requirements of railway industry.

3) *Steel*

Historically, steel sleepers have suffered from poor design and increased traffic loads over their normally long service life. These aged and often obsolete designs limited load and speed capacity but can still, to this day, be found in many locations globally and performing adequately despite decades of service. There are great numbers of steel sleepers with over 50 years of service and in some cases they can and have been rehabilitated and continue to perform well.

4) *Plastic/rubber*

In more recent times, a number of companies are selling composite railroad sleepers manufactured from recycled plastic resins and recycled rubber. These sleepers are said to outlast the classic wooden tie, and are impervious to rot and insect attack, and can be modified to provide additional lateral stability while otherwise exhibiting properties similar to their wooden counterparts in terms of damping impact loads and sound absorption.

Aside from the environmental benefits of using recycled material, plastic sleepers usually replace hardwood sleepers soaked in creosote, the latter being a toxic chemical, and are themselves recyclable Plastic/Rubber composite sleepers are used in other rail applications such as underground mining operations.

III. HISTORY OF PIEZOELECTRIC CRYSTALS

Piezoelectric phenomena were first published in 1880 by Pierre and Jacques Curie. Their experiment consisted of a conclusive measurement of surface charges appearing on specially prepared crystals (tourmaline, quartz, topaz, cane sugar and Rochelle salt among them) which were subjected to mechanical stress. These results were a credit to the Curies' imagination and perseverance, considering that they were obtained with nothing more than tinfoil, glue, wire, magnets and a jeweler's saw.

In the scientific circles of the day, this effect was considered quite a "discovery," and was quickly dubbed as "piezoelectricity" in order to distinguish it from other areas of scientific phenomenological experience such as "contact electricity" (friction generated static electricity) and "pyroelectricity" (electricity generated from crystals by heating).

After that there has been a lot of improvisation by various dignitaries to get the best. Now, piezoelectric falls into the barium titanate family.

In fact during World War 1, most of the classic piezoelectric applications with which we are now familiar (microphones, accelerometers, ultrasonic transducers, bender element actuators, phonograph pick-ups, signal filters, etc.) were conceived and reduced to practice.

During the Second World War, countries like Japan, Soviet Union, USA isolated research groups working on improved capacitor materials discovered that certain ceramic materials exhibited dielectric constants up to 100 times higher than common cut crystals. Furthermore, the same class of materials (called ferroelectrics) was made to exhibit similar improvements in piezoelectric properties.

The advances in materials science that were made during this phase fall into three categories:

- Development of the barium titanate family of piezoceramics and later the lead zirconate titanate family.
- The development of an understanding of the correspondence of the perovskite crystal structure to electro-mechanical activity.
- The development for doping both of these families with metallic impurities in order to achieve desired properties such as dielectric constant, stiffness, piezoelectric coupling coefficients, ease of poling, etc.

The ideas of the improved materials were not published across the world because most of them were developed during war times and grew in “classified” atmosphere.

The fact is that by nature piezoceramics materials are extraordinarily difficult to develop, yet easy to replicate once the process is known.

Japanese contribution

In contrast to the "secrecy policy" practiced among U.S. piezoceramics manufacturers at the outset of the industry, several Japanese companies and universities formed a "competitively cooperative" association, established as the Barium Titanate Application Research Committee, in 1951.

With new piezoelectric ceramic materials available, Japanese manufacturers quickly developed several types of piezoceramics signal filters, which addressed needs arising in television, radio, and communications equipment markets; and piezoceramics igniters for natural gas/butane appliances.

IV. PRINCIPLE OF PIEZOELECTRICITY

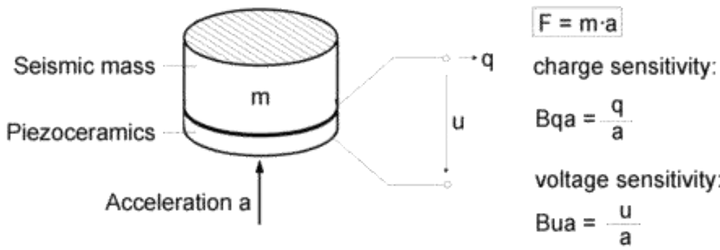
The active element of an accelerometer is a piezoelectric material. The figure illustrates the piezoelectric effect with the help of a compression disk. A compression disk looks like a capacitor with the piezoceramics material sandwiched between two electrodes.

A force applied perpendicular to the disk causes a charge production and a voltage at the electrodes.
The sensing element of a piezoelectric accelerometer consists of two major parts:-

- Piezoceramics material
- Seismic mass

One side of the piezoelectric material is connected to a rigid post at the sensor base. The so -called seismic mass is attached to the other side.

When the accelerometer is subjected to vibration, a force is generated which acts on the piezoelectric element. According to Newton's Law this force is equal to the product of the acceleration and the seismic mass.



By the piezoelectric effect, a charge output proportional to the applied force is generated. Since the seismic mass is constant the charge output signal is proportional to the acceleration of the mass.

Over a wide frequency range both sensor base and seismic mass have the same acceleration magnitude. Hence, the sensor measures the acceleration of the test object.

The piezoelectric element is connected to the sensor socket via a pair of electrodes. Some accelerometers feature an integrated electronic circuit which converts the high impedance charge output into a low impedance voltage signal.
Within the operating frequency range the sensitivity is independent of frequency.

A piezoelectric accelerometer can be regarded as a mechanical low-pass with resonance peak. The seismic mass and the piezoceramics material form a spring mass system. It shows the typical resonance behavior and defines the upper frequency limit of an accelerometer.

In order to achieve a wider operating frequency range the resonance frequency should be increased. This is usually done by reducing the seismic mass. However, the lower the seismic mass, the lower the sensitivity. Therefore, an accelerometer with high resonance frequency will be less sensitive whereas a seismic accelerometer with high sensitivity has a low resonance frequency.

A. Transverse effect:

A force is applied along a neutral axis and the charges are generated along the d11 direction. The amount of charge depends on the geometrical dimensions of the respective piezoelectric element. When dimensions a, b, c applies:

$$Cy = -d11 \times Fy \times b/a$$

Where a = dimension in line with the neutral axis and b is in line with the charge generating axis.

B. Longitudinal effect:

The amount of charges produced is strictly proportional to the applied force and is independent of size and shape of the piezoelectric element. Using several elements that are mechanically in series and electrically in parallel is the only way to increase the charge output. The resulting charge is:

$$Cx = d11 \times Fx \times n$$

Where d11 = piezoelectric coefficient [pC/N]
Fx = applied Force in x-direction [N]
n = number of elements
Shear effect:

Again, the charges produced are strictly proportional to the applied forces and are independent of the element's size and shape. For n elements mechanically in series and electrically in parallel the charge is:

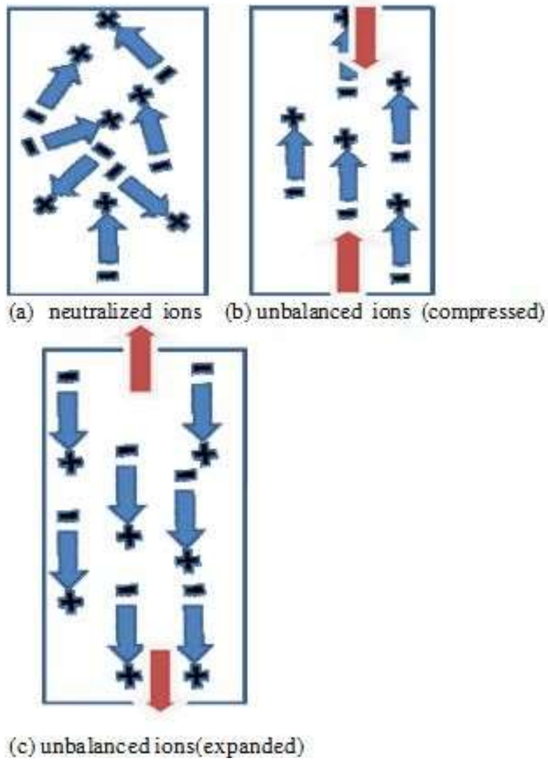
$$Cx = 2 \times d11 \times Fx \times n$$

Where d11 = piezoelectric coefficient [pC/N]
Fx = applied Force in x-direction [N]
n = number of elements

V. MECHANISM OF PIEZOELECTRICITY

In a piezoelectric crystal, the positive and negative electrical charges are separated, but symmetrically distributed.
So that the crystal overall is electrically neutral. Each of these sites forms an electric dipole and dipoles near each other tend to be aligned in regions called Weiss domains. The domains are usually randomly oriented, but can be aligned during poling (not

the same as magnetic poling), a process by which a strong electric field is applied across the material, usually at elevated temperatures.



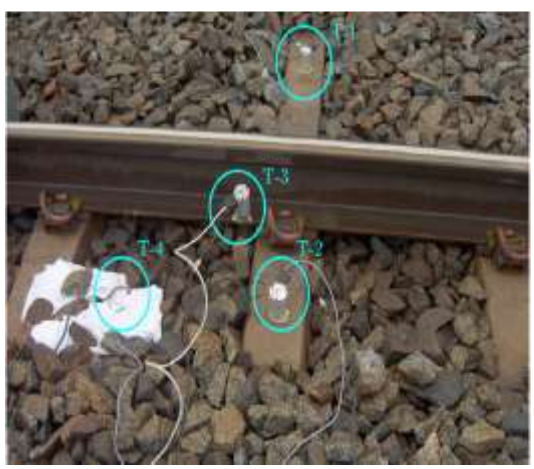
(a) neutralized ions (b) unbalanced ions (compressed)

(c) unbalanced ions(expanded)

When a mechanical stress is applied, this symmetry is disturbed, and the charge asymmetry generates a voltage across the material. For example, a 1 cm cube of quartz with 500 lbf (2 kN) of correctly applied force upon it can produce a voltage of 12,500 V.

Piezoelectric materials also show the opposite effect, called converse piezoelectricity, where the application of an electrical field creates mechanical deformation in the crystal.

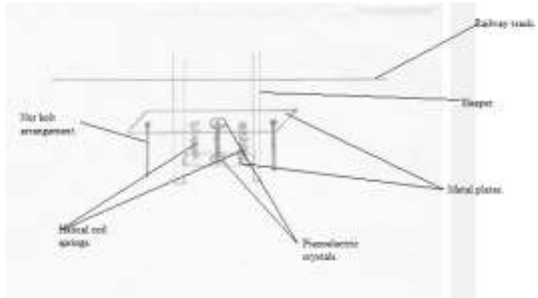
VI. VIBRATION ANALYSIS



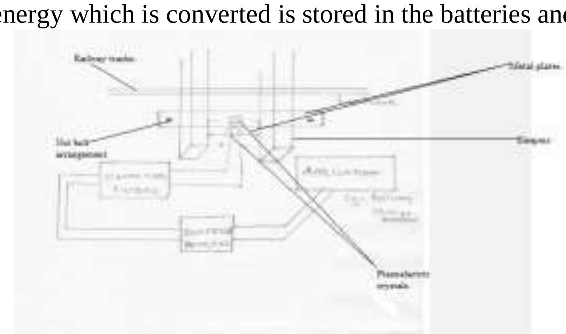
The analysis at point T1, T2, T3 and T4 reveals that the frequency at point T3 is constant. As of now for our concept we require only vibration analysis of point T1, T2 and T4. Point T3 is directly in contact with the tracks where the vibration is very high and we can’t convert this high vibration energy into equivalent electrical energy by usage of the piezoelectric crystals. By analyzing the vibrations of point T1, T2 and T4 we came to know that these vibrations can easily be converted into electrical energy. We are mostly concentrating on point T4 because we don’t want to disturb the sleepers anyhow. We are achieving the vibrations at point T4 by proper arrangements of metal plates as shown in the procedure. We are also implementing the helical coil springs in between two metal plates to increase the vibrations and thus generate good amount of energy.

VII. PROCEDURE

We are implementing these piezoelectric crystals on the metal plates which are attached to the sleepers beneath railway tracks as shown in the figure.



We are implementing on the metal plates because we don't want to disturb the sleepers by any chance. By using the metal plates the entire vibration on the sleepers will be transferred onto the plates, which would be then converted and used. So we are placing the piezoelectric crystals on these metal plates in such a way that the maximum vibration energy is converted into equivalent electrical energy. This energy which is converted is stored in the batteries and thus used for various purposes.



In a city like Mumbai, the frequency of railway trains is very high. It is known there is a running of train in every three minutes. So with the implementation of this concept a lot of energy can be created because trains frequency is very good.

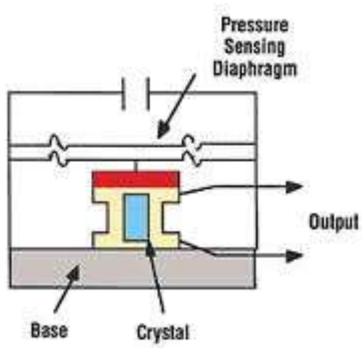
The energy generated will be used in the nearby railway stations. This energy will be thus useful for the working of all the electrical appliances used in the stations. Thus the concept will be able to provide energy at cheaper rate as of now.

The energy created can also be used for the nearby farms if it is required.

The best benefit of the usage of the energy nearby is the less transmission loss and less storage problems. The entire generation of energy can be directly used for various purposes without any much loss and the energy generated is pollution free.

A. Alternative Approach

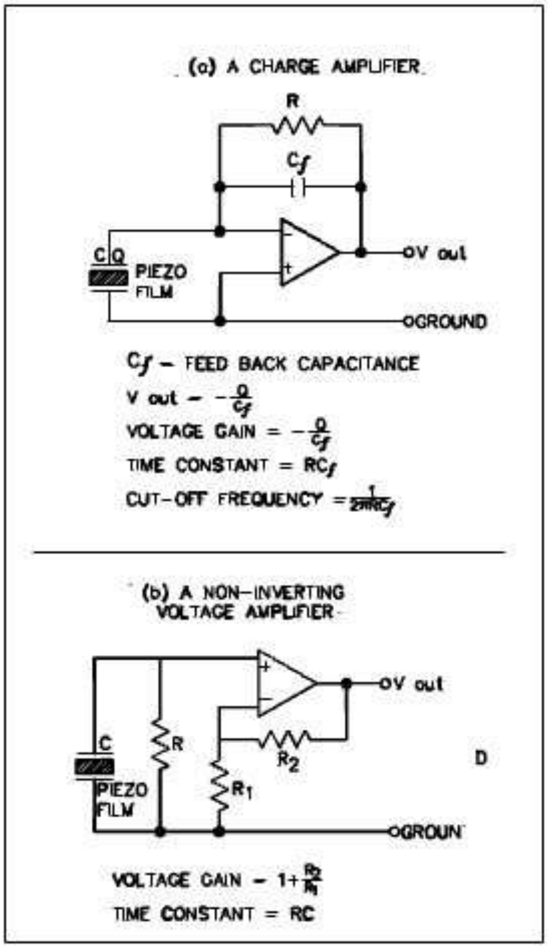
Alternatively we can also use a pressure sensing diaphragm with the crystal enclosed in a protective casing as the piezoelectric crystals are very delicate.



This arrangement can be enclosed between 2 metal strips

Storing Charge in the Batteries

The piezoelectric crystals will generate charge which cannot be stored in a battery for future use. For this purpose we can use a charge amplifier. This charge amplifier will give a voltage output which can be stored in batteries for future use.



The output voltage of the charge amplifier depends on the feedback capacitance, not the input capacitance. This indicates that the output voltage of a charge amplifier is independent of the cable capacitance. The major advantage of a charge amplifier can be realized when a long cable is used between a piezo film sensor and electronics. In addition, it also minimizes charge leakage through the stray capacitance around the sensor. Otherwise, simple voltage amplifiers are sufficient for most applications.

Operational amplifiers offer a great deal of versatility for such applications. Adaptation to a particular application is often as simple as making a few wiring changes. Important op amp circuit characteristics include input bias resistance, film switch capacitance, and EMI shielding.

VIII. CONCLUSION

	Starting Station of your journey	Last station of your journey	Total Trains Found	
	Mumbai CST	Panvel	84	H
	Panvel	Mumbai CST	82	H
	Mumbai_CST	Kasara	14	C
	Kasara	Mumbai_CST	16	C
	Khopoli	Mumbai_CST	6	C
	Mumbai_CST	Khopoli	7	C
	Thane	Vashi	50	H
	Vashi	Thane	51	H
	Thane	Nerul	52	H
	Nerul	Thane	52	H
	Thane	Belapur CBD	22	H
	Belapur CBD	Thane	22	H
	Thane	Panvel	19	H
	Panvel	Thane	20	H
	Mumbai_CST	Thane	293	C
	Thane	Mumbai_CST	310	C
	Mumbai_CST	Dombivili	223	C
	Dombivili	Mumbai_CST	238	C
	Virar	Churchgate	87	W
	Churchgate	Virar	84	W
	Legends --			
	H	Harbor Line		
	C	Central Line		
	W	Western Line		

Thus we can conclude that we can generate energy from vibrations on sleepers beneath the railway tracks with the proper usage of piezoelectric crystals. A lot of energy required by railway stations is now been generated by the sleepers itself. This energy thus can be used in nearby railway stations for working of various electrical appliances. The energy created is at cheaper rate and is pollutant free.

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