Piezoelectricity: An Energy Source for Future Railway Stations

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Abstract
In this period of expanding energy costs and diminishing supplies of non-renewable energy sources, it has become necessary to set up renewable energy based local power sources for shopping malls, different large institutions, factories, airports, railway stations rather than depending on national centralized power grid. This paperreviews some recent experimental research and then provides a proposal to supply electricity for railway stations using piezoelectric materials as a source of renewable energy. Consideration of three different aspects in this proposal ensures highest amount of piezoelectricity supply for the energy demand of a railway station. It will also help preparing every station as energy self-dependent in near future.

Keywords: *Piezoelectric materials, Renewable energy, Piezoelectricity, Energy harvesting.*

I. Introduction

As the request of petroleum product is colossally expanding, after some time, the eventual fate of generating energy utilizing non-sustainable power source will go to a stop. This overconsumption and dangers related is compelling the condition and economy also. This level of outcome in an exceptional measure of CO discharges and greenhouse gases being drawn into the air raising worries on rising ocean levels, expanding normal temperature, and adverse weathering conditions. It is claimed that energy from petroleum products is being devoured 100,000 times speedier than being framed. Additionally, fossil fuel assets, focusing on oil and gas, are relied upon to get drained in the end of 21 century (M. Phillipset *et al.*, 2013). As expressed in IISD Report of the G7 nations, a gathering of finance priests and national bank governors, consented to eliminate the utilization of oil, gas and coal toward the finish of 2100 (M. Harriset *et al.*, 2015). This type of understanding chasing for economical arrangements made by driving nations' offers a green light to incredible speculations openings around the world. Manageability is basically an easy route to a long haul profit income and a motivator towards tackling the "greenies" to grow and produce clean-vitality items (K. Hickson, 2013).Concentrating on the transition of energy, usage of Piezoelectricity, a sustainable power source reaping technique, will lead the following force era into a possible and more solid wellspring of energy.

Piezoelectric materials can be utilized as a method for changing encompassing vibrations into electrical vitality that would then be able to be put away also, used to various purposes. In this paper, we introduce a proposal to provide electricity, an important demand for all railway stations, by utilizing Piezoelectric technique. It discusses how to harvest electricity from different places related to a railway station. A good number of people not only in Europe or Asia but also worldwide prefer railway to travel all over the year. Consequently, the nearby roads, footpaths, platforms are always being crowded by the moving people. Moreover, many cars and buses pass the nearby roads and highway engaged in transporting rail passengers to or from the train stations. There is an opportunity to take advantage of these large amount of moving people and vehicles. Nearby Roads, footpaths, terminal floor will be covered with Piezoelectric materials to harvest electricity. Such materials can also be used in rail tracks near the stations. This paper reviews the corresponding previous research and experimental works. It also describes about piezo-electric effect with piezo-electric materials. Then information is provided to show the method of electricity generation from roads using piezo-electric materials. Moreover, we have also shown how to utilize

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piezo-electric effect in the walking floor or footpath and rail tracks for energy harvesting effectively.

II. Related work

Innowattech, an Israeli company, has directed trials to show this vitality at the Technion Institute of Technology in Haifa where a vehicle went over a street under which IPEG (Innowattech Piezoelectric Electric Generators) had been planted 6cm under the street level and at a separation of 30cm separated (T. Henderson, 2009). In UAE (United Arab Emirates), there is a test directed to create power from the Piezoelectric Roads. The analysis was effectively led and now the down to practical streets are enroute of development (P. G. Phataket *et al.*, 2016). In certain schools of United States of America, electricity is generated from Piezoelectric Tiles in the passage when students walk through them. Furthermore, East Japan Railway Company (JR East). It led an exhibit test from January 19 to March 7, 2008, at Yaesu North Gate, Tokyo Station, on power-producing floor. Introduced at the ticket door zone, it produces power from the vibrations made by travelers strolling through the ticket gates. The control creating floor is implanted with piezoelectric components, which are 35 millimeters in distance across, and circle formed parts utilized for amplifiers. It utilizes 600 of these components for every square meter. While the amplifier makes sound by changing over electric signs to vibrations, the floor receives the switch component that produces power by tackling the vibrational power created from travelers' means. It is being created by JR East with the point of making stations all the more ecologically agreeable and vitality effective (P. G. Phataket *et al.*, 2016, P. Dhingraet *et al.*, 2009). An exploration work researches the monetary, natural and social parts of introducing 1Km trail utilizing energy harvesting Pavegen piezoelectric floor tiles at the Railway Station of New Delhi (A. Singh *et al.*, 2016). The investigation uncovered that the establishment of the Piezoelectric tiles would prompted the colossal reserve funds and would add to natural mindfulness by advancing manageability and efficient power vitality era, and the measures of power collected over their 5 years life expectancy could recoup the expenses of beginning purchase, transport, establishment, upkeep and transfer of the tiles.

III. Piezoelectricity

A piezoelectric substance is one that delivers an electric charge when a mechanical stress is applied like when the substance is pressed or extended. Alternately, a mechanical deformation is created when an electric field is connected. This impact is framed in precious stones that have no focal point of symmetry.

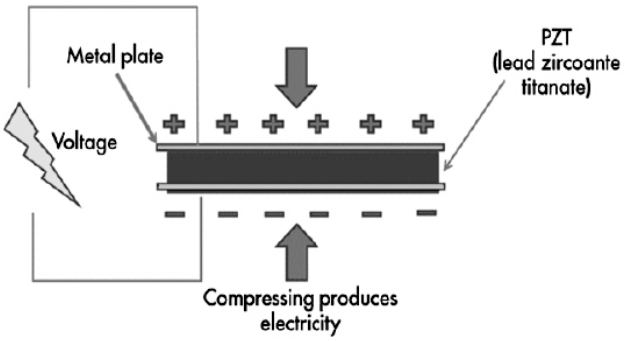

Figure 1: Piezoelectric effect through compression of a piezoelectric material. (C. Yang, 2016)

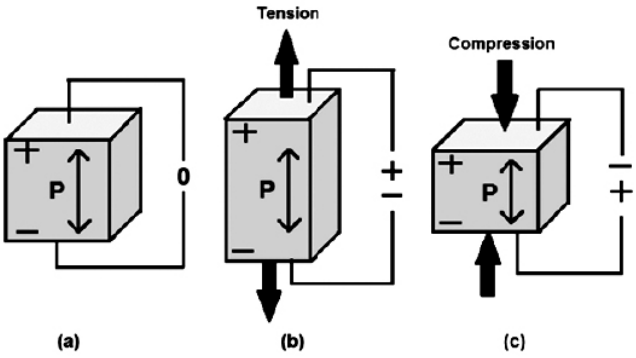

Figure 2: Schematic of piezoelectric effect;(a) piezoelectric material, (b) energy generation under tension, (c) energy generation under compression. (D. Vatansever *et al.*, 2012)

In 1880, Pierre and Jacques Curie, amid their test take a shot at crystallography, demonstrated that some crystalline materials, for example, Rochelle salt, create electric charges when subjected to mechanical burdens, known as the direct piezoelectric effect. The converse impact, i.e., that a connected electric field instigates a mechanical twisting, was numerically anticipated by Lippman in 1881, from fundamental thermodynamic standards and progressively checked tentatively by Curie siblings. Piezoelectricity is an aftereffect of the material properties at the minuscule level. Piezoelectric pottery are crystalline materials whose essential cell, underneath a given temperature (Curie temperature), has an awry dissemination of charge giving a lasting polarization. A plainly visible square of crystalline material is comprised of a gathering of grains and areas. Every area has a bearing common polarization.

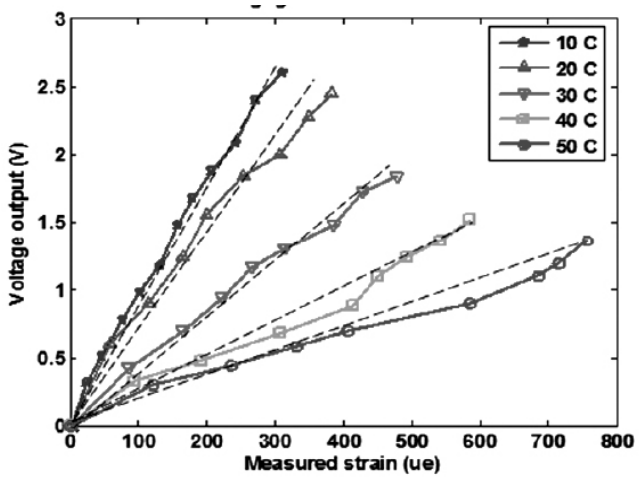

Figure 3: Correlation between measured strains and voltage output of Piezo material at varying temperatures. (U.S. Dept. of Transportation, 2013)

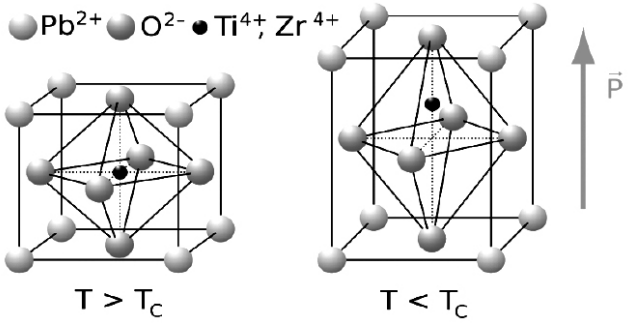

Figure 4: Crystal of Ceramic typePiezo material. (Pinin, 2010)

However, in typical conditions, the areas are haphazardly arranged and the general polarization of the piece is factually invalid. On the off chance that a solid electric field (2000V/m) is connected for an adequately prolonged stretch of time, the areas have a tendency to factually situate toward the electric field and a net polarization is actuated. The polarization remains when the polarizing field is evacuated. The acquired material piece is spell bound piezoelectric fired. The coupling amongst distortion and electric field is because of the geometric impacts identified with space reorientation caused by a connected electric field. The piezoelectric impact is a property that exists in numerous materials. There are a few Piezoelectric Materials, for example, Quartz, Topaz, Lithium Neobait, Rochelle Salt and so forth. The unpleasant interpretation is, in this way, weight - electric impact. In a piezoelectric material, the use of a pressure or stress brings about the development of a charge in the material is called piezoelectricity. (A. Singh *et al.*, 2016)

IV. Piezoelectric Roads and Highway

In almost every country, a huge number of people come to and go out from the train stations through the whole day or night. Therefore, all the roads near the stations remain always busy by various heavy and light weighted transport vehicles. Putting piezo electric materials in these roads, we can generate green electricity and supply it to the station. In United Arab Emirates, there was an analysis directed to produce power from the Piezoelectric Roads. The examination was effectively directed and now the commonsense streets are enroute of development. (P. G. Phatak *et al.*, 2016)

In a research project supported by the National Science Foundation of China, they proposed a roadway reaper that utilizes piezoelectric harvesting units for searching energy from movement-instigated vibrations(X. Jiang *et al.*, 2014). The proposed roadway vitality reaper is a pressure based framework, which produces vitality under pressure drive, and the created control is a heartbeat control enlisted with every pressure cycle. Fig. 6 demonstrates the side cross-sectional perspective of the proposed roadway reaper installed on the surface of the street, F_{left} and F_{right} are utilized to display the tire powers caused by one single pivot of an auto.

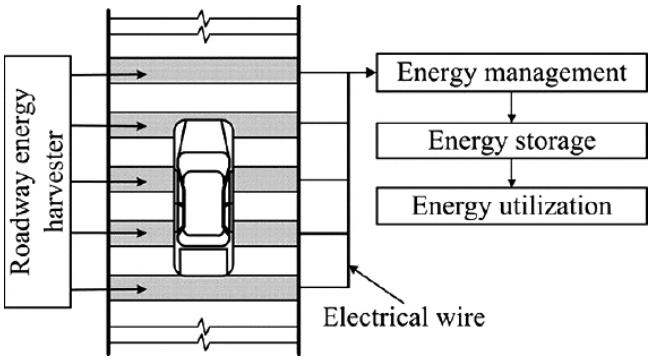

Figure 5: Electricity generation from road & highways. (X. Jiang *et al.*, 2014)

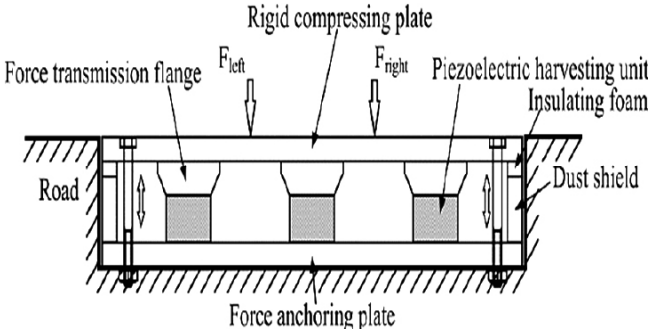

Figure 6: Cross section of proposed piezoelectric road(X. Jiang *et al.*, 2014)

As appeared in Fig. 6, the proposed roadway gatherer is a case molded and primarily involved three reaping units, three force transmission flanges, a rigid compressing plate, and a force anchoring plate. Inflexible compacting plate, consolidated with compel transmission rib and drive tying down plate, guarantees that the tire powers apply equitably on three reaping units. Two flexible settling individuals, for example, jolts are utilized to hold the structure together and connected a pre-pressure constrain to the reaping units. At the point when autos disregard, the weight and vibration caused by the moving vehicle make time variation drives on reaping units which produce electrical power. It ought to be noticed that the roadway collector is pre-compacted with the goal that power will in any case be produced amid the bouncing back of the pressure.

Another study informed about the amount of produced piezoelectricity by different international vendors using road technique (D. Hill *et al.*, 2014). Data are given below in Table 1.

Table 1: Statistical data of the study

Parameters	Genziko	ODO-T	Innowattech	Virginia Tech
Power per km (single lane)	13 MW - 51 MW	486 kW	100 kW - 200 kW	0.0018 kW - 0.5 kW
Vehicles per hour	600 - 2250	600	600	600
kW per km per vehicle per hour	21.6 - 22.6	0.81	0.16 - 0.3	0.000003 - 0.00083

There are several factors affecting piezoelectric road efficacy. For instance, vehicle's speed and weight, traffic flow capacity etc. (R. Kour *et al.*, 2016). Energy generation is greater with higher speed. Basically, the higher the constrain applied the more distortion of precious stones and in this way higher vitality delivered. The same guideline applies for vehicles; a truck will produce more vitality or energy than light obligation vehicles and bikes. After executing such innovation, this parameter would be first considered. The general innovation execution will unquestionably give less vitality if control pavements are outlined in ranges were less continuous vehicles traverse. It is proposed to apply control pavements on occupied streets where a sensible number of vehicle limit flow. Planning the area of energy black-top is an fundamental choice to address energy issues. (S. P. Tiles, 2016)

V. Piezoelectric Materials in Floor Tiles

Piezoelectric floors are intended to catch the squandered vitality and assets, and store or redistribute them where they are required. Energy is produced when a man ventures on tiles that component piezoelectric characteristics. The measure of vitality produced relies on the heaviness of the individual, most extreme redirection, and kind of development. This

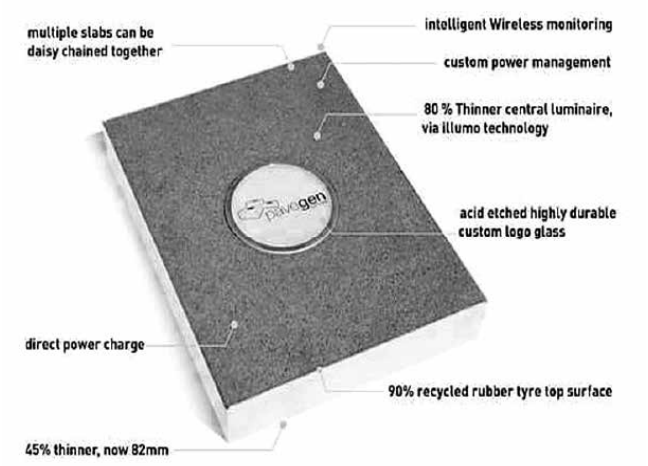

Figure 7: Piezoelectric floor tiles. (A. Singh *et al.*, 2016)

active vitality is changed over into power. We will put these tiles in station's platforms, near ticket counters, walkways, footpaths etc. The East Japan Railway Company directed a show explore from January 19 to March 7, 2008, at Yaesu North Gate, Tokyo Station, on another power-creating floor. It produces power from the vibrations made by travelers strolling through the ticket entryways. (P.Dhingra *et al.*, 2009).

Figure 8: Experimental use of piezoelectric floor tiles. (C. Scholer *et al.*, 2009)

The power-creating floor is installed with piezoelectric components, which are 35 millimeters in width, and circle molded parts utilized for amplifiers. It utilizes 600 of these components for every square meter. While theamplifier makes sound by changing over electric signs to vibrations, the floor receives the invert component that produces power by saddling the vibrational power created from travelers' means. It is being produced by JR East with the point of making stations all the more naturally cordial and vitality effective.

VI. Piezoelectric Rail Tracks

Each of the rail cars of a train has high weight. When the wheels of a rail car rotate over the track, the metallic rail track encounters strong stress and pressure. We will provide piezoelectric materials under rail tracks along 2-3 km rail line near a station so that we can harvest electricity. The railroad tracks on the stage of the rail route stations will be supplanted by the Piezoelectric material ceramics which will be associated with the Piezoelectric Railroad Generators. As the preparation will go through this stage, there will be a Pressure and a Compression at the same time on the earthenware production which will deliver Piezoelectric effect in them bringing about the era of power by the generators.

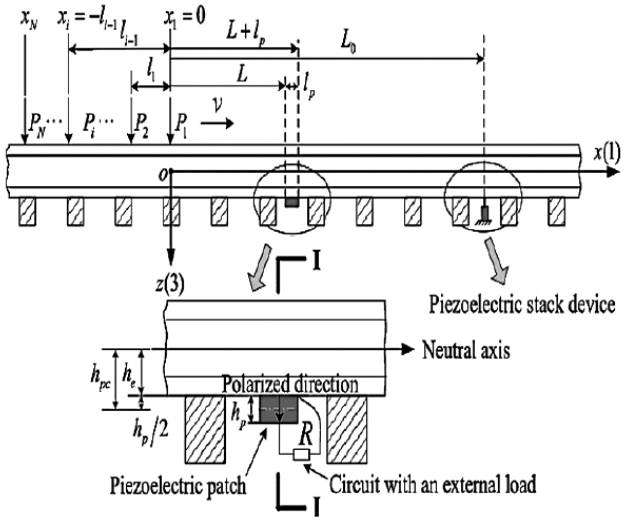

Figure 9: Schematic railway track with piezoelectric energy harvesters. (J. Wang *et al.*, 2015).

Such a related research work (J. Wang *et al.*, 2015) carried out in China gives a hypothetical guide in the plan of piezoelectric patch and stack energy harvesters utilized as a part of railroad frameworks.Figure 9 represents a schematic of railroad track structure with piezoelectric patch-type and stack-type vitality reapers. A piezoelectric patch-type energy harvester will be placed at the bottom of a rail. Furthermore, a piezoelectric stack-type energy harvester will be introduced at the base of the steel rail by an

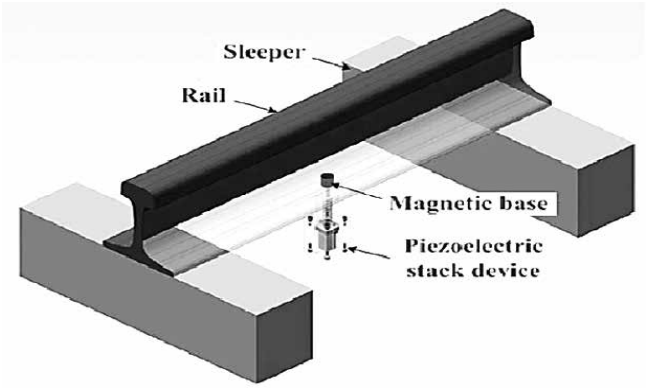

Figure 10: Schematic of piezoelectric stack. (J. Wang *et al.*, 2015).

associating gadget. The coupling association between the piezoelectric stack and rail will be done through a piezoelectric stack gadget and a magnetic base. The proposed piezoelectric stack device will have 8 parts: a displacement transmission rod, a compression spring, a force transmission unit, a piezoelectric stack, a whole metal shell, screw bolts and a wire hole. The compression spring will convert the transverse track displacement of the rail into a force, which will be then transmitted to the piezoelectric stack. However, these both type of harvesters will have separate energy harvesting mechanism.

VII. Integration and Supply

The following block diagram illustrates a general concept of integrating the produced piezoelectricity from different sources such as nearby roads of a train station, footpaths, platforms, walkway, rail tracks.

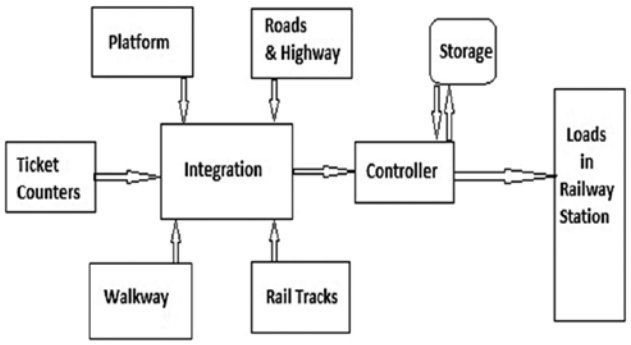

Figure 11: Schematic diagram of piezoelectricity integration and supply.

There is a controller for power management and a storage like batteries for energy reservation purposes. Generated electricity can be supplied to different electrical loads present in the railway station.

VII. Conclusion

In this paper, a proposal of energy harvesting utilizing piezoelectric materials for railway stations has been exhibited. It is another way to deal with lead the world into executing greener advances that are gone for ensuring the earth against environmental pollution. While this paper demonstrates a good potentiality of energy harvesting from piezo-electricity in railway station, many opportunities for extending the scope of this research remain. The possible produced electricity will not be sufficient to make a station completely self-energy dependent. There is a future scope to work on the efficiency improvement of our described methodologies. Apart from that, incorporation of other types of clean energy such as solar and wind energy with piezoelectricity might be a new direction of this present work.

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