A REVIEW ON RECOVERING THE ENERGY DISSIPATED DUE TO PARASITIC LOSSES DURING THE VEHICLE OPERATION USING PIEZOELECTRIC TECHNOLOGY

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Abstract - *As technology is changing every day, the use of electronic components and devices are increasing. In such a condition electricity is the driving factor for the advancement of technology. In this sense, almost every system to come under advanced technology requires devices that operate on electricity. Further, as the evolution of transportation mode is at a rapid pace, automobile industries are experimenting with different systems and configurations to make transportation comfortable and safer (for both passengers and surroundings). Safety and ride comfort are related to different parameters like road conditions, vehicle capabilities, etc. To safeguard the environment, an efficient combustion engine needs to be developed or the need to look for alternative clean fuel is growing. To improve vehicle capabilities, sensors should be embedded in the vehicle. In this paper, the harvesting of piezoelectric electricity is studied as a step further to alternative clean fuel. The piezoelectric material is used to convert mechanical energy into electrical energy. Therefore, it is used commonly by automotive industries. This report focuses on exploring a new arena where the piezoelectric effect can be applied as traditional resources of energy are the inverse of depletion, this form of the source can help to control the demand for energy in the future.*

Key Words: **Piezoelectric Energy Harvesting, Regenerative Tires, Piezoelectric Material, Surface modified potassium sodium niobite, Piezoelectric Technology**

1. INTRODUCTION

As the world is moving towards environmentally friendly methods to generate electricity and the mode of transportation which is based on internal combustion is not efficient and environment friendly. Many types of research are happening on alternative modes of transportation which is more environmentally friendly and based on renewable resources. Many automobile companies are focusing on the development of better electric vehicles and better battery technology to achieve a higher range and reduce charging time. Researchers are also focusing on harvesting energy which gets lost and reduces the efficiency of the vehicle.

Internal combustion engine vehicles are less efficient as it loses its energy in heat and friction. The concept of waste energy harvesting is not a new topic but only a few devices are seen in the application for example using the heat of an engine to heat the cabin of a car in winter and a turbocharger to compress the intake air by using exhaust gases. IC engine vehicles are not environmentally friendly as it uses fossil fuel which is non- renewable and creates pollution after combustion. So, the more efficient and environmentally friendly alternative is electric vehicles. One of the main challenges of electric vehicles is that the range of electric vehicles is lower than IC engine vehicles due to the lower energy density of batteries than diesel and petrol. At present, electric vehicles use only regenerative braking to increase the range of electric vehicles. But we can harvest energy from other parts of the vehicles like the vibration of suspension and deformation of the tire. Such technology is not widely applied in production cars due to the reasons like the higher cost of a harvester, low energy generation, and other limitations of the harvester. So, researches are happening on piezoelectric harvester used in tire. Piezoelectricity is the electric charge that accumulated in certain solids such as quartz crystal in response to applied mechanical stress. Some commonly used piezoelectric material is lead zirconate titanate (PZT), polyvinylidene difluoride (PVDF), barium titanate ($BaTiO_3$), etc. Sensors use piezoelectric materials to measure vibration and in devices like microphones to produce and detect sound. We can use a piezoelectric material-based harvester to generate electricity from the tire and other vibrating parts like suspension. We can use the piezoelectric harvester in IC engine vehicles as well to increase the fuel economy. We can operate small devices and sensors by using generated piezoelectricity.

Piezoelectric tires generate electricity due to the load of the vehicle, so it is advantageous to heavy load carrying vehicles and off-road vehicles. Due to the weight of the vehicle, the sidewall of the tire bulges out and the section height decreases such deformation can be utilized to apply force on piezoelectric material which generates electricity. The concept of energy harvesting is not limited to tires but we can use it in suspension as it vibrates in bumps of the road. Harvesting energy from running vehicles on the road is also possible by using a piezoelectric harvester.

This paper gives a compressive review of previously published papers related to piezoelectric energy harvesting.

This paper gives a summary of various papers related to method, efficient device, materials and alternatives for harvesting energy from a vehicle.

2. MATERIAL

2.1 Piezoelectric Materials

Satyaranjan Bairagi *et al* (2020) [1], PZT (Lead Zirconate Titanate) is one of the best piezoelectric material for the generation of more energy but it has more than 60% toxic lead so, several research articles have been published on lead-free nanocomposite-based materials but the piezoelectric properties obtained are not up to the mark. Surface modified potassium sodium niobite (SM-KNN) incorporated PVDF electrospun fibrous web based nanogenerator has been developed to improve the efficiency then the highest voltage obtained is 21-volt, current of 22-microampere, the density of 5.5 microamperes per centimeter square, and the power density is near to 115.55 microwatts per centimeter square which is remarkably high.

Piezoelectric energy harvesting is an emerging technology to harvest clean energy without harming the environment. The commonly used piezoelectric energy harvesting materials are led zirconate titanate (PZT), polyvinylidene difluoride (PVDF), barium titanate (BaTiO3), etc. According to the previous paper and article, PVDF has been tested as a promising piezoelectric polymer because of its properties like flexible structure and higher piezoelectric coefficient. PVDF polymer material has different crystal phases such as alpha, beta, gamma, and Etta. Beta crystalline phase is considered more responsible for piezoelectric property and Alpha crystalline phase is more thermodynamically stable state. Alpha phase needs to be transformed into the beta phase to get piezoelectric properties in PVDF polymer for which the electrospinning technique has become a highly recommended method among others because the nanofibrous web gets ejected from need tip under a high electrical field. Dhakras et al. has fabricated a piezoelectric mat using PVDF polymer and nickel hexahydrate salt-based electrospun web in which they have reported that the Beta fraction value has been increased by 30% in comparison to pure PVDF sample. Due to the improved mechanical stretching influenced by the nickel hexahydrate salt in the electrospinning process, the output voltage has also been improved in the case of nanocomposite based piezoelectric generator. A unique piezoelectric nanogenerator has been developed by using SM-KNN nanorods loaded PVDF matrix based electrospun nanocomposite web where the combined effect of SM-KNN filler and in-situ poling in electrospinning operation has been disclosed which increases the overall performance of piezoelectric material.

Table -1: Summary of power generated from piezoelectric [1]

Type of sample	Output voltage (v)	Output current (mA)
P-PVDF	500 mV ± 0.06	1 ± 0.05
PVDF/1% SM-KNN	18 ± 0.19	1.81 ± 0.10
PVDF/3% SM-KNN	21 ± 0.18	22 ± 0.07
PVDF/5% SM-KNN	2.5 ± 0.20	3.87 ± 0.03

As we can observe from the above table, the surface-modified KNN material can harvest more energy than PVDF piezoelectric material. The table shows that small modification of the surface of PVDF with 3% surface modification KNN material can harvest the electricity with high voltage output of 21V and output current of 22mA but on further increasing the percentage of SM-KNN to 5% will result in decrease of output voltage and current

2.2 Power generation from the material

Aditya Pandey *et al* (2020) [2], their study says that at 350 degrees Celsius, the piezoelectric material will change the physical structure. In this, they have taken a reading on 80km/hr speed and they have generated 9.30W and 15.914V from the piezoelectric plate and dimension of the PZT model used has length 150mm, width 30mm, number of plates is 63, and thickness of PZT plates is 2mm. After all the mathematical calculations the resultant power output from the vehicle is 89.86Wh and the plates were placed in parallel to get more current and Fuller Wave Rectifier has been used to convert obtained AC current to DC.

2.3 The behavior of the piezoelectric material under the variation of temperature and pressure

The article by Vaishali Upadhye *et al* (2016) [3], according to the study, the behavior of the piezoelectric material changes when the pressure and the temperature varies and also the production of the electricity and also energy harvesting capacity of the piezoelectric material changes under the variation of temperature and pressure. As we know that the electric material depends on resonate frequency so, when the frequency increases then the amount of harvesting of the electricity increases. When the temperature increases then the resonant frequency of the piezoelectric element decreases and vice-versa. The relationship between temperature and the resonant frequency is linear and inversely proportional according to the graph given below

The relationship between the resonant frequency and the pressure is directly proportional and linear. Increase in pressure increases resonant frequency and vice-versa.

Table 2:effect of temperature on resonant frequency

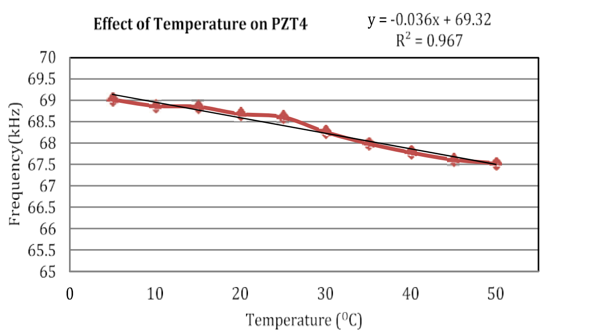

Fig -1: Effect of temperature on resonant frequency of PZT

According to the work of Hailu Yang *et al* (2017) [4], the piezoelectric ceramic type used is PZT-5H. A circular piezoelectric ceramic piece has been used having a 20 mm diameter and 7.5 mm in thickness which has three pieces of piezoelectric ceramic. Three pieces of piezoelectric slices are connected in parallel and adjacent two surfaces have the same polarity.

A universal servo-hydraulic test device (Cooper HYD25-II) is used to apply a sinusoidal load.

Tests conducted are:

-Constant loading frequency and different loading magnitudes
-Constant loading magnitude and different loading frequencies
- Effect of temperature on piezoelectric energy generation

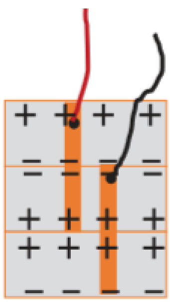

Fig -2: The structure of piezoelectric unit [4]

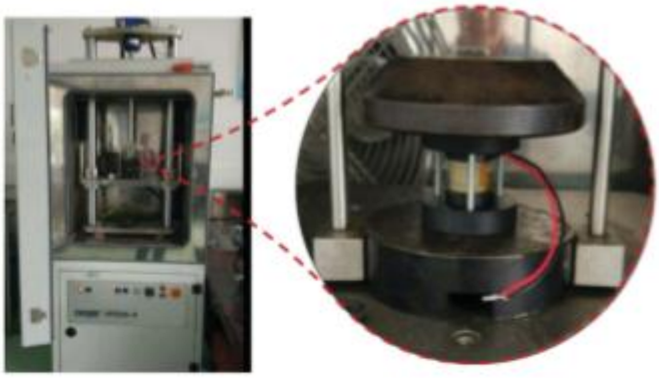

Fig -3: Loading test of the piezoelectric unit [4]

The power generated by the piezoelectric harvester is affected by different parameters like temperature, loading frequency, and loading magnitude. The amount of charge generated by the piezoelectric harvester is linearly correlated with open-circuit voltage. The electric energy generated increases with an increase in loading frequency and the relation is a cubic polynomial. Energy output efficiency increases with an increase in temperature and voltage increases with an increase in loading magnitude.

3. METHOD

For utilizing the loss of power from the vehicle, using a piezoelectric energy generating system in the tire and a vehicle's suspension system is commonly observed. Apart from this, piezoelectric material has been observed to be configured as a replacement for different sub-components on a few occasions. Generally, for the generation of electricity from the tire, a piezoelectric material is chained or attached in a different configuration in the tires. When the vehicle moves, force is applied to the piezoelectric material, and electricity is generated. This generated electricity is stored in batteries or capacitors. The piezoelectric material can be installed in the tires in different ways.

3.1 Piezoelectric materials are used in automobile

Hrishikesh Kulkarni *et al* (2018) [5], The piezoelectric material is used to convert mechanical energy into electrical so it is used commonly by automotive industries so this report focuses on exploring new parts where the piezoelectric effect can be applied as traditional resources of energy are inverse of depletion, this form of the source can help to control the demand of energy in future. The change in direction of polarization of electric dipoles due to mechanical stresses is the reason for the production of voltage. Common materials used for the piezo effect are lead zirconate titanate (PZT) as it is economical than others.

The basic application is for power generation in vehicles as energy is wasted while the tires rotate on the ground and this wasted energy can be utilized to run small electronics parts that need less energy for functioning but as much as tire inner surface should be covered by PZT material for better output. Another application is tire pressure sensor (TPS) as recent technology is unreliable and bulky which may affect balancing, furthermore, it will be easy for repairmen. Can also be used as a knock sensor placed on the engine head to sense vibration by engine knock.

Piezo fuel injectors are another application whose main integral part is a crystal that expands when electrical energy is applied on it due to mechanical stress and acts as a normal fuel injector and acts 4-5 times faster than normal injector with precision.

It can be concluded that although the voltage produce is low it can be efficiently used in various automotive systems to enhance the operation as they are compact and precise but sometimes cost may be high Piezo fuel injectors are another application whose main integral part is a crystal which expands when electrical energy is applied on it due to mechanical stress and acts as normal fuel injector with the pace of 4-5 times faster than normal injector with precision. It can be concluded that although the voltage produce is low it can be efficiently used in various automotive systems to enhance the operation as they are compact and precise but sometimes cost may be high.

3.2 Power generation from the tire

Kurian V Kurian *et al* (2018) [6], The hybrid engine is taken for an experiment where the electric motor is to be charged by electric energy obtained from the piezoelectric effect from the tires and piezoelectric patches are used in the rim of wheels to extract energy and further stored in the battery. A prototype of the vehicle(cycle) with main parts as a frame made of mild steel, DC motor, carbon brush, chain drive to convert rotational effect into pulling effect, pedal, piezoelectric patches, and the battery is made for experimental model. A carbon brush conducts the electricity between the stationary wires and the rotating rotor part of the electrical motor. For this project, a carbon brush is used to keep piezoelectric patches in contact during the rotation of the wheel. The piezoelectric patches in the rim of wheels are connected with carbon brushes and a special roller is attached at one corner of wheels so when the cycle starts then the pressure is applied on patches of rim via tire when the roller gets tightens. This results in the generation of electricity which can be stored in a battery.

Muhammad Kamran *et al* (2017) [7] The paper has proposed the use of piezoelectric material and energy harvesting from the electrical vehicle tire. According to the illustrated mechanism, the vehicle tires are loaded layers of the Piezoelectric along the periphery of the tire. The result found that the piezoelectric material is kept in the periphery can produce electricity and store it in the battery. A study says that material is several times better than quartz and ceramics. PVDF material is better because of its low thermal conductivity, high corrosion resistance, good mechanical strength, and high abrasion resistance. The rising requirement of the energy harvesting field in the most efficient way is to use smart, intelligent, and adaptive materials. Such as piezoelectric material. Piezoelectric material harvests the electric charge when mechanical stress and strain is applied on its surface.

There are 3 main types of classification of tires as Diagonal(bias) tire, belted bias tire, and Radial tire. Radial tires are regular users in the automotive industry that's why this paper is taken as the radial tire for mathematical calculation. The PVDF material is kept along the circular ring to the periphery of the tire and it is considered to be more efficient than having the PVDF material to be kept inside the surface of the tire. When the tire move and the stress will be applied to the tire according to the contact patch and direct load is acting on the piezo material through the tire when it moves in the road and thus will make sure that it can harvest electricity. Electricity is harvested in piezoelectric materials due to mechanical stress and strain applied in that part of piezoelectric material that is in contact with the tire to the road surface. Piezoelectricity is a direct result of the piezoelectric effect. The electricity is harvest is to fed to the car battery. When the car will move at a very high speed more than 60km/hr. Most of the parts of the tire of the PVDF will be coming in contact with the road surface and thus will ensure constant harvesting of electricity.

John David Adamson *et al* (2004) [8] has patented the concept of generative tires using a reinforced piezoelectric material. Piezoelectric material covered inside the matrix of epoxy was mounted on the interior crown surface of the tire unidirectionally. This reinforcement of resin is provided to piezoelectric fibers to control the uneven strain which can damage the fiber and efficiency in the generation of electricity can be reduced. Hence, the force can be uniformly distributed throughout the piezoelectric material. It has defined piezoelectric material covered inside the matrix of epoxy as a Power generation device (PGD). The generated electric power from PGD is sent to the Power conditioning module (PCM), which is an electrically coupled selected electrode layer, to rectify the resultant current and further to the electrolytic capacitor for storage.

Van den Ende *et al* (2011) [9], had presented a piezoelectric patch with a PZT polymer composite assembled in the composition made up of a urethane along with powder of PZT-5A on a support layer of polyethylene terephthalate film and has an electrode of gold installed inside the tire.

The energy is dissipated by the wheels to the atmosphere can be stored by transforming into electrical energy by the piezoelectric effect which will help in the innovation of automobile vehicles [2]. This results in control of the depletion of resources as mechanical stresses in tires are converted into electrical energy to meet growing energy demands. The study of Tata Nexon EV tire (215/60 R16 size) is done and PZT-5A piezoelectric material is used based on properties like high curie temperature, high compressive, and tensile strength [2].

PZT is suitable for high-temperature conditions but they are brittle and may fail to take the continuous load so packaging is compulsory. Some important properties of packaging materials while selecting are young's modulus, poison's ratio, density, tensile yield strength, thermal expansion, etc. This project tire has different layers as inner layer, ply, bead and apex, breaker, and thread which are properly managed in the manufacturing process [2].

In another work by Singh KB *et al* (2012) [10], a high-density PZT-ZNN layer on a bimorph cantilever with two mechanical stoppers was presented which would generate energy by radial vibration if tire. Mechanical stoppers are provided to confirm limited strain in the piezoelectric layer.
Further,

Xiangdong Xie *et al* (2015) [11], presented a concept in which a patch of piezoelectric material (PZT 4) is sandwiched between two steel plates and fixed in the inner surface of the tire. The steel plate is used for uniform strain.

Gustavo Antonio Navarro *et al* (2017) [12] had a patented concept of piezoelectric power generating tire apparatus which has embedded piezoelectric fiber in the form of cable in the outer circumference of rubber tube inside the tire. The generated energy is transmitted by induction through a wireless inductive coupler and wireless transmitter installed in the rim and energy is further stored in the capacitor.
Not only in the crown of the tire, but piezoelectric material can also be used in carcass too. But it won't be much efficient in power generation as PZT fibers won't be subjected to strain properly. When it is installed on the crown below threads, due to radial compression of tire strain will be enforced to the piezoelectric fiber. Additionally, using some reinforcement to the geomaterial from top and bottom, uniform force or strain will be induced even if the vehicle is running on a rough surface as the material used for reinforcement possess stiffness.

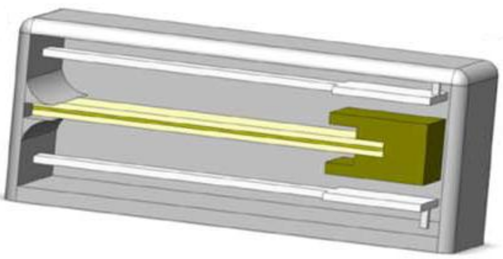

Fig -4: Piezoelectric layer in cantilever [10]

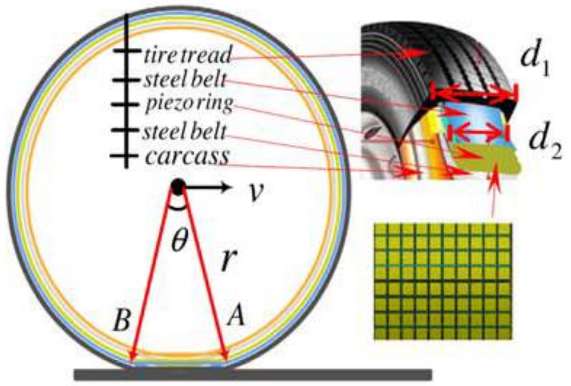

Fig -5: Piezoelectric tire model with piezo ring sandwiched between two steel belts [11]

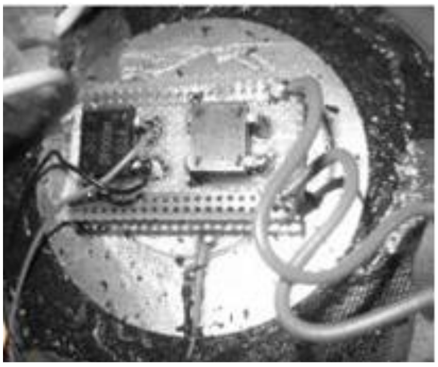

Fig -6: Piezoelectric tire installed with PZT (Lead Zicronate Titanate) [17]

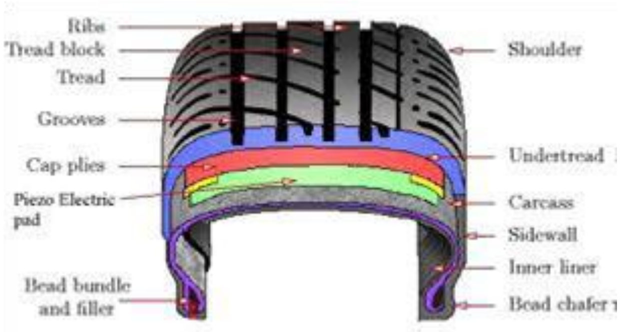

Fig -7: Piezoelectric tire installed with PZT pad [17]

The paper discusses the use of Lead Zirconate Titanate (PZT) and Polyvinylidene Fluoride (PVDF) in three different ways to harvest energy and their advantages and disadvantages [6]. Energy can be harvested from tires to run the tire sensors like Tire Pressure Monitoring System (TPMS) Sensor, Vehicle Speed Sensor (VSS), and Strain Monitoring Sensor. Under the load of the vehicle, the section height of the tire decreases, and the sidewall bulges out which deformation can be utilized to harvest energy [6].
Three methods are:
-PZT bender bonded to the tire.
-PVDF bent bonded to the tire.
-PVDF ribbon attached to the tire bead.

In the first two methods, the harvesting elements are bonded to the inner liner of the tire opposite to treads. In the third method, PVDF is attached to the ribbon and the ribbon is bonded to the rigid bead section. In this method, energy is harvested by the deformation of the ribbon which is caused by the deformation. The paper considers the third method as an ideal method because of damage prevention, minimized effect on the deformation of tire, damage-free removal of the ribbon, the possibility of the mounting sensor on the rim. [6]

Table -2: comparison of energy harvesting method in per unit area [6]

Method	Element	Dimension	Area ()	Power (mW)	Power/area (mW/)
1	PZT	25mm disc	491	4.6	9.37
2	PVDF	40mm	1600	0.85	5.31
3	PVDF	1540mm (3 pieces)	1800	0.23	1.27

Table -3: comparison between PZT and PVDF on the same basic application [6]

Criteria	PZT	PVDF
Deformability	Low	Very high
Piezoelectric charge constant (d33)	High (100)	Low (33)
Cost	$2 per element (25mm diameter, area= 491)	$330 per 216280 mm sheet ($271 per 491)
Temperature range (c)	High (up to 130)	Low (up to 80)

PZT elements bonded to the tire have a higher power output per unit area and cost is also lower but it has lower flexibility.

3.3 Energy harvesting from suspension by using piezoelectric material

Wiwiek Hendrowati *et al* (2012) [13], The major loss of energy from the suspension system is considered and tried to control the energy waste by using Multilayer Piezoelectric Vibration Energy Harvesting (ML PZT VEH) Mechanism in suspension and the piezoelectric material (PZT) used is multilayered and specially designed so the electricity generated will be amplified. This mechanism is kept in series to the spring of suspension which results in no alteration of performance of the suspension.

This mechanism will reduce the amplitude of vibration and creates a greater force for producing electricity but if the force is too large then the elastic rubber band placed at the outer part of the mechanism will control it. Dynamic analysis of the vehicle is carried out mathematically with and without using the mechanism and simulated and responses are different in both cases.

While mounting the ML PZT VEH mechanism the voltage produced is 2.75 times larger and the power produced is 7.17 times larger while compared to direct mounting and it is also verified this mechanism does not affect the performance of the suspension.

Zhen Zhao *et al* (2019) [14], The paper describes the new type of piezoelectric harvester which increases the efficiency of power generation. A passenger car can generate 100 to 400 W of electricity when driven at 97 km/hr on a good road surface. An off-road vehicle traveling at 80 km/hr on a rough surface can generate 2048 W due to a high level of vibration intensity. The electromagnetic energy harvester is widely used due to its higher energy conversion efficiency, compact structure, fast response velocity, and strong controllability. There are two types of the electromagnetic harvester, they are linear and rotatory harvester. The new device can generate three times as much energy as an electromagnetic harvester. The dual-mass piezoelectric harvester was designed to collect effective energy with a maximum power of 42.08 W and can reach 738 W which depends on road condition. Piezoelectric harvester generally suffers problems like vibration energy dissipation and reduced harvesting efficiency.

The device has motion conversion and energy conversion components. The motion conversion component converts linear motion to rotatory motion. Piezoelectric harvester generally suffers problems like vibration energy dissipation and reduced harvesting efficiency. The device has motion conversion and energy conversion components.

The motion conversion component converts linear motion to rotatory motion. The energy conversion component converts the rotatory motion into the excitation of the magnet which applies force on the piezoelectric patch to generate electricity.

The device increases harvesting efficiency due to the high frequency of the magnetic excitation force applied and low friction between the stator and rotor ring.

Numerical calculation is done in the paper by changing various parameters which give the result that generated electric power increases with an increase in the length and thickness of the piezoelectric patch and the magnetic slab, the driving speed of the vehicle, and the road roughness. The power generated increases with a decrease in space between the stator ring and the rotor ring, the width of the piezoelectric patch, and the magnetic slab. The practical configuration of the device can provide power up to 332.4 W.

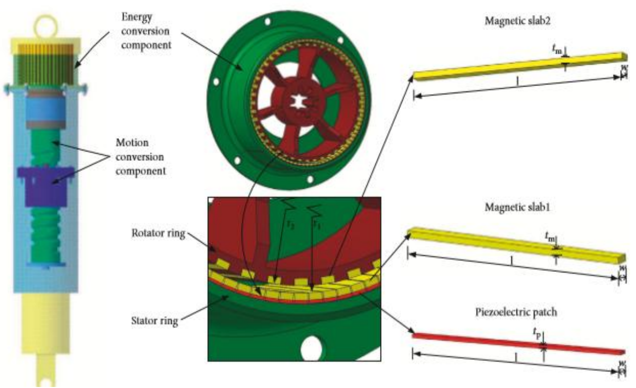

Fig -8: Schematic diagram and geometries of the piezoelectric energy harvester [14]

Zhen Zhao *et al* (2019) [15], Energy dissipation of the vehicles due to road bumps can be harvested and can be used to power electrical parts, and for that dual-mass suspension system equipment can be used with piezoelectric materials are to be used to harvest the electricity from the vibration of suspension. The researcher's study on suspension system energy harvesting shows that a simple car at 90km/hr can generate 40-100 W of energy and can increase up to 3% for off-road vehicles and energy harvested can reach up to 2040W.

Structural design and modeling are done of the system under different road conditions where the piezoelectric material used are PZT and its electrical capacity can be calculated by equation, $C = Cv \times 3.142(R2 - r2) \times 0.01 / (3.142(0.0132 - 0.0062) \times h)$ and model is verified with actual data and simulated data.

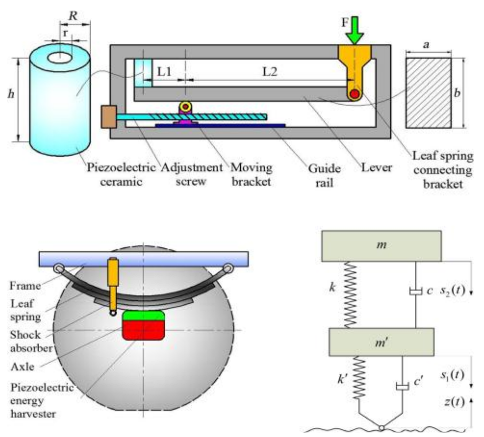

Fig -9: Dual mass suspension system [15]

4. RESULT

Based on the practical and theoretical analysis from referred papers, outcomes are mentioned below.

According to the work of Khamenei far and Azimpour *et al* (2008) [16], 42 mW power was analytically generated from 14 piezoelectric resonators (3 mW each) with dimension 9.20 * 4.38 * 0.99 cm^3 which was conducted on the average passenger car.

Further, from the work of Van den Ende *et al* (2011) [9], a piezoelectric patch with a PZT polymer composite at the speed of 50 km/hr produced power of 30 $\mu W/cm^2$.

In another work of Singh KB *et al* (2012) [10], which used a high-density PZT-ZNN layer on bimorph cantilever with two mechanical stoppers generated 31 μW of power acquired at 80 Hz and 0.4 g RMS base excitation.

According to the work of Aashish Chhabra (2015) [17], 4.6 mW power can be generated using a 25mm disc within the area of around 485 mm^2 with a rough speed of 9 km/hr using lead zirconated titanate (PZT).

A dual mass model of the harvester in tire presented by Xie and Wang (2015) [11] with improvised configuration could produce 42.08 W of power at a speed of 144 km/hr.

Deepam Mauryaa *et al* (2018) [18] has analyzed P245/65R17 105S tire with the piezoelectric patch (PVDF based Kureha piezo film) of 80 mm subjected to load of 3000N with approximated radial and tangential stiffness of 1562 KN/m^2 and 2212 KN/m^2 respectively running at speed of 112 KM/hr. From this analysis, a power of 580 μW was generated which is enough to power 78 LEDs at a time.

Table -4: Summary of power generated from piezoelectric tire

Author	Configuration	Material	Dimension	Vehicle speed/ Excitation	Output power
Khamenei far and Arzanpour	Bimorph	Mide Technology harvester	14 piezoelectric resonator of 92 * 43.8 * 9.9 mm^3	50 km/hr	42 mW
Van den Ende *et al*	Patch	PZT-5A fibers	40 * 16.5 * 0.175 mm^3	50 km/hr	30 $\mu W/cm^2$

Singh KB *et al*	Bimorph	PZT-ZNN	25 * 5 * 0.4 mm^3	0.4 g RMS at 80 Hz	31 µW
Aashish Chhabra	Patch	PZT	25 mm disc within 285 mm^2	9 km/hr	4.6 mW
Xie and Wang	PZT ring	PZT-4	3 rings with dia 0.5 m and width 0.01 m	144 km/hr	42.08 W
Deepam Mauryaa *et al*	Patch	PVDF based Kureha piezo film	80 mm film	112 km/hr	580 µW

Aditya Pandey (2020) [2], The obtained result shows that with the application of the piezoelectric effect this vehicle runs an extra 1km for every 80km of running which means it will help to increase the range rather than supplying energy completely. For better results, better sensors can be used and this effect can be used on other vehicle parts like suspension, damper, etc., to harness more energy. The mechanism is capable to generate after running for the 1hr in 80 km/hrs. Speed then they generate 89.8627Wh. According to the data the present technology is not sufficient for the required energy harvesting. Their study says that mechanisms are not enough to generate the electricity the amount is required. In the future, the mechanism will revolutionize and one day they can harvest sufficient energy so that can charge the battery.

Muhammad Kamran1et(2020)[7] The work of this paper is to define a method of harvesting electricity using PVDF material and the mathematical calculation proves that the electrical vehicle can run more than 37 miles after the onetime charge of the battery and 37 miles it can run with help of piezoelectric material are introduced in are placed inside the tire and that can charge the battery and increase the efficiency of the electric vehicle. Also, the cost of PVDF and its application is not so costly, so that it can save about $500 is expected over the life of the tire. Overall, the introduced and method of energy harvesting is considered as a good way than other because this paper says that they can harvest up to 28% efficiency than other the research paper that can be introduced in the electric vehicle.

Table -5: The production and consumption which traveling is 100 km and efficiency [7]

S. N o:	Km /h	Energy consum ed (KVH)	Energy Produc ed (KVH)	Efficien cy (η)
1.	50	21.25	6.07	28%
2.	60	21.25	6.07	28%
3.	70	21.25	6.07	28%
4.	80	21.25	6.07	28%

As we can observe from the table that the speed does not affect the efficiency after 50km/h and the consumption we can see is 21.25KVH and the energy is generated by the tire is 6.07KVH which is 28% efficient. We know that, we don't have that material or technology that can produce a 100% charging facility but, in the future the electric vehicle will be going to use the technology.

5. FUTURE SCOPE

The piezoelectric material is a future dominating technology because of its unique property and it can produce clean energy without harming the environment. It may help to generate more electricity or energy that may replace the unsustainable method of energy harvesting technology or fuel. The piezoelectric material is employed in different fields like energy harvesting, sensor, etc. As we know the automobile sector is a very big industry where the piezoelectric material has a wide possible application because piezoelectric material is a very sensitive material so that it can be used as a sensor as well as a harvester to harvest energy from small vibration. The wide research is done in a piezoelectric material so that it can be used in a tire for harvesting electricity for the battery to charge itself but our present technology is not sufficient to generate high voltage. This year's research suggests that the modified surface of the 3% KNN material to the PVDF can generate up to 21 voltage which is 4 to 5-time greater than the previously known material [1]. The previous technology was not able to generate sufficient electricity they produce only a 1% charge after running 100km and the cost is going to be high [2]. As we see this year's research paper which has shown as a new advanced technology that can charge up to 28% by running 100km with the minimum speed of the 50km/hr and the outcome is satisfactory. So, that the cost of the product won't be much high as compared to the result we got [4]. By looking at the advancement of technology, we can say that in the future piezoelectric tires will be widely used to generate electricity and that will help to increase the range of electric vehicles by increasing the efficiency of the vehicle. Developing a better piezoelectric material and method that can harvest more electricity. Most of the need for the future. Designing an innovative piezoelectric harvesting device will be seen shortly. In the future energy harvesting from the suspension of the vehicle will also be widely used as the energy is dissipated from the suspension by using dampers such energy can be used for the power harvested.

6. CONCLUSIONS

Power loss in vehicles due to various factors has been always an existing problem since its development. Still, it cannot be eliminated despite lots of studies, research and development conducted. In the meantime, present researchers are shifted to the energy harvesting technique by optimistically viewing problems into an opportunity. In recent times, piezoelectric energy harvesting has been one of the created opportunities which indeed has been huge and boundless due to its potential applicability. There have been numerous published articles related to piezoelectric harvesting and in this article, we have tried to concisely summarize some impactful articles including few patents focusing particularly on the area of piezoelectric harvesting in vehicles. We hope and believe that this article will be helpful for present researchers and aspirants of the research area which can bring some more fruitful achievement to the field of piezoelectric energy harvesting. While taking a look at piezoelectric material, Lead Zirconate Titanate (PZT) had been used earlier but due to its lead content, it came out to be environmentally hazardous. Thereafter, Polyvinylidene fluoride (PVDF) broke into the field due to its versatile strength and increased range of operational parameters. Further, work suggested slight surface modification of PVDF with Potassium sodium Niobite (KNN) material can yield a higher value of power. Studying different parameters that can affect the performance of piezoelectric material such as loading frequency, loading magnitude and temperature have seen playing an important role. From research, it is found that energy output efficiency increases with an increase in temperature and voltage increases with an increase in loading magnitude and the electric energy generated increases with an increase in loading frequency.

Since the development of the concept of generative tires, the configuration has been changed often from installing piezoelectric resonator at different location of tires to creating a chain patch of piezo material and embedding it to a different location of the tire, most often on the inner periphery of tire aligning with some other material as reinforcement to provide stiffness to the system. So, the system won't be subjected to uneven stain or deformation across the surface, which could potentially damage the fibers and impact the efficiency of the system. Not to forget, the replacement of damaged fibers from the interior would be a tedious task to perform on regular basis.

Also, harvesting of energy using is not limited to the strain of tire but can be used in suspension, energy harvesting form suspension was generally done by using electromagnetic harvester but it had a disadvantage of low energy density. Piezoelectric harvester device can be used to generate electricity with high energy harvesting efficiency. The harvesting device consists of a motion conversation component to convert the linear motion of suspension to rotating motion and an energy conservation component that exerts a force on the piezoelectric material to generate electricity in a higher amount due to the lining of piezoelectric material around the rotating component.

Also, vibration engine parts can be utilized to convert vibrational energy to electrical or another useable form of energy, for which further study is required. Based on the practical and theoretical analysis from referred papers, it is quite inconclusive to say power generated from piezoelectric tires can be used to run vehicles as a whole but can be used to operate sensors and other peripheral devices to add advanced edge data-driven control of the vehicle. As many of the topics covered in this article and those not covered here but related to similar fields are being researched continuously. So, we strongly believe shortly piezoelectric harvesting won't just be an additional power source to power peripheral sensors or to add range to the vehicle but can be the main source with some small amount of supporting source requirement.

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