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Stability improvement in vehicles by heating Tyre using harvested Energy from Piezo Sensor and its Impact on the Characteristics of Tyre

[1]N. Vikram, [2]Arjun Krishna B, [3]Akilan K, [4]N ShriHari, [5]Mr. David Andrews V
[1,2,3,4]IV Year Student, [2]Asst. Professor, SRM Institute of Science &Technology, Chennai, India,
[1]vikram.nattu@gmail.com, [2]arjunkrishna98@gmail.com, [3]akilan0250@gmail.com,
[4]shriharichandran@gmail.com, [5]vdavidandrews277@gmail.com

Abstract: This paper explains the heating of tyres to increase the resistance between the tyre and road, thereby, increasing the grip of the tyres to improve the stability of the vehicle. Heating of tyres implemented by harnessing energy using piezo sensors located inside the rim of the tyre excited by the tyre pressure. Careful study on the characteristics of the tyre rubber is carried out using Simulation Software Ansys and the modeling using CAD design. Analysis of tyre done to conclude maximum temperature withstanding capacity of tire.

Keywords: *Piezo sensor, Tarmac, Frustum shape, Inductive coupler, Wireless transmitter, Wireless receiver, PZT*

I. INTRODUCTION

Rubber compounds become soft on heating. Soft compound after heating will result in more surface area which will be in contact with the tarmac. Increase in surface area of tyre increases friction and the resistance between tyre and the tarmac .More friction equates to more grip in the tyre.

A piezoelectric array (series combination of piezo sensor) is mounted in one or more tyres of the vehicle. As the vehicle drives down the road, the tyre is flexed during each revolution to distort the piezoelectric sensor to generate electricity. Piezo sensor generates an AC voltage when excited by the mechanical stress or external stimulation.. The present environmental concerns demands the need for usage of clean energy or non conventional energy sources for power-generation.

When the vehicle wheel is unloaded, the tube does not exert much of load on the inner carcass of the tyre. When loaded, due to the spring mass of the vehicle, the tube exerts an appreciable amount of load on the inner carcass of the tyre[1]. This load varies with different vehicle velocities and used to excite the Piezo Sensor Fig.1.1

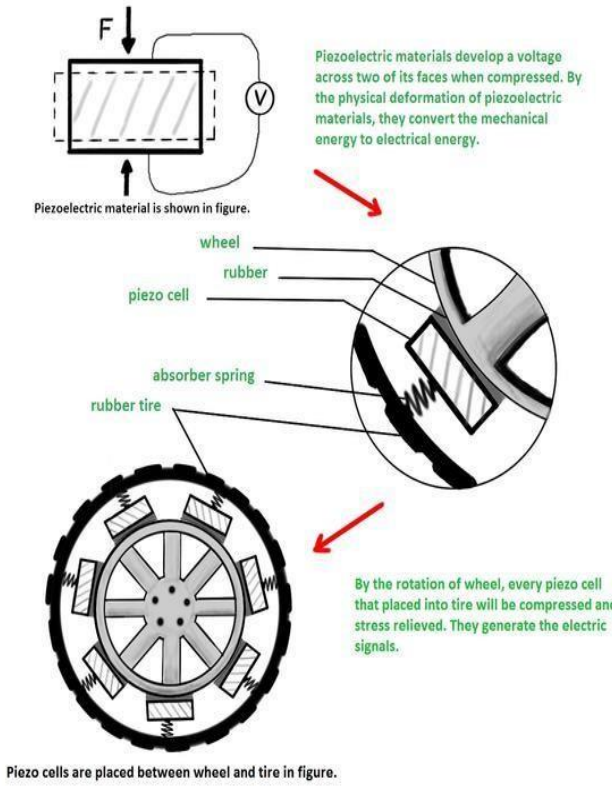

Fig: 1.1 Housing of piezo sensors inside tyre

II. DESIGN OF PIEZOELECTRIC MODULE

The structure of the piezoelectric module used in the energy [1][2] harvesting system is a frustum (Fig 2.1). The variation in the output voltage with reference to change in the upper face diameter for a fixed base diameter of the module is shown in graph (Fig.2.2). The obtained simulated

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output voltage from the COMSOL Multi physics software for a direct load of 500N (compressive) on the upper face with the base fixed for PZT-5A material is tabulated and the relationship between output voltage and the face diameter of piezo electric module is shown in the graph. With the increase in the upper diameter of the frustum-shaped module the output voltage decreases and with decrease in the base diameter, the output voltage increases.

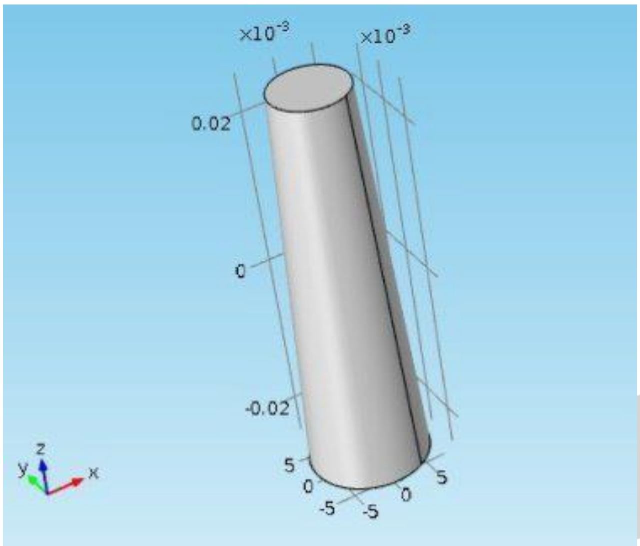

Fig 2.1 CAD Drawing of the Piezo Electric Module.

The mesh size used for the simulation is free-tetrahedral and as 'stationary physics module' piezoelectric device is chosen. From the graph plotted (Fig 2.2), the piezoelectric sensor module with base diameter 15mm and top face diameter 10mm is chosen as the test module.

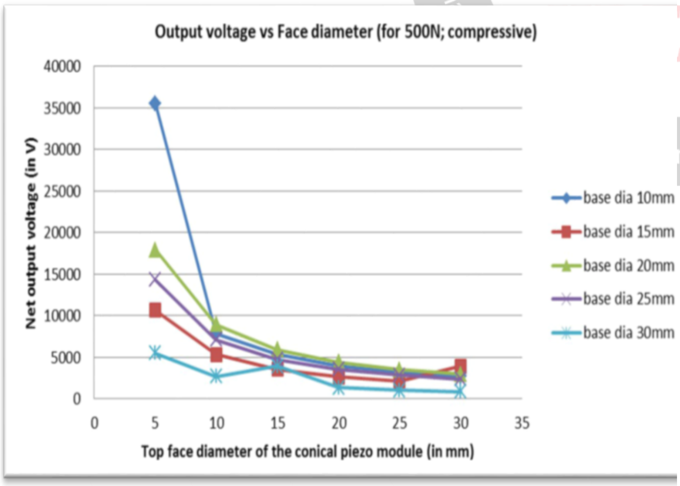

Fig.2.2 Relationship between output voltages and face diameter of the piezoelectric module

$$K = \sqrt{\frac{\text{Mechanicle Energy Stored}}{\text{Electrical Energy Applied}}}$$

Or

$$K = \sqrt{\frac{\text{Electrical Energy Stored}}{\text{Mechanicle Energy Applied}}}$$

III. ARRANGEMENT OF PIEZOELECTRIC MODULE IN TYRE

The piezoelectric sensor modules are arranged along the circumference[3][4] of the tyre (Fig. 3.2). The dimension of the piezoelectric sensor module, as inferred from (Fig.2.1), has a base diameter of 15mm and a top face diameter of 10mm and a height of 30mm. The tyre chosen for the purpose is designated as 165/80 R14. The modules are arranged in 5 circular columns with each column consisting of 30 piezo sensor modules. The modules are then covered by a layer of tyre material of thickness equal to the thickness of the tyre carcass. The positioning of tube and rim will remain same.

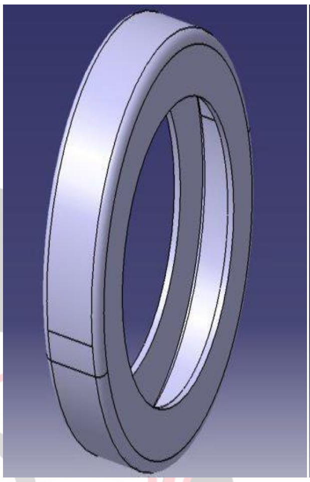

Fig. 3.1

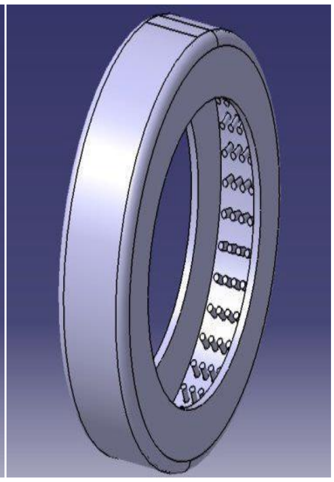

Fig. 3.2

Fig: 3.1 CAD MODEL OF RUBBER TYRE WHERE THE PZT ARE TO BE ARRANGED

Fig: 3.2 CAD MODEL OF ARRANGED PZT COVERED WITH ANOTHER LAYER OF TYRE RUBBER

IV. MODULE ARRANGEMENT USING CAD DRAWING

The arrangement of the modules is represented by a CAD drawing in Fig. 4.1. The hatched lines represent the tyre[3] rubber material. The side and the front view is also shown in Fig 4.1

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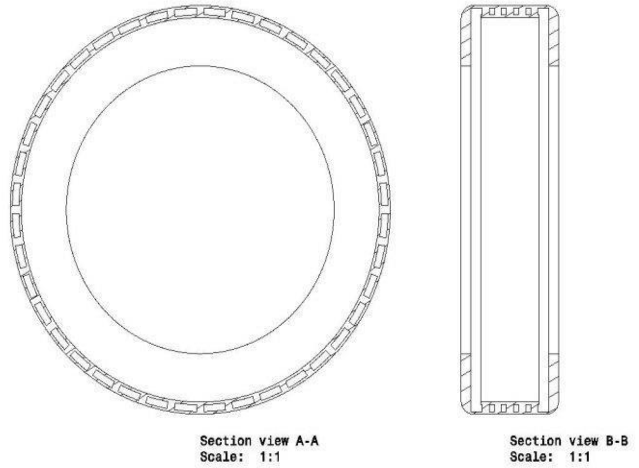
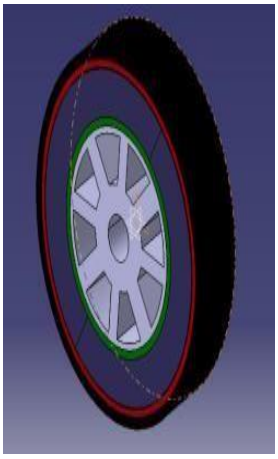


Fig 4.1 THE ASSEMBLY OF PIEZO SENSOR MODULE INSIDE THE TYRE USING CAD.

V. ARRANGEMENT OF THE METAL PLATE



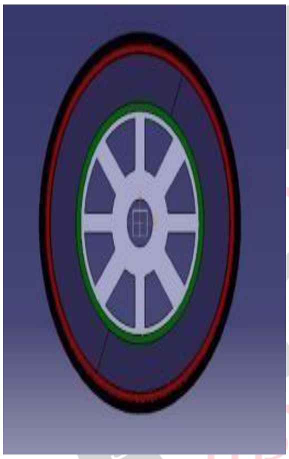


Fig.5.1 ISOMETRI VIEW **Fig.5.2 FRONTVIEW**

The above figures (Fig.5.1and Fig.5.2) shows the CAD model of the tyre with the provisions for the piezo-electric sensor and the metal plate[3],[4] along with the housing of the components. The red region represents the heating plate followed by the tube of the tyre. The green layer represents the piezoelectric sensor. The piezoelectric sensor is placed between the rim of the tyre and the tube. The power generated from the piezoelectric Sensor is supplied to the metal plate and thus the heating effect is achieved. The metal plate is of high resistance to enhance the heating effect. The piezoelectric crystals are arranged between the rim and the tyre to produce the necessary electricity required for heating [5] On heating, the temperature of the tyre increases, increases the pressure of the tyre. The material used for the purpose of [9] heating is Nichrome-60. The resistance of the heating material is approximately equal to 10.14 Ω.

VI. METHOD OF GENERATING ELECRTICITY BY THE COMPRESSION OF VEHICLE TYRES

Piezo sensor output is processed by the signal conditioning circuit and cascaded amplifier stages. Output stage is driven by the push-pull stage [8] to map the load impedance (heating plate of a tyre. The system is designed[14] with hybrid power system to manage worst case situation**.**

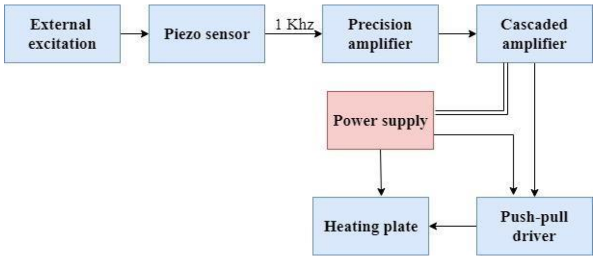


Fig.6.1 SYSTEM BLOCK DIAGRAM TO PROCESS PIEZO SENSOR OUTPUT TO HEAT PLATE

VII. STEPS INVOLVED IN EXECUTION AND OUTCOME

- Embedding one piezoelectric cable within a rubber exterior of the vehicle tyres.
- Rolling the vehicle on the vehicle tyres to detect the weight of the vehicle compressing the vehicle tyres during rotation.
- The weight of the vehicle compressing at least one piezo electric cable within the vehicle tyres to generate current.
- Conveying the current to one capacitor using the current stored to store charge for the electrical systems of the vehicle.

VIII. ANALYSIS OF THE PIEZO ELECTRIC MODULE AND THE TYRE.

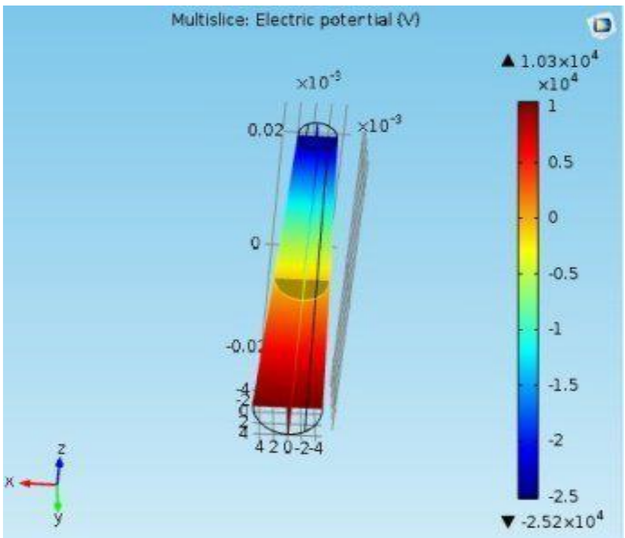


Fig.9.1 PIEZO ELECTRIC MODULE AND TYRE ANALYSIS

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The electrical potential distribution [11] throughout the crystal is shown in Fig.9.1. The analysis gives the electrical distribution of the module when subjected to pressure variation. The deflection of the module with the electrical distribution is also shown in Fig.9.1. The boundary conditions were set up and the pressure variations are applied. The analysis is done using the 'analysis software' to obtain electrical distribution.

IX. RUBBER TYRE ANALYSIS

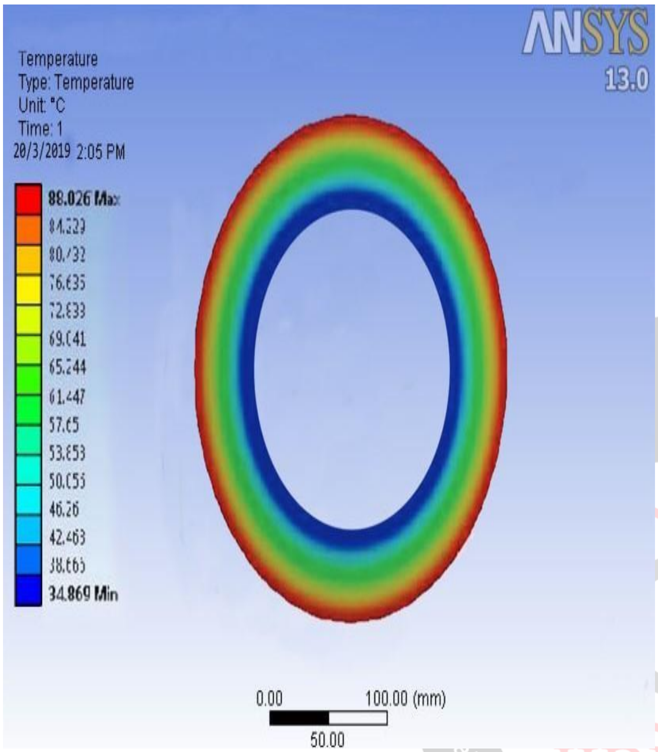

Fig.10.1 ANALYSIS OF THE RUBBER TYRE

The analysis of the rubber surface (or) the outer surface of the tyre[5] is shown in Fig.10.1. The number of modules in the contact patch area is 63. The tire material is modeled into an equivalent spring-damper system with required spring stiffness and damping coefficient values. The piezoelectric module can also be modeled as a spring-mass[13] system with required spring stiffness and equivalent mass values., The maximum temperature that is achieved by the heating effect is 88 degrees. The maximum temperature that a commercial tire can withstand is 100 degrees. The subsequent layers of the tires and their with maximum and minimum temperature is shown in Fig.10.1.

X. CALCULATIONS

The tire pressure of a passenger [6],[7] vehicle measured is about 32 psi. Assuming the weight of the vehicle with the passengers be 1000 kg with the equal weight distribution both at the front and rear side, the load acting on each tire is identical (250 kg or 2453 N).

For the approximate calculation of contact area of the tyre when loaded, the following relation is used [10].

Contact patch area = force applied/tyre pressure = (2453 N)/(0.2206N/mm2) = 11120 mm2

The tyre pressure is converted from psi to N/mm2.Since the base diameter of each of Piezo sensor module is 15mm ,the area covered at the base by each module is given by the area of the circular base

Area of circular base = 0.25 x π x (base diameter)2 = 0.25 x π x (15)2 = 176.25 mm2.

Therefore, the approximate number of modules that will be under the load can be calculated as:-

Number of Piezo sensor modules= (Contact patch area) / (area of circular base of a single module)

= 11120/176.25 = 63 (approx.)

XII. SIMULATION OF PIEZO MODULE

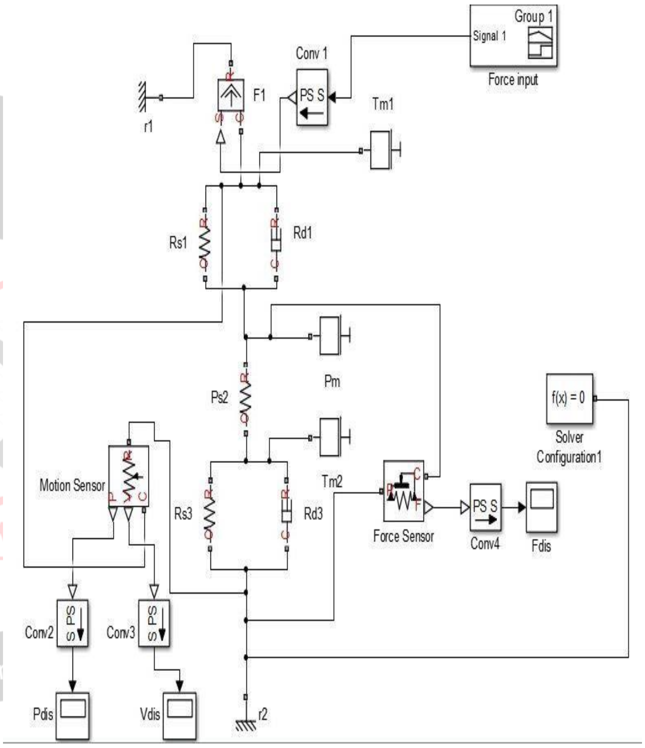

Fig.12.1 PIEZO MODULE SIMULATION

The Piezo sensor module is simulated for a load of 39 N in COMSOL Multi physics software Fig.12.1 and the output electric potential is found out to be 414 V with resistive load. These piezoelectric modules will generate high power[12] compared to the output of a single piezoelectric module.

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XI. XIII. POTENTIAL DISTRIBUTION ON APPLICATION OF COMPRESSIVE LOAD

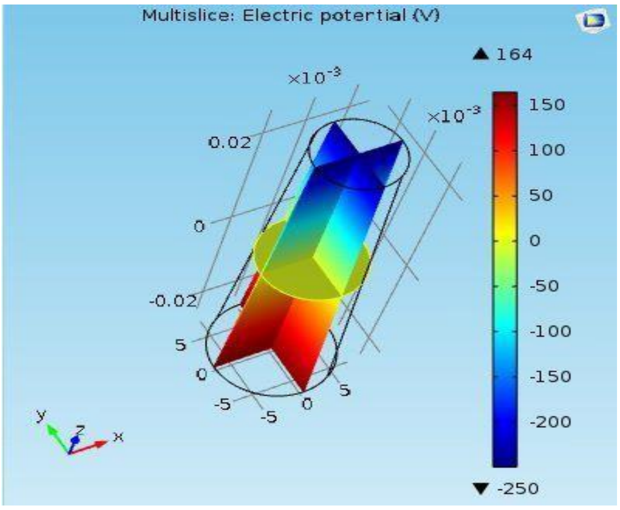

Fig.13.1 ELECTRIC POTENTIAL DISTRIBUTION IN PIEZOELECTRIC MODULE ON APPLICATION OF 39N OF COMPRESSIVE LOAD

At 80 rpm, the first design generated an [12] average power of 4.6 mW with a peak voltage of 45.5 V. Similarly under the same motion conditions, the second design generated 0.85 mW with a peak voltage of 62.3 V, and the third design generated 0.23 mW and 18.7 V. Different resistive loads were used for each design to approach the maximum power output condition.

XIV.CONCLUSION

Thus it is concluded that the temperature increase in tyre is achieved by system using piezoelectric Sensor. The electricity gets generated because of the pressure applied on the tires. The electricity is passed on to the metallic plate placed between the tube and tyre to get a better grip on the road and increases the traction. Any ice stuck on the tyre can also be melted. By increasing the temperature of the tires, the pressure in the tyre can be monitored. A good estimate is for every 10° fluctuation in air temperature, vehicle tyre pressure will adjust by about 1 psi. Heating of tyres is done basically to increase the resistance between the tyre and the road, thereby, increasing the grip of the tyres. Rubber compounds become soft on heating. The soft compound will have more surface area in contact with the tarmac. As a result, the resistance due to friction offered is higher when compared to a cold compound. More friction equates to more grip attained by the tires. Analysis of tyre reveals the maximum increase in the temperature due to heating of tyre using piezo sensor module is 88 degrees and the maximum capacity of the commercial tyre is 100 degrees. .

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