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Design and simulation of piezotyres using comsol multiphysics 4.3b software tool

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ABSTRACT

This paper proposes a new design of a vibration-based piezoelectric generator, utilizing mechanical energy within a rolling tyre. A thin piezoelectric ring is placed in the inner layers of the rubber tyres, so the stress is varying on the piezoelectric ring at the road and tyre interface. As a result we can get electric current; it would be used for charging batteries in vehicles. In this paper, we have reported the design and simulation of Piezotyres by COMSOL Multiphysics.

Keywords: Tensile stress, Tyres, Vibrations, Compressive stress, Mechanical energy, Power generation, Power supplies, Piezoelectric devices, Sensors.

INTRODUCTION

As electricity is playing a vital role in present day world we have to utilize every chance in generating electricity apart from major power generation techniques like Thermal, hydel, nuclear, solar, wind, fuel cell, tidal. Here every chance guides to new energy generating technique. In small scale energy can be collected from devices or components that convert the given physical input to electrical output for example piezo electric devices i.e. they convert the mechanical force (stress, strain, pressure, magnetic strength) to electric voltage.

Piezotyres are the tyres lined with piezoelectric materials that utilizes the mechanical stress (between tyre and road) during motion and provides electrical output which in turn used for battery charging or live utilization.

In 1880, the brothers Pierre and Jacques Curie discovered that some crystals developed surface charges when compressed. They furthermore found that these charges were proportional to the applied pressure. This phenomenon was later named “piezoelectricity” by Wilhelm Gottlieb Hankel, and is historically referred to as the direct piezoelectric effect. Additionally, in these same crystals, a strain is produced under application of an electrical field. This is commonly referred to as the converse piezoelectric effect. The material constant relating strain and charge in a piezoelectric material is known as the piezoelectric charge modulus, d , and is typically quoted in units of $pC\ N$ or $pm\ V$. In order for a material to be piezoelectric, it must have a noncentrosymmetric crystal structure.

It was not until 1921, that a useful application was developed for piezoelectricity. It came in the form of a quartz crystal oscillator that was developed by Walter Cady to provide good frequency stability for radio systems. Then, in 1947, the first commercial phonograph pickups based on barium titanate (BaTiO3), a piezoelectric ceramic, were introduced. Modern applications of piezoelectric materials now include high voltage ignition systems, piezoelectric motors, ink-jet printer heads, acoustic speakers, sonar, ultrasonic transducers, frequency filters, acoustic delay lines, electrical transformers, and a wide range of physical sensors, such as acoustic, force, pressure, and acceleration sensors .

Piezoelectric Materials in MEMS

A number of papers have been published on the use of piezoelectric and ferroelectric materials in MEMS. Piezoelectric materials commonly used include zinc oxide (ZnO), aluminum nitride (AlN), and lead zirconate titanate (PZT). The choice of piezoelectric material depends on several selection factors including deposition methods, process complexity, integrated circuit (IC) compatibility, and material parameters.

A. The production of electricity or electric polarity by applying a mechanical stress to certain crystals.
B. The converse effect in which stress is produced in a crystal as a result of an applied potential difference piezoelectrically.

The generation of an electric charge in certain non-conducting materials, such as quartz crystals and ceramics, when they are subjected to mechanical stress (such as pressure or vibration), or the generation of vibrations in such materials when they are subjected to an electric field. Piezoelectric materials exposed to a fairly constant electric field tend to vibrate at a precise frequency with very little variation, making them useful as time-keeping devices in electronic clocks, as used in wristwatches and computers.

1. Use of comsol multiphysics

The software package selected to model and simulate the pipe flow module was COMSOL Multiphysics Version 4.3. It is a powerful interactive environment for modelling and multiphysics were selected because there was previous experience and expertise regarding its use as well as confidence in its capabilities. A finite element method based commercial software package, COMSOL multiphysics, is used to produce a model and study the flow of liquid in different channels. This software provides the flexibility for selecting the required module using the model library, which consists of COMSOL Multiphysics, MEMS module, microfluidics module etc. Using tools like parameterized geometry, interactive meshing, and custom solver sequences, you can quickly adapt to the ebbs and flows of your requirements, particle tracing module along with the live links for the MATLAB. At present, this software can solve almost all problems in multi physics systems and it creates the real world of multi physics systems without varying their material properties. The software is very user friendly and easy to understand, easy to implement for making various designs, in the form of finite element analysis system.

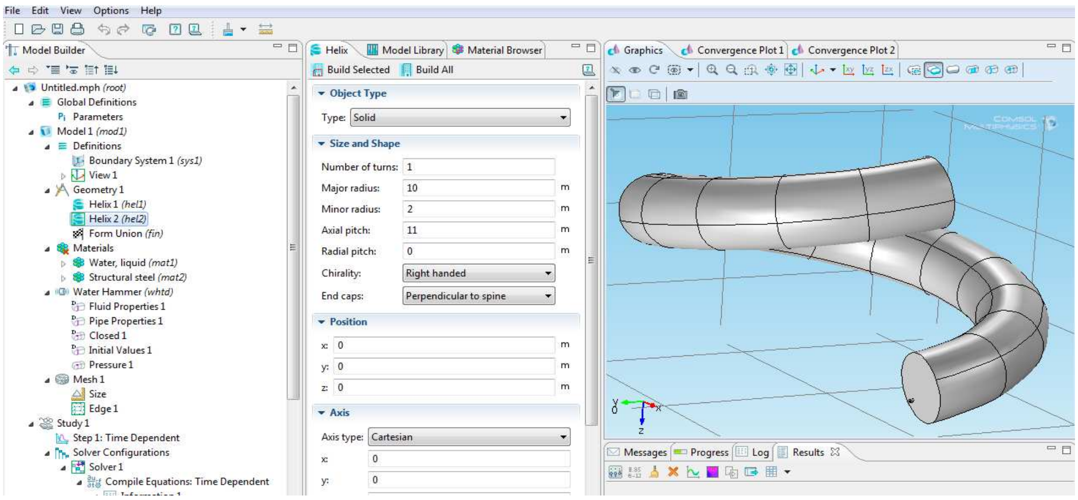

Figure 2. Multiphysics modelling and simulation software-COMSOL

2. Designing Procedure:

At the point of road and tyre interface stress is exerted on the piezoelectric material inside the tyre.

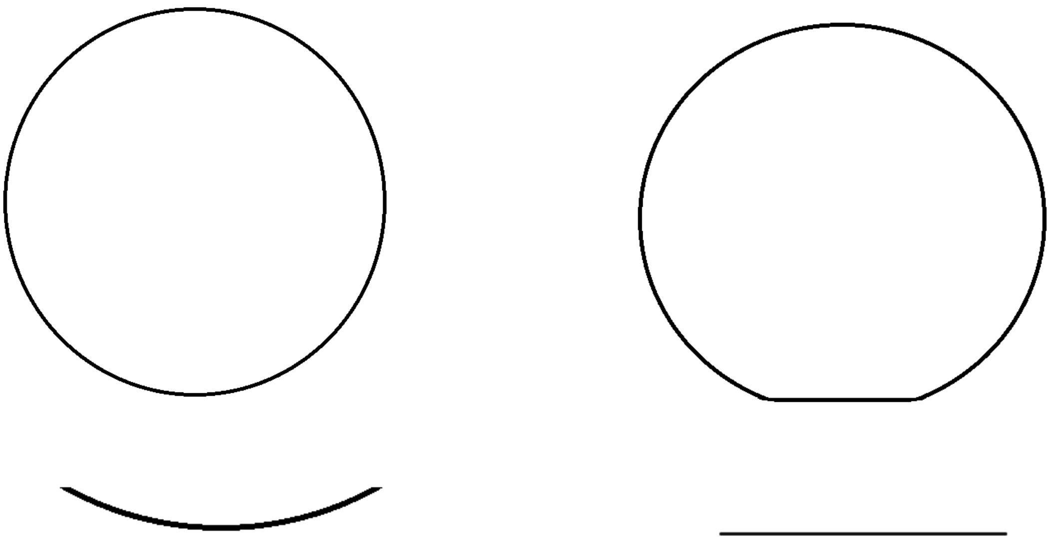

Fig: Showing the deformation of piezo layer at the interface of road and tyre.

As piezo layer undergoes deformation there is an output voltage, so when the tyre is moving electric potential is produced continuously.

The piezotyres is designed using Comsol multiphysics 4.3b. For this structural mechanics> solid mechanics and piezo electric devices are selected and the designing is as follows.
A steel rim with geometry (1*0.7)m is builted.

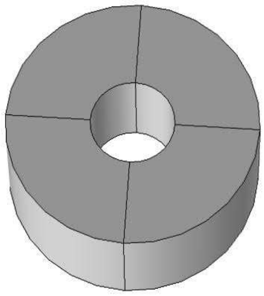

Fig: Steel Rim

For the steel rim rubber tyre is attached around it.

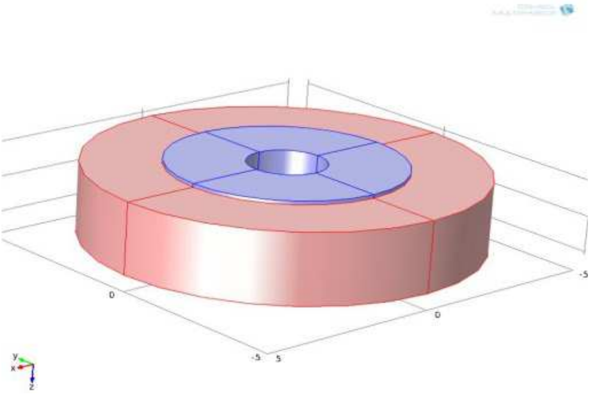

Fig: General rubber tyre

Insertion of piezo material:
A thin layer of piezoelectric material with thickness 0.05m is attached around the tyre as shown in figure.

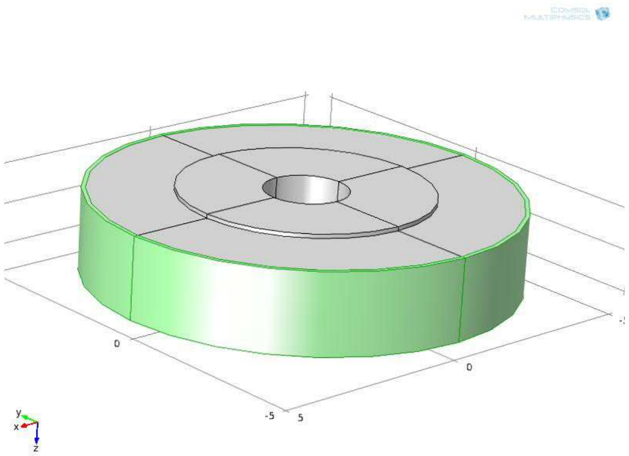

Fig: Tyre with piezo layer

Now again attach rubber layer around piezoelectric material .Thus piezo tyre is completed

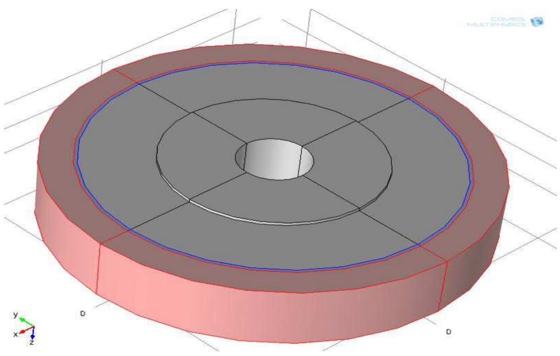

Fig: piezo tyre

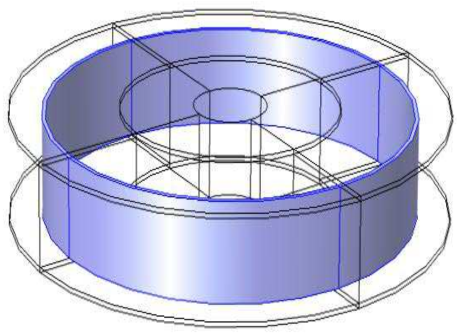

Fig: Transparent view

MESHING:

Discretizing of the model into small and simple pieces is called the meshing. For discretization purpose we are using the different shapes and sizes. In this module we are using the FREETETRAHEDRAL, and then distributed to the total module through distribution technique. For applying the meshing we follow the following steps.

Free triangle:

In the Model Builder window, right-click Model 1>Mesh 1 and choose More Operations>Free Tetrahedral.

Distribution:-

Click the Build Selected button. Total meshed structure is as shown in the following figure.

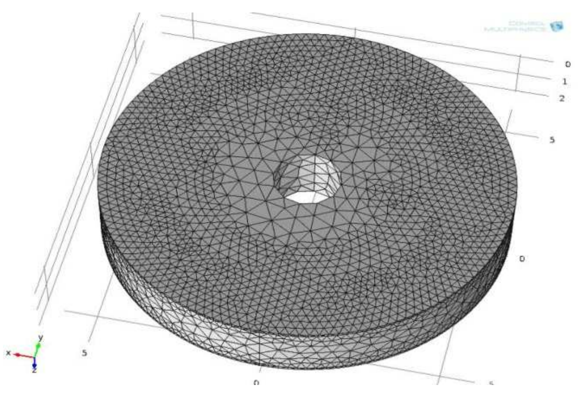

Fig: mesh

RESULTS AND DISCUSSION

For view the output of the device we are using the 3D plot groups.

Deformation:
When default stress is applied on the tyre, the piezo layer of tyre undergoes a maximum deformation of 45x10^-21 as shown in figure below.(The bulging part shows deformation)

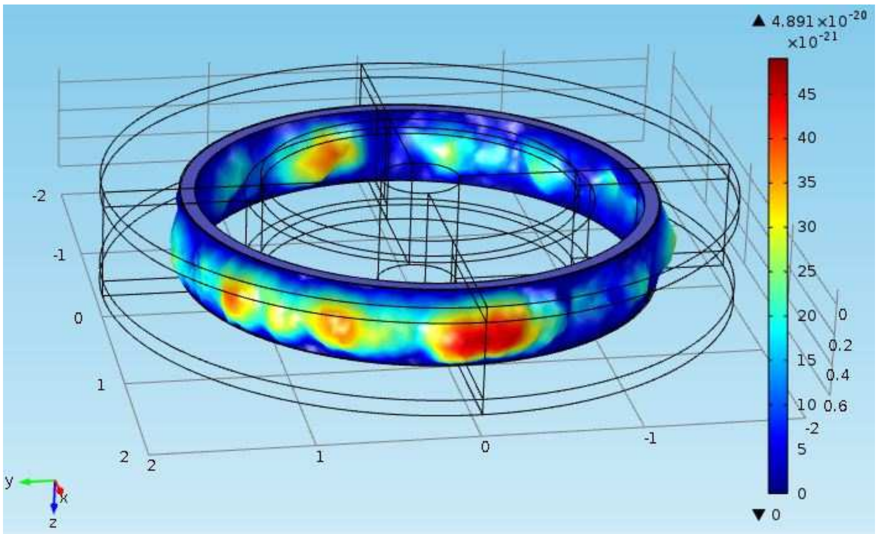

Fig:-3D plot group1

Output:
The obtained deformation derives an output of 8v. In the figure 3D- plot group2 the thin slices shows the voltage distribution at the stressed part of tyre.

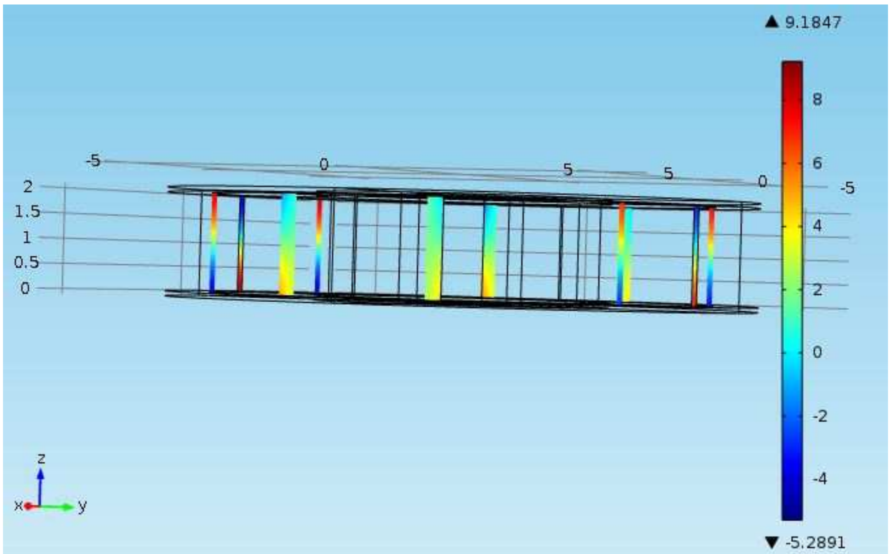

Fig: -3D plot group2

Simulation:
After simulation we got better results by reducing the radius of tyre as follows.

Deformation after simulation:

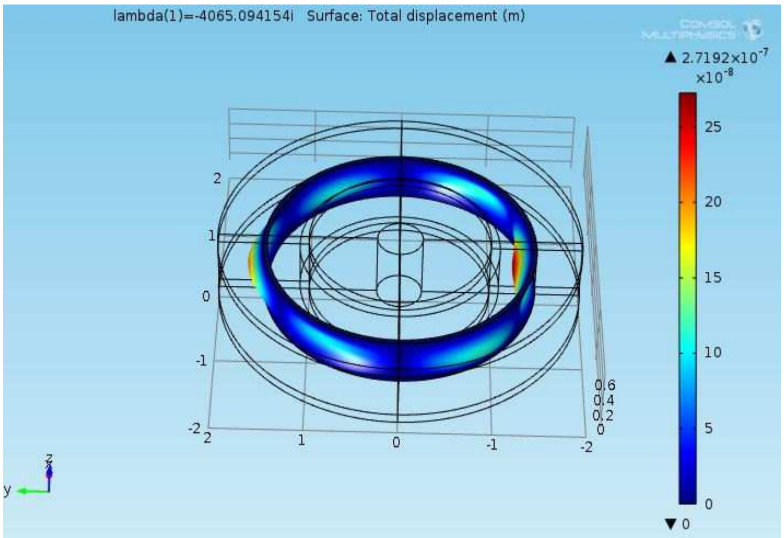

Fig: 3D plot group3

3D plot group3 shows that after simulation there is a deformation of 25x10^-8.

Output after simulation:

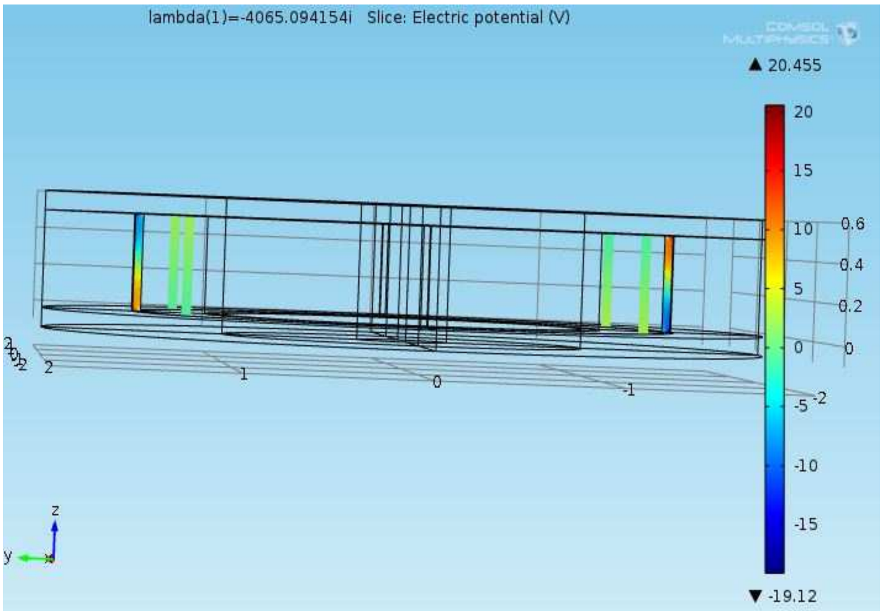

Fig: 3D plot group4

The 3D plot group4 shows output after simulation i.e. 20v.

The design of piezotyres was made by using COMSOL Multiphysics software version 4.3b. In which by using, electric potential produced in these tyres is used to charge the batteries in auto mobiles. By reducing the radius of the tyre and thickness of piezo layer best results are obtained.

CONCLUSION

MEMS technology exploits the existing microelectronics infrastructure to create complex machines on a micrometer scale. Extensive applications for these devices exist in Tracking the position of an object is an important engineering problem that finds many application areas including military, industrial, medical, and consumer applications.

As electricity is very scarce today we should not waste even a small source of power. This piezotyres provide the space for utilizing the mechanical stress to electrical voltage in automobiles (in motion).

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