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Piezoelectric Tires for Sustainable Power Generation

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Abstract: ***Electricity is crucial for advancing technology, and with the increasing use of electronic devices, it has become essential. As transportation evolves, the automobile industry is exploring different systems to enhance safety and comfort. To address environmental concerns, efficient combustion engines or clean alternative fuels are being sought. Vehicle capabilities can be improved by embedding sensors. This report explores piezoelectric electricity harvesting as a step towards clean energy. Piezoelectric materials convert mechanical energy into electricity, making them common in automotive applications. This offers a new opportunity for sustainable energy as traditional resources deplete.***

Keywords: Piezoelectricity, Electricity Harvesting, Sustainable Energy, Energy Consumption, Generator Efficiency, LED Fairy Lights, CAD Model, Piezoelectric Material, Ecological Footprint, Bridge Rectifier, Charge Amplifier, Capacitor, Battery Backup, Optimal Cross - Sectional Area, Classes of Piezoelectric Materials.

1. Introduction

Our world population currently is at [1] 8.1 billion. Could we imagine how many cars would be owned by people across the globe? There are around 1.47 billion cars in this world [2] Now imagine how much petrol or diesel is used by an average car in one year? And us 8.1 billion people are so reliant on technological advancements we have made, that it's impossible and unthinkable to live even one day without them. We are leaving an enormous footprint on our planet, and a major source of the environmental footprint comes from cars. Piezoelectric effect is a process that enables the conversion of mechanical energy, due to the contact between a wheel of a vehicle and the surface/road, into electrical energy. Piezoelectricity refers to the accumulation of electric charge in specific solid materials, such as ceramics, human bone, and DNA, in response to mechanical stress.

Why not we use the mechanical energy produced by the cars when moving. They produce significant mechanical energy through the rotational motion of their tires. Considering the weight of an average car, a substantial amount of mechanical energy is generated, currently being dissipated into the ground without any purpose. A rough calculation can be drawn with how much Mechanical Energy can be drawn. With two formulas:

[3] K. $E_{Rotational} = ½ \times I \times w^2$
[4] K. $E_{Tanslational} = ½ \times m \times v^2$

If we assume
1) Tire Mass: 10kg
2) Tire Radius: 0.3m
3) Tire mass = 10 kg
4) Tire radius = 0.3 meters
5) Vehicle mass = 1000 kg
6) Vehicle speed = 30 meters per second

And calculate:
1) KEtranslational = ½ x 1000 kg x (30 m/s) 2 = 450, 000 Joules
2) I = ½ x 10 kg x (0.3 m) 2 = 0.45 kgm2
3) w = 30 m/s / 0.3 m = 100 radians/second
4) KErotational = ½ x 0.45 kgm2 x (100 rad/s) 2 = 2250 Joules
5) KEtotal = 450, 000 Joules + 4 x 2250 Joules = 461, 000 Joules
6) 461, 000 Joules / 3600 joules/watt - hour = 128 watt - hours

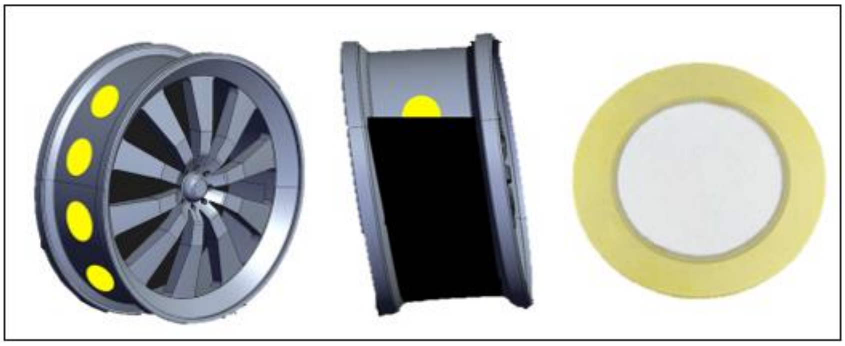
However, the value is theoretical and efficiency of generators differ. So we could expect 80%. Efficiency and assume that the Electrical energy could be approximately 100 watt - hours. As there are factors like Frictional loss, Heat loss, Transmission loss, and more. [5] This can power a string of 10 LED fairy lights for several hours, typically 0.5 - 1 W per bulb and more. Thus, I believe this is a useful usage of energy, even though this Electrical energy may not be able to power an Air conditioner, it can power a Battery backup or charge your iPhone [6].

2. What could be possibly done?

Firstly, a sample of sketched a tire model with embedded piezoelectric material. The challenge was integrating them without disrupting a typical tire's interior. Simply attaching discs directly inside will be risky due to the pressure and forces they would face, potentially leading to them detaching. Placing them on the outer wheel wouldn't generate electricity because they wouldn't touch the ground during rotation.

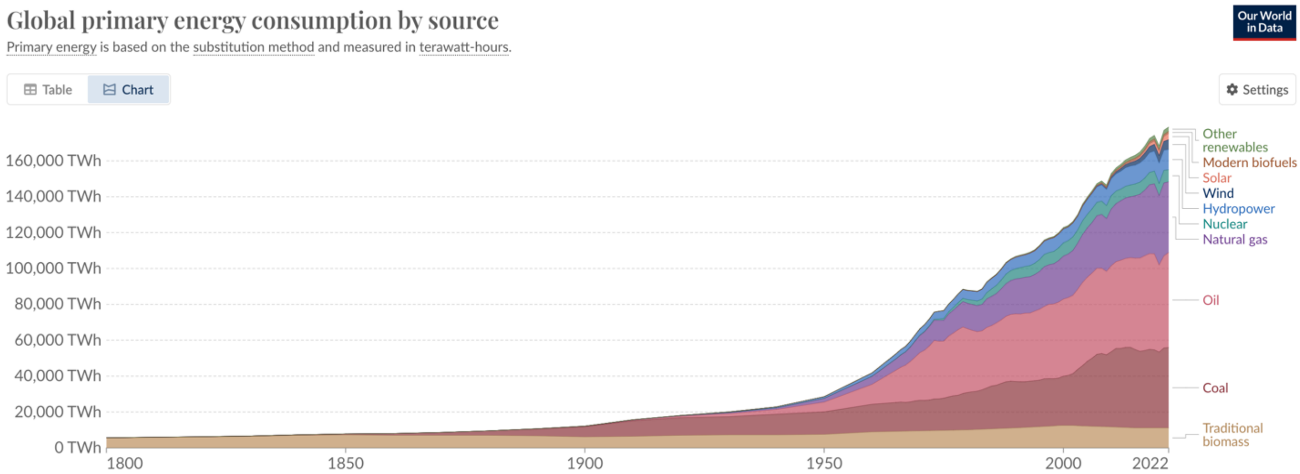
Next, I thought of coming up with a "noise - reducing tire" featuring an interior foam layer for smoothness and sound dampening. This provided an intriguing solution – the foam could offer the necessary resistance for the piezoelectric discs at high speeds, relying on the surrounding foam to apply pressure and activate the piezoelectric effect.

So, the tire would look something like this (with and without padding layer):



[7] CAD Models. [8]

The usage of yellow circles on the diagram is because I plan on using this type of Piezoelectric material: [9]



Our escalating reliance on energy - intensive devices is resulting in a substantial ecological footprint on our planet. I believe that each individual bears a degree of responsibility, to mitigate the environmental impact that we collectively contribute, whether knowingly or unknowingly. The provided chart illustrates the average energy consumption around the world from 1800's.

3. Reach

There exist hundreds of millions of cars in operation, and any of these vehicles has the potential to be equipped with this particular type of tire for electricity generation. While electric vehicles (EVs) can directly utilize the energy produced by these tires, this innovation is not exclusive to EVs. Even in the case of gasoline - powered cars, the generated energy can be stored for future use. Therefore, anyone who operates a car becomes a potential customer for these tires.

Considering that cars have been in existence since the late 1800s [10] and are expected to remain prevalent in the foreseeable future, this product holds relevance for a broad audience of car users. While the electricity generated from an individual car tire may seem negligible, it is the cumulative impact of the many vehicles using this technology that becomes significant. The modest amounts of electricity generated from millions of cars equipped with these tires can have a substantial and positive overall effect.

4. How does this work?

The Piezoelectric Discs in the wheel are connected in parallel. The final disc in the wiring is linked to the bridge rectifier, which is embedded into the wheel. [11] Whenever the tire rotates, the Piezoelectric discs generate a voltage due to the mechanical energy applied to them. The bridge rectifier then converts the AC current generated by the Piezoelectric discs into a DC current. This DC current is then sent to a charge amplifier to ensure that the electricity generated by the Piezoelectric transducer is not lost through leakage. Finally, the charge amplifier is connected to a capacitor, which discharges the voltage generated to a battery.

5. Conclusion

However, there's more to it. To maximize the amount of electrical output produced, we need to determine the optimal amount of force and the optimal cross - sectional area. Different classes of piezoelectric materials such as ceramics, crystals, and polymers exist. By determining the appropriate class of piezoelectric material, with further experiments, as well as its optimal shape and size, we can maximize the output generated.

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