PhS Student :

Ahmad DELBANI

Title :

5th Generation Road: exploring the possibilities of electricity production by triboelectric effect from the mechanical energy of the tire/road contact

Abstract

Road transportation remains one of the main vectors of people's mobility. Since the first walking trails to our current car lanes, the road has not ceased to evolve by adapting to travel needs and reinventing itself with innovations and societal challenges. Today, it has become safer and more durable. Tomorrow, it will switch to the area of the "5th Generation Road (R5G)". It will be cooperative, smart and automated: it will communicate and exchange energy with vehicles; it will be able to diagnose and repair itself and will be made more and more recyclable materials.
Thus, the R5G will contain a large number of sensors that will regularly measure and transmit information (quantity, type/weight of vehicles, temperature, humidity, wear...). This raises the problem of regular power supply to these communicating and "abandoned" systems. The first solution is the use of photovoltaic cells. Indeed, solar energy is increasingly being used, not only for its ecological advantages but also for its economic advantages. It is renewable and therefore inexhaustible, unlike fossil fuels.
Despite the advantages mentioned above, this solution also has disadvantages mainly due to the irregularity of its energy production. Indeed, production depends largely on sunshine and therefore on the time of day (day or night), the weather (cloud cover) and also on the efficiency and cleanliness of the panel surfaces (dirt problems). However, the power requirement of these communicating systems remains the same regardless of the time of day, season or weather, so other alternatives as power sources must be explored in parallel.
Triboelectricity could be one of the possible options for the conversion of mechanical energy from a vehicle's passage on the road. Based on direct contact and not on the resonance of the mechanical system, it requires a smaller mass displacement than electromagnetic or piezoelectric transducers and is perfectly adapted to both flexible and inexpensive materials, making its use much more adaptable to different field configurations.
Triboelectricity as a means of converting mechanical energy into electricity for powering sensors and the Internet of Things was introduced in 2012 by Z. L. Wang, professor at Georgia Tech, who proposed the concept of the "Tribo Electric Nano Generator (TENG)"[1, 2]. Like any electrostatic transducer, to be effective a TENG must (i) generate a large number of charges per contact using two materials with high triboelectric affinities, and (ii) have a large capacitance variation between during and after contact. A third difficulty is that TENGs are only effective if they generate voltages of several hundred volts, which complicates their conditioning electronics [4-6].
Mechanical energy recovery systems based on triboelectric foams can be placed directly on the pavement, for example directly included in speed humps that can be deformed by subsidence or sliding. Each passage of a vehicle on the roadway thus locally modified will create a current peak that can charge a capacitance or a small battery to power an electronic system. The objective of this thesis is to develop a system generating enough energy to allow each vehicle passage to send, through low consumption wireless communication, sensor information, for example for triggering a safety signal in a risk area, or information on the type and/or weight of a vehicle, the humidity level of the road...
The thesis will be co-supervised by Malal KANE (Director of Research at Ifsttar) and Philippe BASSET (Professor at ESIEE Paris) and will take place in the institutions of the two supervisors (both institutions are components of the Gustave Eiffel University).

The work will consist of three main parts:
1. Develop a flexible device allowing the creation of electrical energy when deformed by a vehicle. First, a low-cost approach based on polyurethane foam will be considered. This part will take place in the ESYCOM laboratory.
2. Study the different possibilities of integration into the pavement and possible modifications to be made to the structure according to the different options (on or under the pavement, remote electronic or not...). This part will take place on the Ifsttar test track and will include reliability studies.
3. Develop the energy recovery device and its electronics to deliver a regulated voltage to power a communicating wireless sensor. This part of the thesis will be conducted jointly at Ifsttar's EASE and ESYCOM laboratories.
Despite the rather experimental aspect of the thesis, a significant scientific production in the form of journal articles is expected. Nano Energy (Elsevier, IF=15.5) and Smart Material and Systems (IOP, IF=3.5) are considered for the transduction part, and the Transaction of Industrial Electronics (IEEE IF=7.5) journal for the circuit part.
The candidate must have solid basics in electronics. Knowledge in the field of flexible materials is a plus. Good English is mandatory. The PhD diploma will be awarded by the Gustave Eiffel University.

References
[1] F. R. Fan, Z. Q. Tian, Z. Lin Wang, "Flexible triboelectric generator". Nano Energy. 1 (2): 328–334, 2012
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