VIBRATIONAL ENERGY HARVESTING TO ELECTRIC TRANSDUCTION IN A HIGH EFFICIENCY ELECTRIC VEHICLE

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ABSTRACT
The high efficiency vehicles are those utilizes very small quantities of fuel to travel as longer as possible distances. To accomplished the target, it is necessary many efforts to improve mechanical and electrical solutions. This work is related to a project to enhance electrical source in three prototype vehicles projected by Federal Technological University of Paraná in Pato Branco. In the vehicle, the electrical energy is used in lights, sensors, displays and motor. The propose of this work is to use an energy harvesting system based in vibration to transduce the induced vibration from the floor and from the engine to the vehicle into electricity to supply the electrical demands of the vehicle and extend the car battery life. Coupled to the harvester it is proposed a controller project to drive the energy harvesting system to an optimized interaction between the external vibrational excitation and harvester resulting in improved transduction result. It is expected an increase of the vehicle autonomy and a better result in the competition.

Keywords: Energy Harvesting, Telemetry, High Efficiency Vehicle, Battery Extension.

INTRODUCTION
At the Federal Technological University of Paraná, Campus Pato Branco, there are 3 teams dedicated to the development of prototypes vehicles of high efficiency with different guidelines. These teams and projects have something in common, they all utilizes an auxiliary battery, responsible for providing power to the electronic systems in the prototype, such as headlight, brake light, controllers, communication systems and telemetry.

This work deals to this competition teams providing a possible solution to enhance their battery life and extend autonomy and results. The purpose is use an energy harvesting system based in vibration to transduce mechanical energy coming from the vehicle during their movement into electrical output power to extend the battery life.

Using vibration to supply electrical power through energy harvesting is a recent exploration for sustainable electrical source and can be accomplished by electrostatic, electromagnetic and piezoelectric means [1]. Nevertheless, energy harvesting systems can use small thermal gradients, solar radiation and wind power [2] as potential source to electrical transduction, is the piezoelectric technology the most promised direction for an efficient result [1-4].

The energy harvesting systems presented a not efficient resulting output power because their low transduction, nevertheless for this research it is proposed a controller based on Linear Matrix Inequalities (LMI) for vibration maximization according optimum control $H_{\infty}$.

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There will be numerical analysis to elaborate an optimized distribution of piezoelectric plates in the vehicles and will be an experimental evaluation to verify the numerical results. It is expected an increase of battery life and an improvement of vehicle results in terms of efficiency distance overpass related to energy available.

**NUMERICAL ANALYSIS**

The mathematical model referring to piezoelectric plates coupled to an output voltage will be analyzed according to the mathematical model of input vibration in the systems as exogenous excitation. The model for piezoelectric material coupled to a output voltage is given by [5] as shown in equation (1):

\[ \ddot{x} + 2\zeta \dot{x} - \frac{1}{2} \chi (1 - x^2) - \chi v = w \]

\[ \dot{v} + \Lambda v + \kappa \ddot{x} = 0 \]

Where the state variable are \( x \) position, \( \dot{x} \) velocity and \( \ddot{x} \) acceleration. The constants are \( \zeta \) damping, \( \chi \) piezoelectric mechanical coupling, \( v \) resistance voltage, \( \Lambda \) reciprocal of time constant to load the capacitor, \( k \) is piezoelectric electric coupling and \( w \) is the exogenous excitation. The space state of given energy harvesting system model can be set changing variable as \( x = y_1 \), \( \dot{x}_1 = y_2 \) e \( \ddot{x} = y_3 \), giving [6]:

\[ \dot{y}_1 = y_2 \]

\[ \dot{y}_2 = -\frac{1}{2} y_1 - 2\zeta y_2 + \chi y_3 + f \cos \Omega t \]

\[ \dot{y}_3 = -\kappa y_2 - \Lambda y_3 \]

**RESULTS AND DISCUSSIONS**

In this project, the total power generated is satisfactory, greatly increasing the battery's usage time. The simulated Controller in the MatLab application is able to make the controller amplify the voltage and output enough to make it useful for the system, so according to James Clerck Maxwell and Michael Faraday's studies, electric motors are not perfect, that is, an energy that is injectable is not totally used, a small portion and dissipated. From that energy, a portion dissipated through the vibration to produce an energy production system and cause the developed system to achieve increased energy efficiency.

**CONCLUSIONS**

This project provides a great future perspective because it presents a simple way to transform the mechanical energy that is being diffused by the vibration, in electric energy.

After analysis and experiments, it was verified that the PZT grid connected to the motor together with the controller shows a great improvement in the generated energy levels.
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