Modeling of an Electromechanical Energy Harvesting System using an Linear Movement

Barbara Lafarge, Octavian Curea, Amélie Hacala-Perret, Benjamin Talon

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B. LAFARGE, O. CUREA, A. HACALA
ESTIA Recherche, Technopole IZARBEL
Bidart, 64210, France
b.lafarge@estia.fr, o.curea@estia.fr,
a.hacala@estia.fr

B. TALON
SOBEN SAS, Village Artisanal de Regourd
Cahors, 46000, France
benjamin.talon@soben.fr

***Abstract*_** *The complexity of today's vehicles is constantly increasing with new devices enhancing safety or comfort. Unfortunately, these new devices need energy to operate and sometimes their installation and, more precisely, their wiring is difficult because of moving parts or it complicates maintenance activities. This abstract presents the design, modeling and bench experiments of an energy recovery system that can be easily integrated in a car suspension. This work is the result of the collaboration between SOBEN company and ESTIA Recherche.*

Keywords—regenerative; energy harvesting; vehicle suspension; electromagnetic.

I. INTRODUCTION

Nowadays, the need to develop new kind of transportation is obviousness considering environmental issues. In this context, even low energy levels are interesting. We will focus on conversion of repetitive movements due to roads irregularities and driving conditions such as acceleration, braking and curves.

According to the literature, the linear electromagnetic generator is used to generate low powers for sufficing system of electronics power needs. [1], presents a brief history of energy harvesting: the techniques of conversion and management power, and batteries charging. The linear generators could be used to, for example, extend the lifetime of human implants [2-3], to generate power from human body motion [4], to create an inertial generator [5] and [6], to create a linear alternator in loudspeakers [7], or to harvest energy from low frequencies [8-9].

Estimates of the available energy on suspension were performed and show interest in developing systems to recover it. The potential reduction estimation in CO_2 emissions is between 1.4 and 5g/km [10].

In this paper, the idea is to present the model and simulation of the energy recovering system and to compare the results with measurements.

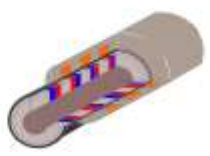

Figure 1: Configuration of energy recovering system

II. ENERGY HARVESTING SYSTEM CONFIGURATION

A. *System Description*

Fig.1, shows the detailed configuration of the proposed energy recovering system. In the central shaft of the system are integrated permanent magnets (PM) with the magnetic fields in opposition. This arrangement concentrates magnetic field lines around the coils, placed in the body of the system. The connection of the coils is in parallel, but it may also be in series in order to increase the output voltage. In both configurations, the recovered power is the same.

B. *Energy Harvesting System Design*

The dynamic modeling of this relies largely on the accurate representation of the magnetic field distribution and interaction with the coils. In this section, we propose a model of the distribution of the magnetic field and for the electromotive force.

The electromotive force (EMF) is governed by the equation (1). According to Faraday's law, a time varying magnetic field will induce an electric current.

$$e = - N_s * d\phi / dt \quad (1)$$

Here, $\boldsymbol{e}$ is EMF, $\boldsymbol{\phi}$ represents magnetic flux and $\boldsymbol{N_s}$ is the number of coil.

To simplify the model, we assume a sinusoidal variation of the magnetic fields inside the coils:

$$\phi(t) = B_{max} * S * \sin(\varphi * t + \varphi_o) \quad (2)$$

Here, $\boldsymbol{\varphi_o}$ is the initial phase and $\boldsymbol{S}$ is the area of the coil.

The EMF can be linked now to the displacement speed:

$$e = - N_s * d(\ B_{max} * S * \sin(2\pi * (v / d) * t + + (2\pi * p_e * h_{ec}) / h_{ae})) / dt \quad (3)$$

Here, B_{max} is the magnetic induction, v is the displacement's speed of permanent magnet, d is the displacement, p_e is the coil position, h_{ec} is the coil and armature winding height, h_{ae} is the magnet and tooth height.

The EMF and resistivity of each coils which equations are given, with L_{total} and R_{total}, are for each terms, the sum of inductance and resistivity of each coils,

$$U_{total}(t) = -L_{total}*di(t)/dt - R_{total}*i(t) + e(t) \quad (4)$$

III. Calculation, Analysis and Experimentation

The simulation results are obtained using a system level and a finite elements level modeling. Both models are studied and the results are compared.

A. System level Model

This simplified model allows us to access all the important parameters: displacement, strength, speed, harvesting power and voltage. The simulation with Matlab is complete rapidly and the results are accurate.

B. Finite elements Model

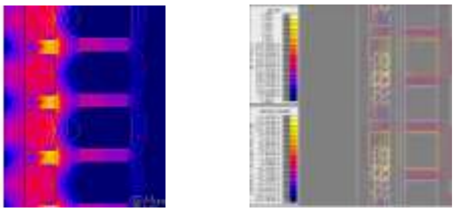

Figure 2: Finite Element Model of half damper : isovalue, isoligne of flux magnetic and magnet direction

Fig. 2 shows the spatial magnetic field distribution in the system obtained with the Flux 2D software. Results on EMF magnetic forces are also available.

C. Experimentation

Figure 3: Quarter car test bench

Theoretical studies and simulations are based on the experimental bench shows in Fig.3. This bench will be also used for the experimental validation of the model.

IV. Results

In this section, we compare results of measurement, finite element models and system level model implemented, according to the same system input (Fig. 4). Currently, we imposed a sinusoidal variation of the displacement speed as inputs of the models and test bench. Tests will be done also for a "real" road profile.

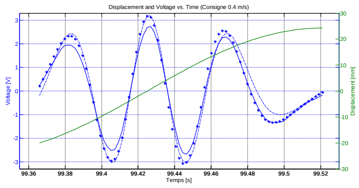

Figure 4: Suspension displacement [green] and Output voltage: Measured [blue], Matlab [blue--] and Flux 2D [blue*] (maximum speed: 0.4 m/s, displacement frequency: 2.625 Hz)

V. Futur Works

The first results are encouraging because, even if the amount of energy recovered is low, it can be sufficient to ensure. The current system has been designed with standard components. The next phase is the optimization of the system geometry to increase the amount of produced energy taking into account the weight reduction and the ease of integration into the suspension and, more generally, in the vehicle.

Acknowledgment

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