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Mathematical Modeling Of A Vehicle Crash: A Nonlinear Approach

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1 Introduction

One of the essential processes in designing a vehicle is its security validation. For such purpose, crash tests must be performed in order to demonstrate the security that the vehicle provides. However, these crash tests showed to be very expensive due to all the specifications and procedures needed to perform them. Therefore, alternative methods have been developed with the purpose of substituting these crash tests, like the finite element method and the lumped parameter models.

In this paper, a method which allow us to obtain the responses of a mathematical model from a full scale experiment's data of a vehicle crash is presented. The objective is to create a model that can give some of the data needed to design a vehicle, like its behavior during a frontal impact, thus the time of application of security equipment can be known.

2 Background

The model proposed in this paper is a spring-mass-damper system, where the damper will act after a deformation of the spring. The spring will be considered to have an elasto-plastic behavior, having a loading spring stiffness, k_L, and an unloading spring stiffness, k_U, where $k_U > k_L$. The damping parameters will be obtained by using the Rayleigh method, which propose that the damper coefficient is proportional to the mass and the spring stiffness.

The model will be represented by two second order differential equations which govern the two phases of the movement: the first part is a simple harmonic motion, represented by equation (1); and the second part is a damped one, represented by equation (2). The

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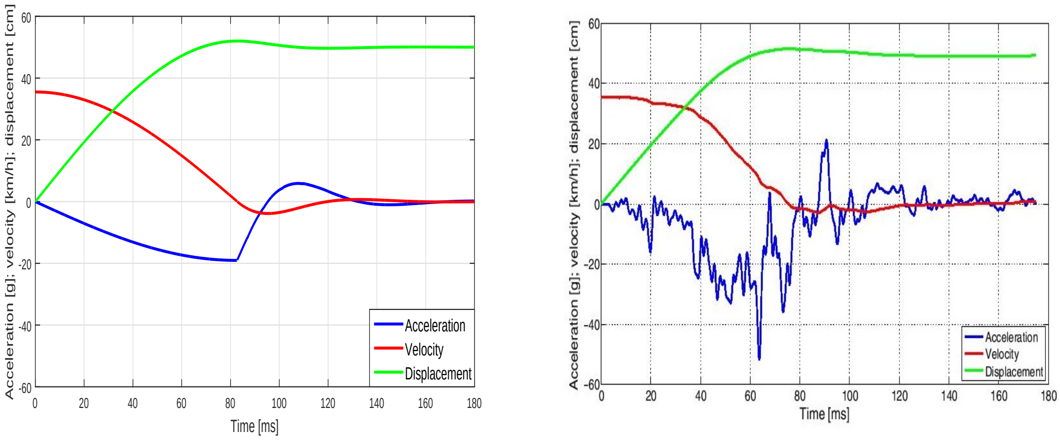

(a) (b)

Figure 1: Model's Response and Signal from The Experiment [2]

responses of the model will be obtained by applying the Runge-Kutta algorithm on the equations.

$$m\ddot{x}(t) + k_L x(t) = 0 \tag{1}$$

$$m\ddot{x}(t) + c\dot{x}(t) + k_U x(t) = 0 \tag{2}$$

The necessary initial conditions for the simulation were taken from [2]. Figure 1 shows the model's responses (Figure 1a) next to the signal experimentally measured (Figure 1b).

3 Conclusions

The results obtained by the presented method showed to be adequate for representing the vehicle collision and in conformity with the literature. The use of a spring with an elasto-plastic behavior in the mathematical modeling of a vehicle crash showed to be effective in representing the real vehicle crash phenomenon. Moreover, the use of damping made the model's responses be more similar to the signal measured in the experiment, giving then very reasonable results.

References

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