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Analysis of the dynamics of an electromechanical system subjected to two orthogonal and interdependent dry-friction forces

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Abstract: This work analyzes an electromechanical system with dry-friction forces. The system is composed of two coupled subsystems, a mechanical and an electromagnetic (a DC motor). The mechanical subsystem is subject to two dry-friction forces, modeled as Coulomb friction. Due to these two dry-friction forces, the resulting motion of the mechanical subsystem can be characterized by two qualitatively different and alternate modes, the stick- and slip-modes, with a non-smooth transition between them. The dry-friction forces acting on the mechanical subsystem are orthogonal and interdependent. In this paper, we construct the initial value problem that governs the system dynamics and we define the necessary conditions for the occurrence of the stick- and slip-modes. Numerical simulations are performed and the system response is analyzed for different combinations of mechanical and electromagnetic parameter values. One of the objectives is to quantify the stick-duration.

Keywords: electromechanical systems, dry-friction, stick-slip oscillations, stick-duration

1. Introduction

The presence of dry-friction in mechanical systems may induce stick-slip oscillations, a type of non-smooth dynamics [1,2]. When stick-slip occurs, the system response is characterized by two qualitatively different modes, the stick- and slip-modes [3-5]. The occurrence of stick-slip oscillations in mechanical systems is usually related to the existence of a force that saturates, i.e., a force whose magnitude is bounded, that is, the norm of the force is bounded, in certain conditions. The end of a stick-mode is related to the saturation of this force.

In this paper, we analyze stick-slip oscillations in a system with two orthogonal and interdependent dry-friction forces. Besides that, the system analysed is composed of two subsystems that interact, a mechanical and an electromagnetic (DC motor). Traditionally, stick-slip is analysed as the interplay of a friction force and an elastic one. In our case, there is no elastic force, it is substituted by a force generated by the motor. Then, we analyze stick-slip as the interplay of three forces: two dry-friction forces and one electromagnetic force (generated by the motor). The coupling between the two subsystems means mutual influence, i.e., the dynamics of the mechanical subsystem influences and is influenced by the dynamics of the electromagnetic subsystem [6-9]. Consequently, the dry-friction forces present in the mechanical subsystem affect and is affected by the interaction. Furthermore, the sick-slip oscillations affect and are affected by the electromechanical coupling. This paper is a continuation of our previous work [10] in which we analyze a simpler electromechanical system than the studied here. In [10] the electromechanical system was

subjected to just one dry-friction force. The presence of two orthogonal and interdependent dry-friction forces turns the system dynamics richer.

2. Results and Discussion

The system analyzed is a simple electromechanical system. It has just one mechanical and one electromagnetic degree of freedom. Due to the dry-friction forces, the system mode at each instant (stick or slip) depends on the state of the whole system, i.e., depends on mechanical and electromagnetic variables. Besides, during the stick mode, the motor rules the system dynamics. This is described by an initial value problem involving the current in the electric circuit of the motor. We consider that the construction of the dynamics (the initial value problem) that governs the dynamics of an electromechanical system with stick-slip is the major contribution of our work. Another contribution is the definition of the necessary conditions for the occurrence of the stick- and slip-modes. Depending on the values of the electromagnetic and mechanical parameter variables, the system response can be composed by: only slip mode (stick does not happen); sequence of alternate slip and stick modes (stick-slip oscillations); a slip followed by only a stick; only stick mode (the stick lasts forever). Numerical simulations are performed and it is shown the stick- and slip-modes parts in the response of the mechanical and electromagnetic subsystems.

3. Concluding Remarks

We analyze stick-slip oscillations without an elastic force (the most usual configuration in the literature). Instead of the elastic force, one has the force generated by a DC motor. Besides, we analyze stick-slip in a system subjected to two orthogonal and interdependent dry-friction forces. After the construction and analysis of the system dynamics, we quantify the stick-duration, one of the variables of great interest in systems with stick-slip dynamics.

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