Nonlinear control of friction-induced vibrations by using cascade architecture

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Abstract. This study proposes a new nonlinear control scheme for friction-induced vibrations (FIV). The approach consists of two stages. The first stage transforms the system into a cascade of independent subsystems and then the second stage focuses on the monitoring of the transient and stationary regimes of the associated dynamics. A comparison between the closed-loop performances of the proposed solution and of an input/output linearization technique has revealed a better efficiency of the present solution, especially for transient tuning in the presence of limited control amplitude. Moreover, the observed performances have shown interesting robustness with respect to the saturation of the corresponding control.

Introduction

Mitigating friction-induced vibrations (VIB) is of central importance in numerous applications [1] in order to avoid their negative effects on the system performances. Numerous methods ranging from classical techniques based on proportional integral and derivative (PID) actions [2] to more sophisticated nonlinear and robust techniques [3, 4], were proposed. Most of these studies have focused on the stability of the steady state at the stationary regime, however, and have neglected transient properties of the controlled FIV. The present work deals with the active control of FIV, and pays particular attention to ensuring good transient properties in terms of damping and settling times. It proposes a new scheme which consists of two control stages. The first stage puts the system into a cascade of independent subsystems the dynamics of which becomes simpler to control. Then, the second stage designs feedback controllers with specified damping characteristics.

Application and results

The Hultèn system given at the left side of Figure (1) and which is widely used in the FIV framework, is considered in the present study in order to assess the efficiency of the proposed control scheme. A comparison between the latter and the nonlinear control based on input/output linearization was carried out. One of the results obtained by both methods is given at the middle and the right side plots in Figure (1). It consists in the time evolution of the vertical displacements X_1 of the mass. The right side plots are zooms on the X_1 transient. Results have revealed that the new architecture yields an asymptotically stabilized dynamics with better transient properties than that obtained by applying an input/output linearizing state feedback. Furthermore, it allowed a better compromise between the damping properties of the transient and the amplitudes of the corresponding controls. Finally, its stabilizing effects have exhibited a better robustness than the input/output linearizing state feedback with respect to the saturation phenomenon occurring when the control amplitudes reach high levels.

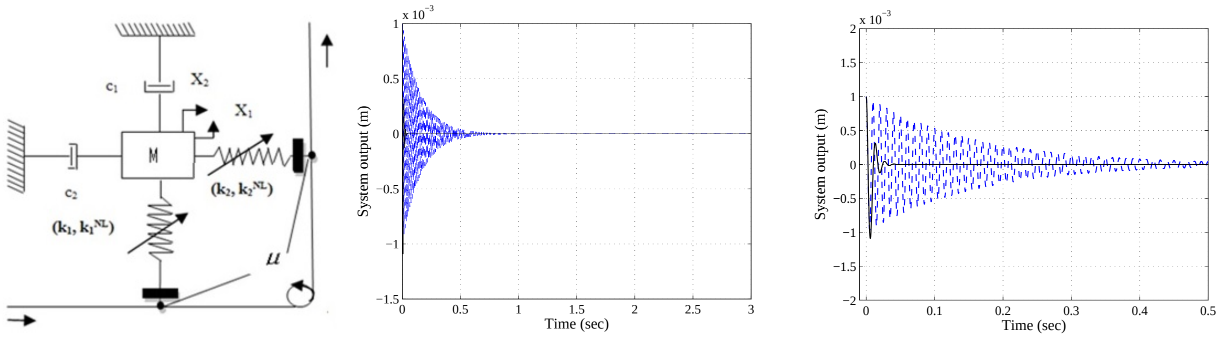

Figure 1: From left to right-Hultèn system - The controlled displacement X_1 -Zoom on the transient of the controlled X_1. Solid line: Cascade architecture based control, dashed line: Input/output linearizing state feedback control

References

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