Vibro-impact dynamics of a universal experimental rig with two-sided constraints

Bingyong Guo*, **Yang Liu***

*College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter, UK

Abstract. This work studies the vibro-impact dynamics of a universal two-sided drifting experimental rig with two-sided constraints which can be used for experimental testing of many piecewise-smooth dynamical systems, such as the impact oscillator [1], the drifting oscillator [2], and the capsule system [3], and their control strategies. In particular, we will focus on investigating the grazing and sliding bifurcations induced by the impact and friction encountered by the experimental rig, and compare the dynamics of the systems with one-sided and two-sided constraints.

Introduction

Vibro-impact systems have been widely utilised in engineering practice. One notable application is to provide vibro-impact-driven progression for self-propelled mechanism [4]. For such a mechanism, the environmental friction and vibro-impact dynamics induce very rich and complex non-linear phenomena in the system. Inspired from the design of our previous experimental rig [5], which was a vibro-impact two-sided drifting system with one-sided constraint, a novel two-sided drifting experimental rig with two-sided constraints was developed as shown in Figure 1(a). The aim of this work is to compare the dynamics of the vibro-impact systems with one-sided and two-sided constraints, the so-called capsule system which were studied numerically in [6]. We wish to use this new rig to investigate various grazing and sliding bifurcations observed in the capsule system [3].

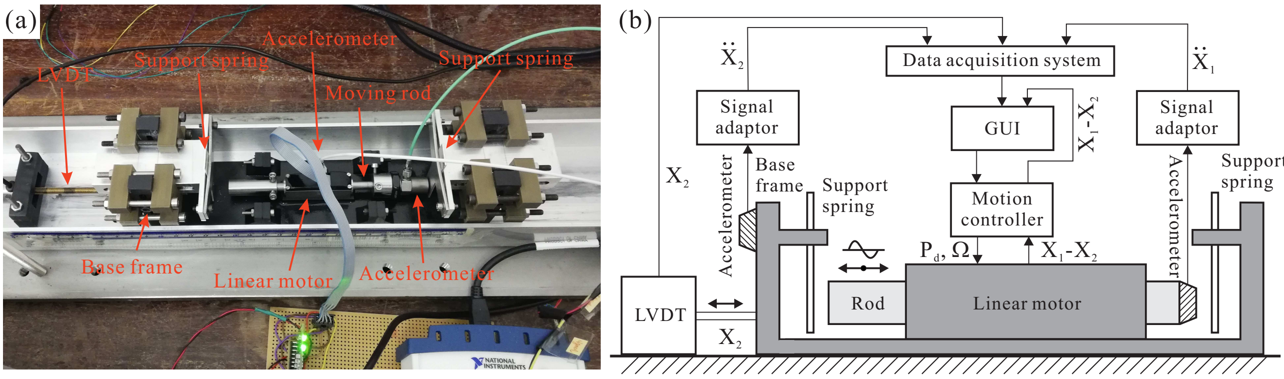

Figure 1: (a) Photograph and (b) schematic of the novel two-sided drifting experimental rig.

Experimental apparatus

A schematic of the experimental rig is presented in Figure 1(b). As can be seen from the figure, a linear DC servomotor was mounted on a base frame which also held two support springs with adjustable stiffness. The motor has a movable internal rod harmonically excited with a desired frequency and amplitude, Ω and P_d, via the electromagnetic field provided by the coils in the motor. The moving rod will contact with the front or the back support spring when their relative displacement is equal to zero. The absolute displacement of the base frame is X_2 which was measured by a linear variable differential transformer (LVDT). The relative displacement between the rod and the base frame, $X_1 - X_2$, was measured through the motor using Hall sensors. The accelerations of the rod and the base, $\ddot{X}_1$ and $\ddot{X}_2$, were obtained using two accelerometers mounted directly on the rod and the base, respectively. The signals from these devices were captured and observed in real time using a data acquisition system.

Acknowledgments. This work has been supported by EPSRC under Grant No. EP/P023983/1.

References

[1] Liu, Y., Páez Chávez, J. (2017) Controlling coexisting attractors of an impacting system via linear augmentation. *Physica D* **348**:1-11.

[2] Liu, Y., Páez Chávez, J., Pavlovskaia, E., Wiercigroch, M. (2018) Analysis and control of the dynamical response of a higher order drifting oscillator. *Proc. R. Soc. A* **474**:20170500.

[3] Guo, B., Liu, Y. (2019) Three-dimensional map for a piecewise-linear capsule system with bidirectional drifts. *Physica D* **399**:95-107.

[4] Guo, B., Liu, Y., Birler, R., Prasad, S. (2020) Self-propelled capsule endoscopy for small-bowel examination: Proof-of-concept and model verification. *Int. J. Mech. Sci.* **174**:105506.

[5] Liu, Y., Pavlovskaia, E., Wiercigroch, M. (2015) Experimental verification of the vibro-impact capsule model. *Nonlinear Dyn.* **83**:1029-1041.

[6] Yan, Y., Liu, Y., Liao, M. (2017) A comparative study of the vibro-impact capsule systems with one-sided and two-sided constraints. *Nonlinear Dyn.* **89**:1063-1087.