Study the Bifurcations of a 2DoF Mechanical Impacting System

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Abstract. Impacting mechanical systems with suitable parameter settings exhibit a large amplitude chaotic oscillation close to the grazing with the impacting surface. The cause behind this uncertainty is the square root singularity and the occurrence of dangerous border collision bifurcation. In the case of one degree of freedom mechanical systems, it has already been shown that this phenomenon occurs under certain conditions. This paper proposes the same uncertainty of a two-degree freedom mechanical impacting system under specific requirements. This paper also shows that the phenomena earlier reported in the case of one degree of freedom mechanical systems (like narrow band chaos, finger-shaped attractor, etc.) also occur in the two degrees of freedom mechanical impacting system. We have numerically predicted the narrowband chaos ensues under specific parameter settings. We have also shown that the narrowband chaos can be avoided under some parameter settings. At last, we demonstrate the numerical predictions experimentally by constructing an equivalent electronic circuit of the mechanical rig.

Introduction

Various dynamical systems are observed in multiple areas of science and engineering, where impacts occur between the components of the systems. These systems exhibit a rich sort of dynamical phenomena, especially in the range of parameter values where grazing occurs. The phenomena include transitioning from one periodic attractor to another through the chaotic orbit at grazing, finger-shaped chaotic attractors at the bifurcation point in the Poincaré section, etc. These practical and engineering systems have been studied in detail for the last thirty years, especially on one degree of freedom mechanical impacting system under different configurations [1, 2]. The purpose of this work is to propose a forced two-degrees of freedom mechanical system with a compliant impact. Under some parameter settings, we have shown the onset of chaos in the bifurcation diagram when the amplitude of the externally applied periodic signal is varied. We also have shown that when there is a specific relation between the externally applied signal's frequency and the system's natural frequencies, the chaotic attractor can be avoided, as studied in one degree of freedom mechanical impacting system.

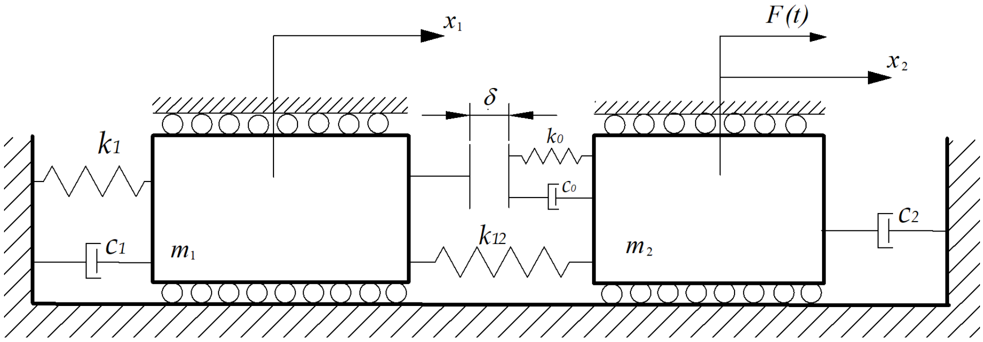

Figure 1: The schematic representation of a two-degree of freedom mechanical impacting system.

System description

A schematic diagram of a two-degree of freedom mechanical system under study is depicted in Fig. 1. It is a forced damped oscillator with a massless compliant obstacle that the mass m_1 can impact. The massless complaint obstacle is attached to another mass m_2 with a spring having spring constant k_o and a damper with the damping coefficient c_o. The mass m_1 is attached to a fixed support by a spring with spring constant k_1 and a damper c_1. The mass m_2 is connected to the fixed support with a damper c_2. The two masses m_1 and m_2 are connected with a spring having spring constant k_{12}. The forcing periodic function $F(t)$ is acted on the mass m_2. Due to the application of the external forcing, the masses m_1 and m_2 started to oscillate from their equilibrium positions. x_1 and x_2 are the amount of displacements of the two masses m_1 and m_2 from their equilibrium positions, respectively. We have observed the dynamics of this system when the amplitude of $F(t)$ is changed.

References

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[2] Seth S., Banerjee S. (2020) Electronic circuit equivalent of a mechanical impacting system. *Nonlinear Dynamics* **99**: 3113-3121.