Dynamical analysis of vibro-impact system with non-ideal excitation

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Abstract. This study is concerned with a vibro-impact system with non-ideal excitation. The mathematical model comprises a crank-slider mechanism and one oscillator attached to it, where the eccentric drive is exposed to non-ideal excitation. There is a base/boundary on the right-hand side of the oscillator and of interest for practical applications is to determine when the oscillator can impact it depending on the ratio between the excitation and natural frequency. Both analytical and numerical approaches are utilized for this purpose, enabling other nonlinear phenomena to be detected as well.

Introduction

Vibro-impact systems appear in many engineering machines, such as hand-held percussion machines, pile driving machines, cutting and grinding machines, etc. Both vibro-impact systems [1] and systems with non-ideal excitation [2] have been analysed separately in many studies but there are only few papers in which these two systems are analysed jointly, i.e. in the form of a vibro-impact system with non-ideal excitation [3]. This study contributes to this shortcoming by investigating a vibro-impact system consisting of a crank-slider mechanism and one oscillator attached to it, where the system is exposed to non-ideal excitation T (Figure 1a). The impact (inelastic collision) occurs during the motion of the oscillator as it can fit a base/boundary on the right-hand side, and the excitation of the driving source is affected by this behavior. The aim is to develop analytical approaches that will enable all possible solutions to be determined, especially impact ones and those that numerical approaches cannot catch.

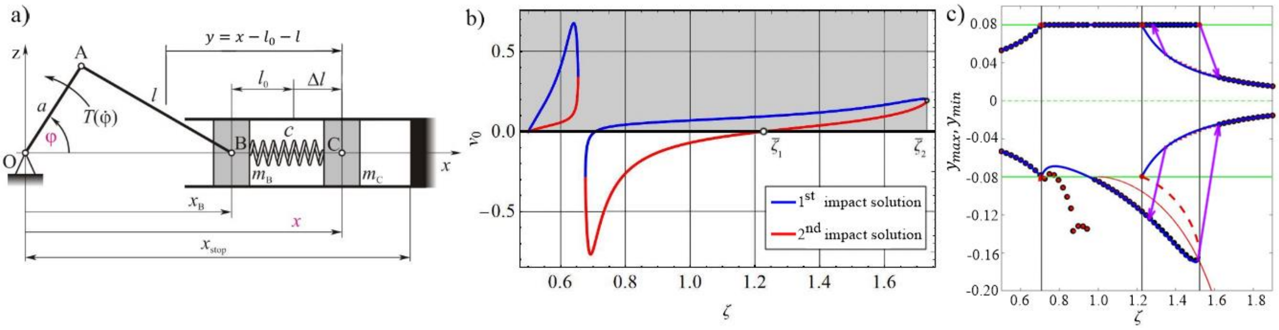

Figure 1: a) Mechanical model (x-absolute coordinate, y-relative coordinate); b) Impact velocity versus frequency ratio; c) Frequency response diagram (**o**, x – run up and close down numerical solutions; —, – – –– analytical solutions; ⟶ - jumps).

Results and discussion

The mathematical model of the system under consideration has a form of two coupled nonlinear equations. By developing an approximate analytical method, a new insight is gained regarding how the impact velocity v_0 changes with frequency ratio ζ (the ratio between the excitation and natural frequency). One solution obtained is presented in Figure 1b, indicating the existence of multiple impact solutions, some of which are physically impossible: they correspond to $v_0<0$, as the oscillator cannot hit the base then. Further analytical considerations yield an amplitude-frequency equation. One corresponding amplitude-frequency diagram is shown in Figure 1c. Numerical results are also plotted, confirming the accuracy of the analytical ones. The region of unstable solutions is indicated by the dashed red line. The green solid lines stand for the boundary at which the oscillator can hit the base. Thus, the frequency-response diagram is flat in the frequency region where such impact solutions appear, which is interest for practical applications. Other solutions are non-impact ones. Jumps of the amplitude can also occur, as noted by the arrows in Figure 1c. Families of amplitude-frequency diagrams are further produced to investigate the system dynamics and the influence of the system parameters on it.

References

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