Preliminary experimental study on the influence of the gap in a vibro-impact system with two-sided constraints

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Abstract. The large displacements caused by exceptional loads, like strong earthquakes, in base-isolated structures can damage the isolation system or lead to pounding with surrounding moat walls or adjacent structures, if the available seismic gap is not sufficient. A possible mitigation measure consists in the interposition of deformable shock absorbers (bumpers). In this work, some preliminary results of an experimental laboratory campaign, conducted considering a single-degree-of-freedom oscillator, excited by a harmonic base acceleration and symmetrically constrained by two unilateral deformable and dissipative bumpers, are illustrated. Particular attention is devoted to the study of the effect of small positive, null and small negative values of the gap amplitude on the system response.

Introduction

The problem of impact is ubiquitous in many engineering applications involving mechanical components or structures repeatedly colliding with one another or with obstacles. In the context of structural pounding, the occurrence of strong earthquakes can produce large horizontal displacements in base-isolated structures, which can damage the isolation system or can lead to pounding with the surrounding moat walls or adjacent structures, if the available clearance is not sufficient. A possible mitigation measure consists in the interposition of deformable shock absorbers (bumpers). This problem inspired several works of the authors, of both numerical and experimental nature, in which a single-degree-of-freedom oscillator, impacting against two deformable and dissipative bumpers, was considered [1, 2] (Fig.1a). The numerical analyses highlighted gradually more varied and complex behaviors, decreasing the gap between mass and bumpers [2]. Furthermore, the combination of small gaps with quite deformable bumpers appeared to be a good choice which allows to realize, compared to the free flight condition, a reduction of both accelerations and displacements or a good compromise between reduction of displacements and limited increase in accelerations [1]. Based on these considerations, a new laboratory campaign was designed and conducted to investigate, in particular, small positive, null and small negative (prestressed bumpers) values of the total gap between mass and bumpers and to validate the numerical predictions. In this work some preliminary results of the new laboratory campaign will be presented.

Results and discussion

The evolution of the experimental forward (red) and backward (blue) Pseudo-Resonance Curves (PRCs) of normalized excursion of relative displacement (η_{d}) and absolute acceleration (η_{a}) of the mass with the total gap G is represented in Fig.1b, c, with respect to one bumper and one value of peak table acceleration.

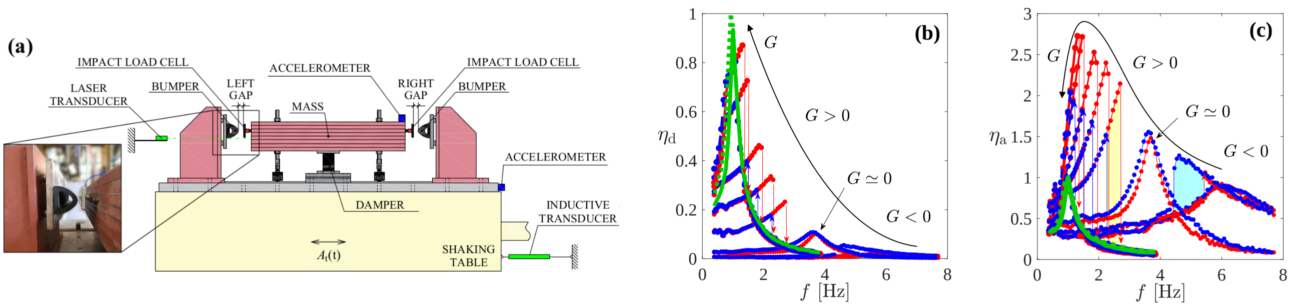

Figure 1: a) Schematic view of the setup; forward (red) and backward (blue) PRCs of: b) η_{d} and c) η_{a} for different gaps G.

It can be observed that, compared to the free flight condition (green curves), the hardening caused by the impact against the bumpers bends the PRCs to the right. They are characterized by the occurrence of jumps, and thus of a *primary right hysteresis* (highlighted in yellow in Fig.1c), and gradually more complex scenarios at low frequencies, associated with *secondary resonances*, as G decreases. The situation returns to be smooth for bumpers initially in contact with the mass ($G \simeq 0$), with the resonance shifted to higher frequencies and without jumps or hysteresis. For $G < 0$, obtained by slightly *prestressing* the bumpers, PRCs bend to the left, due to a softening-like behavior, showing jumps and a *primary left hysteresis* (highlighted in cyan in Fig.1c), while for higher *prestressing* values, the PRCs are no longer bent and show neither jumps nor hysteresis.

References

[1] Andreaus U., De Angelis M. (2020) Influence of the characteristics of isolation and mitigation devices on the response of single-degree-of-freedom vibro-impact systems with two-sided bumpers and gaps via shaking table tests. *Struct Control Heal Monit* **27**:1-21.

[2] Stefani G., De Angelis M., Andreaus U. (2020) Scenarios in the experimental response of a vibro-impact single-degree-of-freedom system and numerical simulations. *Nonlinear Dyn*.