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Assessing the effect of different configurations of inerter-based devices for structural vibration control

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Abstract: The use of lightweight materials with enhanced mechanical properties and improved quality of design due to the use of advanced computer methods have led to the trend of designing increasingly slim structures that are more prone to vibrations. To control these structures, the vibrations mitigation effect of well-known passive control systems such as Tuned Mass Dampers (TMDs) and Base Isolation Systems (BISs), can be enhanced by using a mass amplification device called inerter. In this study, the behavior of this device and its influence on the response of vibration-prone systems is investigated by analyzing different configurations in a civil engineering context, finding optimized parameters and assessing the performance of various suspension layouts with the inerter placed at different positions. Indeed, the position of the device can strongly influence the benefits brought in the structural control design. Therefore, a more critical analysis is proposed with respect to previous studies on the use of inerter-based devices for vibration control, with the aim of consistently investigating the exploitation of these innovative systems in practical applications.

Keywords: inerter, passive structural control, vibration absorber

1. Introduction

To achieve the most effective structural control the fabrication of innovative devices capable of reducing and control both horizontal and vertical vibrations is one of the major challenge for researchers and designers in structural engineering. In this regard, inerters are comparatively recent additions to the arsenal of civil engineers and structural control. The inerter is a mechanical device, introduced for the first time by M. Smith [1], that acts as an apparent mass, called inertance, which can be orders of magnitude larger than its physical mass. In general, the device can be considered as a linear mechanical element in which the two terminals develop an internal force proportional to the relative acceleration of its terminals. Specifically, the mass amplification property can allow to enhance the performance of several mass-dependent devices. On this base, to control the acceleration level, several inerter-based suspension layouts can be employed with the inerter placed at different positions. In literature, various configurations have already been proposed. Nevertheless, some works present results could appear not adherent to the reality and not suitable for practical application [2].

2. Results and Discussion

With the aim of investigating the effectiveness of various suspension layouts comprising the inerter, a comparison between the response of a single-degree-of-freedom system (SDOF) coupled with a classical TMD and SDOF systems equipped with different inerter-based devices is shown in Figure 1. As can be seen, the lowest displacement response results from the layout G1, where the inerter is connected between the ground and the TMD mass. A slightly better result, compared to a traditional TMD, is obtained when the inerter is placed between the main mass and the auxiliary mass, which is arranged in series with a dashpot and in parallel with a spring (configuration K1). On the other hand, contrary to the conclusions in [2], the behavior of the proposed configuration, in which the inerter is simply attached between the main and the TMD mass, appears to be even worse than the configuration in which the device is not included (traditional TMD). It can be concluded that, although it is not a normal use for the inerter (in the original mechanical context the inerter has two independently movable terminals), the best performance is obtained in the case where one of the two terminal is grounded. This different behavior could be due to the presence of a negative inertance in the entries not on the diagonal in the mass matrix. These terms, in fact, are not present in the case of a grounded terminal. Thus, the resistance to acceleration can be considered as a mass element of a mass equal to the inertance itself.

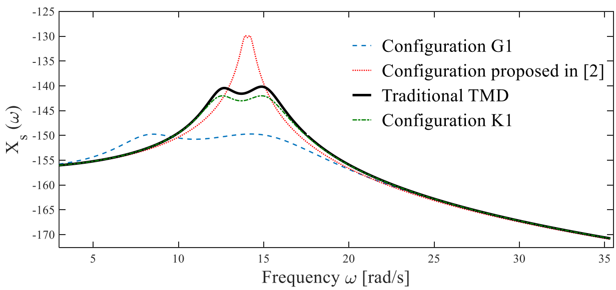

Fig. 1. Displacement response in frequency domain of different configurations

3. Concluding Remarks

This paper demonstrates with a more critical analysis the performance of inerter-based devices for vibration control emphasizing the importance of the inerter location in different suspension layouts. Numerical analysis indicates that to achieve the highest mass amplification effect one of the inerter terminals must be attached to a fixed point.

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