A hysteretic vibration absorber for the mitigation of a flexible structure response

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Abstract. A hysteretic device is proposed to reduce the vibration of a structure. It offers two advantageous aspect.:First it naturally increases the dissipative characteristics of the system. Second, more importantly, the strong nonlinearity of hysteresis produces those nonlinear phenomena which give beneficial effects from the transfer of energy from the directly excited mode to other modes of the structure. A real 2DOF structure is used to demonstrate the effectiveness of the proposal.

Introduction

The trend of designing increasingly lean structures emphasizes the importance of dynamic responses and the need to reduce these effects. A standard technique to lower structural vibration is to use elements capable of dissipating energy. The proposal to add a hysteretic element makes it possible to combine the twofold aim of increasing the structure dissipation characteristics and of introducing a nonlinearity which can potentially facilitate the spreading of input energy among the system modes. After the fundamental work by Den Hartog [1] devoted to the vibration mitigation of linear structures, several papers demonstrated the beneficial effects of nonlinear devices connected to structures [2]. Hysteresis characterizes the mechanical behaviour of various materials and elements. With respect to viscoelastic tuned mass damper (TMD), a hysteretic vibration absorber (HVA) has the advantage that the restoring force combines the elastic and dissipation characteristics without the need of a damper. Furthermore, the multivalued constitutive law and the notable dependence of stiffness and damping properties on the oscillation amplitude include this behaviour among those that are strongly nonlinear. This triggers a large variety of nonlinear phenomena: in particular, the modification of frequencies eases the occurring of internal resonance conditions where modal interactions are responsible for the transfer of energy from the directly excited mode towards not directly excited modes. These phenomena are the topic of previous papers [3]; here, focusing on a specific structural application, a hysteretic device described by the Bouc-Wen model is used in vibration reduction of a two degree-of-freedom system.

Results and discussion

The case of internal resonance 1:1 which resembles the Den Hartog proposal is first dealt with. Other than being a simpler solution, its effectiveness is similar to that of viscoelastic TMD, but only in a definite excitation range, due the dependence of its characteristics on the oscillation amplitude. Moreover, in this case no typical phenomena of nonlinear dynamics are activated. Different is the case of internal resonance conditions n:1, with $n > 1$ which promotes the occurrence of a rich variety of nonlinear phenomena. Among them, the occurrence of a novel mode around the first resonance through a bifurcation mechanism involves the second mode in the response, with a beneficial effect on the vibration amplitude of the directly excited first mode. In Fig. 1a around the first resonance, for a certain value of excitation, two peaks appear in the FRC: the reduction of the response due to the addition of the HVA (red curve) with respect to the uncontrolled case (NC) is evident; this advantageous behaviour still remains in a large range of frequency and intensity of excitation (Fig.1b).
Several other internal resonance conditions could be investigated; this application demonstrates the efficiency of introducing a hysteretic element for the passive control of structural vibrations.

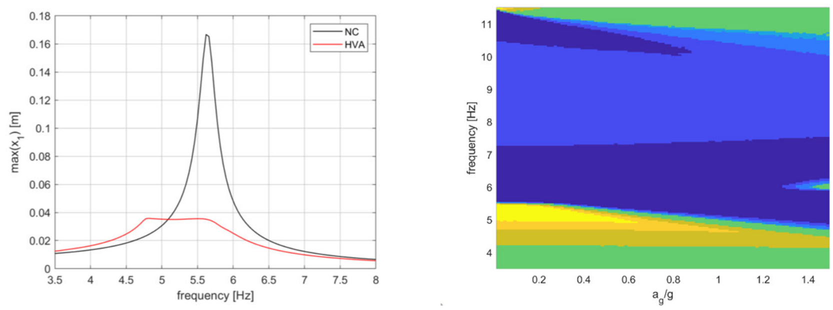

Figure 1: TC4 oscillator close to a (2:1) internal resonance ($\omega_{2A}/\omega_{1A}\cong 2.15$, $\omega_{2B}/\omega_{1B}\cong 1.46$): (a) FRCs of oscillation amplitudes of mass m_1 for non-controlled (NC) and HVA responses at optimal excitation $a_g = 0.83g$ (red curve); (b) Color map comparing the maximum displacements of NC and HVA oscillators (cold colors reveal amplitude reductions)

References

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