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Experimental Study of Global Response of a Model Airplane with a Strongly Nonlinear Store on Each Wing

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Abstract Global dynamics of a model airplane with a strongly nonlinear store attached to each wing under impulsive loading is studied for several combinations of locked and unlocked stores.

Following methods introduced in [1-2], we investigate the effects of local, strongly nonlinear attachments, in this case a store (e.g., an auxiliary fuel tank or missile), attached to each wing, on the global dynamics of a model airplane [3] (Figure 1). The stores are constructed and installed such that, when locked, they contribute only a mass effect to the dynamics, while when unlocked they impart strong nonlinearity to the dynamic response of the plane. The system is studied experimentally, under impulsive excitation to one of the wings, in three configurations: with (a) both stores locked (the baseline linear system); (b) one store unlocked; and (c) both stores unlocked. The measured responses reveal that the unlocked stores drastically affect the participation of the first and second modes of the plane despite being local attachments. These global effects are further investigated by projecting the measured responses of configurations (b) and (c) onto the linear modes of the plane (i.e., with both stores locked, configuration (a)), computed using an experimentally-updated finite element model. These are used to compute the instantaneous total energy of each projected linear modal response. This reveals that, when only one store is unlocked (configuration (b)), the first and second projected modal responses decay at significantly faster rates than the first and second modal responses observed for the linear baseline system (configuration (a)). However, when both stores are unlocked (configuration (c)), the first projected modal response again decays at an increased rate, whereas the second projected modal response closely follows the second modal response of the linear baseline system. These results suggest that, when both stores are unlocked, their modal responses interfere both constructively and destructively depending on the locations of the measurements, resulting in this somewhat counterintuitive outcome of greater effective modal damping with one unlocked store than with two.

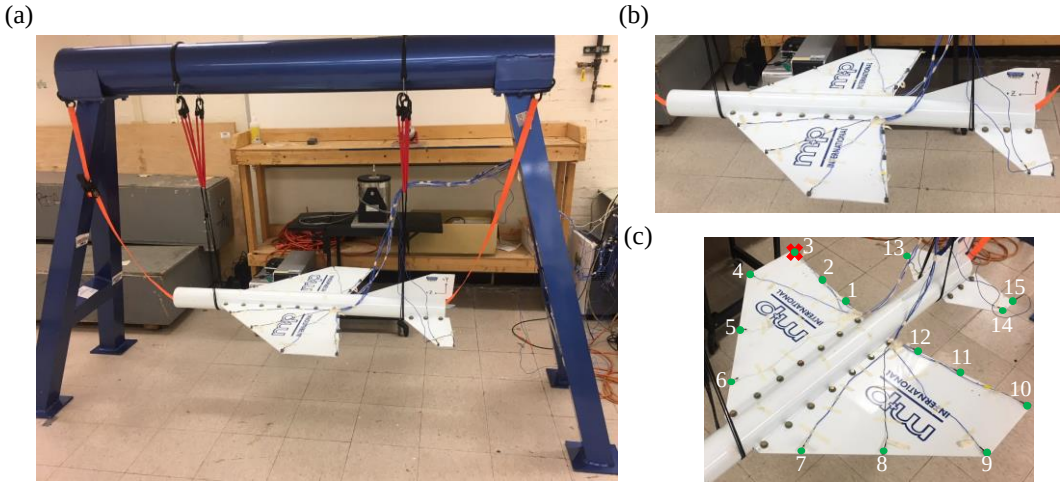

Figure 1: (a) Support structure with the suspended plane fully instrumented, (b) zoomed-in view of the suspended plane, and (c) the instrumentation scheme used for the experimental measurements with green circles and the red cross indicating accelerometer and impact locations, respectively.

References

[1] K.J. Moore, M. Kurt, M. Eriten, D.M. McFarland, L.A. Bergman, A.F. Vakakis, *Direct Detection of Nonlinear Modal Interactions from Time Series Measurements*, Journal of Mechanical Systems and Signal Processing, Special Issue on Exploring Nonlinear Benefits in Engineering. https://doi.org/10.1016/j.ymssp.2017.09.010. (In press)

[2] K.J. Moore, M. Kurt, M. Eriten, D.M. McFarland, L.A. Bergman, A.F. Vakakis, *Time Series Based Nonlinear System Identification of Modal Interactions Caused by Strongly Nonlinear Attachments*, Journal of Sound and Vibration, 438, 13-32, 2019. DOI: 10.1016/j.jsv.2018.09.033.

[3] K. J. Moore, A. Mojahed, L.A. Bergman, A. F. Vakakis, *Local Nonlinear Stores Induce Global Effects in the Dynamics of an Experimental Model Plane, AIAA Journal*. (Submitted)