Nonlinear dynamics inspired control

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Abstract: The field of Nonlinear Dynamics is transitioning from being focused on investigation of nonlinear dynamical phenomena to serving as a new design platform of high-performance structures and devices through the advantageous exploitation of various nonlinear phenomena across different scales. This is true in the field of vibration control as well as in the synthesis of engineered systems and materials.

In this talk, tuned mass dampers (TMD) exploiting hysteretic nonlinearities are shown to perform better than linear TMDs within the design bandwidth. The hysteretic nonlinearity is purposefully designed via use of SMA/steel wire ropes in which energy is dissipated through interwire friction and SMA phase transformations. Perturbation methods and Differential Evolution algorithms are employed synergestically to drive the optimization process. Examples are shown in the field of sway control of multi-story buildings and flutter control of long-span suspension bridges. In addition, the mitigation capability of these TMDs in coping with earthquakes is discussed. The earthquake-excited structures often exhibit softening behavior and strength degradation. Such nonlinear behaviors can severely affect the TMDs performance due to the frequency detuning caused by the structural frequency variations with the oscillation amplitude. On the contrary, nonlinear TMDs can be more robust in terms of nonlinear frequency tuning that can lead to an optimal energy transfer from the structure to the TMD. Two types of nonlinear structures are considered, namely, steel- and masonry-made buildings. The TMD optimal parameters are obtained using a Differential Evolution algorithm according to different cost functions and making use of a set of seven seismic records (city of L'Aquila). The results are discussed for hysteretic TMDs with different mass ratios and in terms of reductions in the r.m.s displacement and Arias intensity.

The talk ends with an overview of recent advances on high-damping nanomaterials made of a hosting matrix and carbon nanotubes (CNT). The hysteresis exhibited as frictional sliding between the CNTs and the polymer chains of the hosting matrix can be largely modified and optimized by adjusting the micro-structural features to optimize vibration suppression up to unprecedented levels. Recent experimental and modeling efforts are discussed in the context of new directions in material design for dynamic applications.

Biosketch

Dr. Walter Lacarbonara is a Professor of Nonlinear Dynamics at Sapienza University. During his graduate education he was awarded a MS in Structural Engineering (Sapienza University) and a MS in Engineering Mechanics (Virginia Tech, USA), and a PhD in Nonlinear Structural Dynamics. His research interests cover nonlinear structural dynamics; asymptotic techniques; nonlinear control of vibrations; experimental nonlinear dynamics; dynamic stability of structures (suspension/arch bridges, aircraft wings, gigantic magnetically levitated rotating rings); modeling and dynamics of macro and nanocomposites. He is Editor in Chief of Nonlinear Dynamics. He is currently serving as Chair of the ASME Technical Committee on Multibody System and Nonlinear Dynamics. He served as general co-Chair and technical program co-Chair of the ASME 2015 (Boston, USA) and 2013 (Portland, USA) IDETC Conferences. He has organized over 10 international symposia and conference sessions.

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He has published over 250 papers and conference proceedings, 3 patents, 10 book chapters, and a Springer book (Nonlinear Structural Mechanics. Theory, dynamical phenomena and modeling) for which he received the 2013 Texty Award nomination by Springer US.