Nonlinear Damping Characteristic of Nanocomposite Beams Via Dynamical Analysis

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Abstract. The nonlinear dynamical behavior of nanocomposite beams made of polybutylene terephthalate and branched carbon-nanotube (CNTs) are experimentally investigated. The frequency response curves of specimens with different CNTs weight fractions are obtained in cantilever configurations by applying a base excitation and measuring the tip displacement. The stationary response of the beams is acquired for different excitation levels in order to capture the nonlinear trend for increasing oscillation amplitudes. In particular, the additional damping provided by the interfacial stick-slip between CNTs and hosting matrix determines a softening response in the small oscillation range exhibited by the reduction of the lowest resonance frequency followed by a hardening trend at higher amplitudes. The experimental results are identified by employing a closed-form solution of the stationary response based on a hysteretic nonlinear beam model.

Introduction

The main source of energy dissipation in CNTs polymeric nanocomposites is attributed to the phenomenon of stick-slip between CNTs and surrounding polymer chains [1], so that the interfacial surface area, topology and CNT/polymer interaction are key factors to understand the nonlinear damping properties [2]. Softening nonlinearity due to the material viscous damping in the hosting matrix combined with hysteretic interfacial dissipation, and geometric nonlinearities (often of hardening type) inherent in structural elements, lead to complex nonlinear behaviors. In particular, in [3] the dependency of the softening-hardening behaviour on the oscillation amplitude was experimentally investigated for evaluating the effectiveness of the dispersion of single walled CNTs in a hosting matrix made of polybutylene terephthalate polymer (PBT).

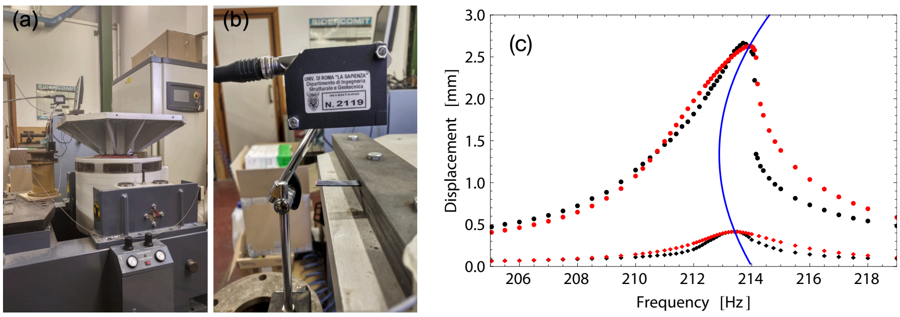

Figure 1: Electro-mechanic shaker (a) and tested beam (b). Comparison between the experimental (black markers) and identified (red markers) FRCs (c) for excitation amplitude equal to 2.35g/0.405g (circle/diamond markers); identified backbone curve (blue line).

Results and Discussions

The FRCs for the lowest mode of cantilever nanocomposites beams with different weight fractions of branched CNTs are experimentally obtained by performing several frequency sweeps for increasing excitation levels. The nonlinear dynamical properties reveal in particular the stick-slip mechanism that induces a softening behavior exhibited by the decreasing trend of the resonance frequency in a small oscillation range. Past a threshold amplitude, the bending curvature geometric nonlinearities become prominent inducing an hardening behavior. Some of the experimental FRCs have been identified employing a closed-form solution obtained in [4] in the context of a hysteretic nonlinear beam model. Such a model is characterized by a continuous hysteretic moment-curvature relationship, mimicking Bouc-Wen models, while the closed-form solutions for FRCs are found out by applying the method of multiple scales up to higher order terms.

The performed identification shows a good agreement with the experimental results including the softening-hardening transition. Further ongoing investigations are aimed at using the identified model parameters to extrapolate important mechanical features of these remarkable materials which are not directly measurable.

References

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