A new methodology for nonlinear analysis of magneto-rheological elastomers behavior under large amplitude oscillatory axial (LAOA) loadings

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Abstract. The aim of present paper is to develop a methodology to quantify nonlinear response of magneto-rheological elastomers (MREs) under LAOA loadings using Chebyshev polynomials of the first kind. This permitted determination of the compression and tension elastic moduli at the minimum, zero, and maximum strain, as alternatives to equivalent linear first harmonic moduli extracted using Fourier transform. The proposed local measures can provide the interpretation of inter- and intra-cycles nonlinearities without observing the stress-strain hysteresis response of MREs under LAOA loadings.

Introduction

Composed of magnetically responsive particles embedded within a non-magnetic soft polymeric medium, magneto-rheological (MR) elastomers (MREs) are multifunctional field-responsive smart materials, whose mechanical properties (e.g., stiffness and damping) can be adjusted on-demand via application of external magnetic field [1]. The shear mode characterization of viscoelastic materials, such as MREs under large amplitude oscillatory shear (LAOS) loadings, has been well established [2]. Ewoldt et al. [3] provided a novel framework for quantifying the nonlinear properties of viscoelastic materials under LAOS loadings in a unique manner, in which the inter-cycle (i.e., strain softening) and intra-cycle (i.e., strain-stiffening) measures can be effectively predicted before observing the stress-strain characteristics response. The nonlinear identification of viscoelastic materials under LAOA has been rarely investigated. Particularly no study has been conducted on non-linear identification of MREs under large amplitude oscillatory axial (LAOA) loadings. Hence, in this study, the main objective is to provide a new methodology for identifying nonlinear behavior of smart viscoelastic materials under LAOA loadings.

Results and Discussion

An experimental test setup was designed for the purpose of characterization of MREs under LAOA loadings and wide ranges of magnetic field intensities. The experimental method is comprehensively explained in earlier work [1]. The stress-strain responses were analyzed to extract the elastic and viscous stress using the decomposition method based on Chebyshev polynomial functions. Using the developed approach for MREs under LAOA, the elastic and loss moduli of MREs at zero strain along with at the extreme unloading, and loadings cycles were calculated and compared with those bases on Fourier approximation and experiment. Figure 1 presents results for the stress-strain curve based on the proposed superimposed elastic and viscoelastic via Chebyshev polynomials. The results compare the total stress with a linear stress approximation via Fourier series. It is clear that the first harmonic approximation lacks nonlinear stiffening and softening at the end of loading and unloading cycles. Further development of the current investigation would allow realizing the instantaneous/tangent elastic modulus at extreme loadings as functions of the linear elastic modulus.

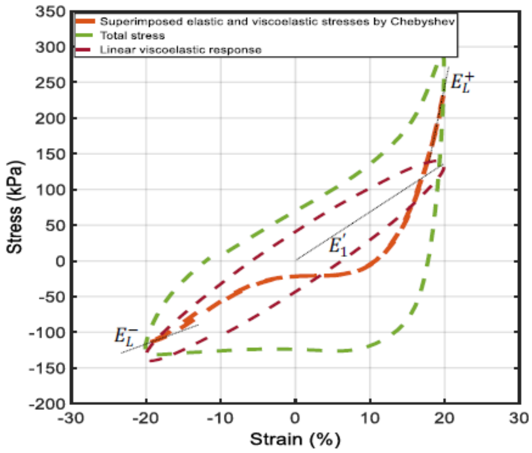

Figure 1: Comparison between linear viscoelastic response by Fourier series (First harmonic mod-uli) and Chebyshev polynomial.

References

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