DYNAMIC VISCOELASTIC MODELING OF INTERFACIAL DEBONDING FOR MAGNETORHEOLOGICAL MULTIFUNCTIONAL NANOCOMPOSITES

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ABSTRACT

A dynamic viscoelastic interface model is proposed to study the effective magneto-mechanical responses of magnetorheological nanocomposites filled with multi-walled carbon nanotubes. It is incorporated with the Eshelby's micromechanics and the elastic-viscoelastic correspondence principles. The effective dynamic stiffness and damping of randomly-dispersed, chain-structured nanocomposites are investigated with the consideration of imperfect interfacial condition between the filler and matrix. Comparisons are performed between the model-based simulation and the experimental data for a specific type of multi-walled carbon nanotube reinforced elastomer nanocomposites to demonstrate the potential of the proposed framework.

1 INTRODUCTION

Interfacial bonding condition between the inhomogeneities and the matrix plays an important role in determining the overall mechanical properties of composite and nanocomposite materials. Imperfect interfaces may arise for various reasons such as thin coating layers, interfacial debonding, and surface chemical reactions. Elastic interface models have been extended to viscoelastic interface models [1] by replacing the interfacial linear spring with its viscoelastic counterpart, which is time and frequency dependent. Carbon nanotube (CNT) reinforced nanocomposites have proved to demonstrate improved mechanical performance including stiffness, strength, and damping when compared with neat matrix materials [2, 3] due to the extraordinary properties of CNTs including nanometer size, high aspect ratio, and high modulus. Imperfect interfaces within nanocomposites allow for interfacial slippage and friction which are among the major sources of energy dissipation, and thus increase the damping capability under dynamic loads. Both interphase and interface models [4-6] have been adopted to investigate the influence of interfacial bonding condition on the overall stiffness and damping of nanocomposites. Interface models are applicable when interphases cannot be defined or identified since they are also mathematically simpler and more transparent.

2 GENERAL SPECIFICATIONS

While previous works involving viscoelastic interfaces focus on the creep and relaxation behavior of composites, in the present paper a micromechanics-based model for composites with both viscoelastic phases and interfaces is developed, which directly addresses the effect of imperfect interfaces on the dynamic viscoelastic behavior of composites; i.e., dynamic stiffness and damping, under dynamic loads. The proposed model is applied to randomly oriented magnetorheological (MR) nanocomposites and simulation results are compared with experimental data. Given the complex shear modulus of matrix silicone rubber and the elastic constants, volume fraction, and aspect-ratio of CNTs, in combination with interfacial parameters, the complex stiffness tensor of the MR nanocomposites reinforced with randomly oriented CNTs is calculated. The dipole-dipole magnetic interaction model is utilized here to simulate the MR effect on the dynamic shear stiffness. Numerical simulations have been performed to take advantage of the proposed model, and the results are compared with the experimental data. Figures 1 and 2 show the comparisons between model predictions and experimental data for the MR effect on dynamic viscoelastic behavior of MR nanocomposites. Similar trends are found here for MR nanocomposites and MR elastomers, in that both the interfacial storage compliance and loss factor are increased when external magnetic fields are applied. This observation further supports the explanation that the applied magnetic fields disturb the stress field at the interfaces between particle aggregates and the matrix, which lead to weaker overall bonding however higher viscosity at the interfaces.

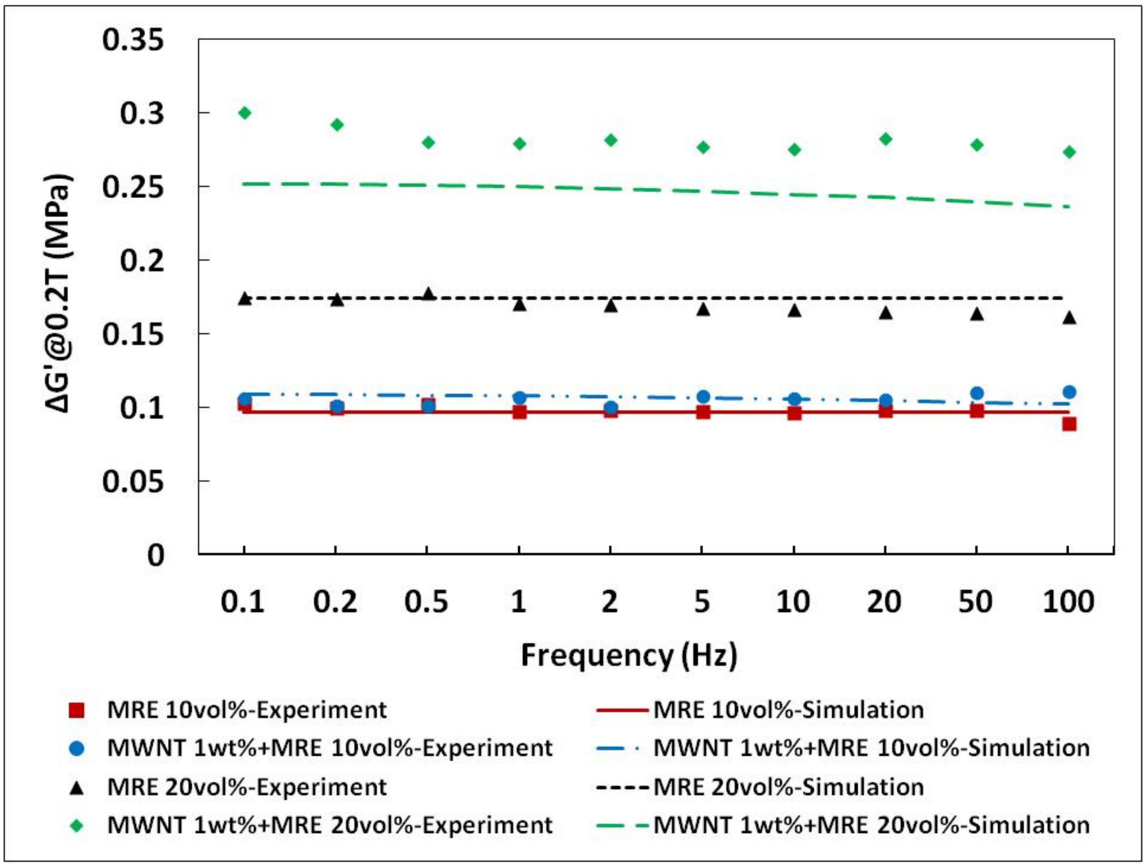

Fig. 1. Comparisons between model predictions and experimental data for the MR effect on storage shear modulus of MR nanocomposites.

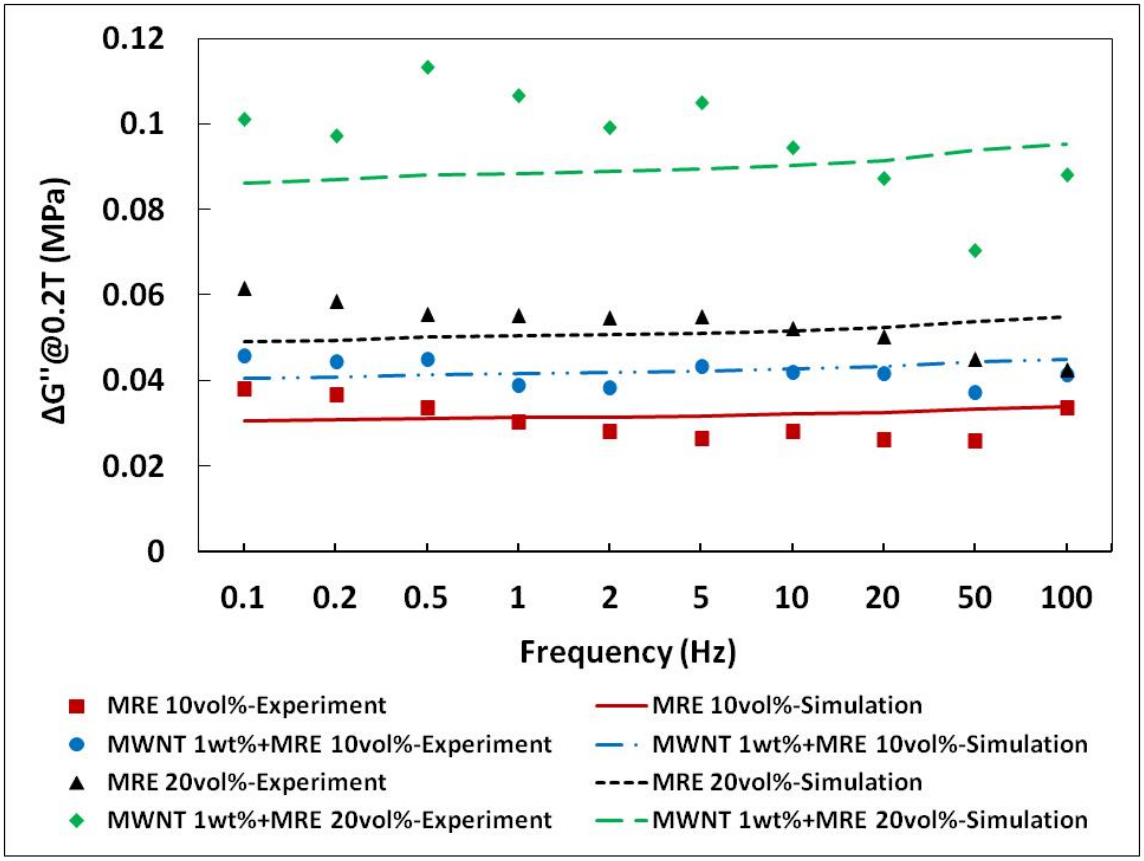

Fig. 2. Comparisons between model predictions and experimental data for the MR effect on loss shear modulus of MR nanocomposites.

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