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A Practical Methodology for Modeling and Verification of Self-Healing Microcapsules-Based Composites Elasticity

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Abstract

This study introduces a practical methodology for modeling of self-healing microcapsules-based composites elasticity with experimental verification. The elastic modulus of the matrix material was determined using dynamic mechanical analysis (DMA). In addition, single-microcapsule micromanipulation compression was performed accompanied by 2D finite element modeling (FEM) to extract the elastic modulus of single-microcapsule. Detailed 3D FEM were constructed to predict the effective elastic properties of the microcapsules-based composites. To define the material properties of these FEM, both of the elastic moduli of the matrix and the microcapsules were used. Microstructures having packing arrangement of simple cubic (SC), body-centered cubic (BCC), face-centered cubic (FCC), and random-monodispersed (RM) microcapsules were investigated. The microcapsules size and shell wall thickness reflect the microstructural geometry at definite volume fractions. Dynamic mechanical analysis was performed to determine the elastic modulus of prepared composites containing 5, 10, and 20 vol% microcapsules. Finally, experimental verification was obtained by comparing the experimental work to the FEM results. Good agreement was achieved. It was found that the volume fraction and the packing arrangement of the microcapsules in the composite were the only parameters that affect the composite effective elastic modulus, while the size and shell thickness of the microcapsules are not effective.

Keywords: microcapsules; composites; finite element modeling; single-microcapsule compression; dynamic mechanical analysis; effective elastic properties

1. Introduction

Composite materials represent a pioneer development in materials due to their high flexibility in designing of structural materials when compared with conventional materials such as metals, ceramics, polymers, etc. [1]. They allow to take the advantages of the exclusive properties of the constituent materials to obtain a final unique tailored behavior. As a result, substantial growth in the use of composites has been greatly influenced by multifunctional design requirements which are demanded from various industrial applications. Epoxy is one of the most widely used polymers in end-use industries including automotive, aerospace, transportation, composites, coatings, etc. [2]. Most epoxy thermosets-based systems encompass a two-part system that after cured, creates a glassy polymer network with advantageous mechanical properties such as strength and stiffness [3]. However, epoxy matrix

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