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ScienceDirect

Procedia Engineering 184 (2017) 486 – 496

Procedia Engineering

www.elsevier.com/locate/procedia

Advances in Material & Processing Technologies Conference

Design and Mechanical-Physical Properties of Epoxy-Rubber Based Composites Reinforced with Nanoparticles

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Abstract

Epoxy rubber based structural composites (ERCs) are used in engineering applications especially in the aeronautical area because they can meet the necessary requirements in new multifunctional systems. These composites exhibit good overall mechanical and thermal performance and they can potentially offer a large variety of functional properties. The data for basic material parameters of these composites are essential for an efficient engineering development process. The present paper discusses the design and characterization of these composites. In general, a combination of structural and energetic functions can be achieved by using different nanoparticle reinforcements in epoxy-rubber composites. This type of material design gives an exigent task to the designers looking to integrate more functionality into the base material of their structure to achieve overall improved system performance. This paper is focused on the design of ERCs reinforced with nano powders in a matrix of epoxy - fresh scrap rubber. It is expected this material would be attractive for industrial applications because of the readily available recycled constituents that are utilized. The mechanical and some physical properties of these composite systems were studied in this research. Microstructural characterization revealed that micro and nano sized reinforcements were dispersed homogeneously in the epoxy-rubber matrix. Mechanical properties were evaluated by means of three-point bending (3P bending) tests, dynamic mechanical analysis and also Brazilian disc test was conducted to see the fracture characteristics. Differential scanning calorimetry analyses (DSC) and X-ray diffraction (XRD) were used to understand better the physical characteristics. Finally, microstructure and fracture surfaces were observed with the help of scanning electron microscope (SEM).

Peer-review under responsibility of the organizing committee of the Urban Transitions Conference

Keywords: Fresh-Scrap Rubber; Three-point bending; SEM; DMA; Epoxy composites

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doi:10.1016/j.proeng.2017.04.119

1. Introduction

The use of "epoxy-rubber" based structural composite materials is increasing a lot recently due to their performance and large spectrum of functional properties. An efficient engineering development process requires the characterization of the material property data and it is an exigence for material suppliers and engineers.

ERCs offer a new prospect to utilize synergistic effects of its constituents to provide certain characteristics or requirements for particular industrial applications such as magnetic electronic components. In order to ensure that structural and energetic functions can be achieved simultaneously, reactive reinforcements can be added to polymer-matrix composites. However, distinctive requirements for strength and reactivity make design of such materials a challenging task. In terms of structural properties, addition of non-dissipative and hard fillers to the polymeric matrices can provide high stiffness and high damping, which is ideal for structural properties [1-12]. Besides, structural length scale and molecular weight between crosslinks (M_c) of epoxy groups, influence mechanical and physical properties. Addition of Ni and Al powder and, also Al + Fe_3O_4 thermite powder mixtures into the matrix have shown significant effect on the energetic reaction between the powders [3, 4, 8-17]. A balanced mixture with these characteristics can result in superior structural and energetic properties.

In this paper, preliminary results have been presented for the design procedure of an epoxy-scrap rubber matrix composite with the exothermic reinforcements mentioned above. During this experimental study, 3P bending tests, Brazilian disc tests and DMA analyses were performed for mechanical characterization. In addition, surface hardness was determined by means of Shore D hardness measurement. Thermal characteristics of the composites were investigated by means of Differential Scanning Calorimetry (DSC) and thermogravimetric analysis (TGA). These tests also showed that mass losses in the composites during the heating. Also, X-Ray diffraction was used for each different type of compositions to determine the different phases in the microstructure. After completion of all the tests and analyses, Scanning Electron Microscopy (SEM) was used to observe the fracture surfaces to study the distribution of different reinforcements and damage characteristics.

Nomenclature

ERC	Epoxy - rubber based structural composites
DSC	Differential scanning calorimetry
XRD	X-Ray diffraction
DMA	Dynamic mechanical analysis
TGA	Thermogravimetric analysis
SEM	Scanning electron microscope
T_g	Glass transition temperature
EDS	Energy dispersive spectrum

2. Materials and Methods

2.1. Material Preparation

At the first stage, a chemical treatment was used to combine very fine dry epoxy powder and fine scrap rubber powder (Styrene–butadiene rubber (SBR) [11-19]) to produce the matrix of the composites used in this study. Epoxy and rubber were mixed and chemically treated by vinyltriethoxysilane then dried in an oven to entirely eliminate any trace of chemicals. This mixture was milled for 24 hours to obtain a homogeneous compound and then heated at 80 ºC for 24 hours. The resulting compound was used as the matrix for the proposed composites.

At the second stage, the reinforcements Al, Ni, Fe_3O_4 and Silica (SiO_2) were added to the matrix in pre-defined ratios and placed in an oven for 48 hours at 110 ºC to eliminate any moisture that the compound might have absorbed during prior processing. During this stage the mixture was mixed every two hours. The size of the nanoparticles was measured by means of laser granulometry. The size of Fe_3O_4 particles was found between 45-70 nm and for Al it was determined as smaller than 23 nm.