Experimental Thermal and Fluid Science 35 (2011) 1458–1462

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

journal homepage: www.elsevier.com/locate/etfs

Experimental investigation of heat conduction in polyester–Al_2O_3 and polyester–CuO nanocomposites

D.C. Moreira [b], L.A. Sphaier [a,b,*], J.M.L. Reis [a,b], L.C.S. Nunes [a,b]

[a] Department of Mechanical Engineering/PGMEC, Universidade Federal Fluminense – UFF, Rua Passo da Pátria 156, Bloco E, sala 216, Niterói, RJ 24210-240, Brazil
[b] Laboratory of Theoretical and Applied Mechanics – LMTA, Universidade Federal Fluminense – UFF, Rua Passo da Pátria 156, Bloco E, sala 216, Niterói, RJ 24210-240, Brazil

ARTICLE INFO

Article history:
Received 8 January 2011
Received in revised form 13 June 2011
Accepted 14 June 2011
Available online 30 June 2011

Keywords:
Composite material
Nanoscale
Nanoparticle
Thermal conductivity
Polymer

ABSTRACT

This paper presents an experimental analysis of the thermal conductivity of nanocomposite systems composed of unsaturated polyester resin (UPR) as matrices and two different metal-oxides nanoparticles as fillers: alumina (aluminum oxide) and tenorite (copper oxide). The nanoparticles used were alpha-Al_2O_3 (30–40 nm) and CuO (30–50 nm). Samples were fabricated using simple molding and homogenization using magnetic stirring. Thermal conductivities were measured using a device that complies with ASTM norms C518-04 and E1530-06. Measurements were taken at three different temperatures (0 °C, 25 °C and 50 °C), for different sets of samples, varying the nanoparticle fraction used in composite systems. Finally, the experimental data are compared with traditional models for predicting the thermal conductivity of composite materials, showing that the traditional models underestimate the measured values.

1. Introduction

Modern technologies continuously need new materials and there is a crescent tendency to design novel compounds using existing constituents. By doing so, one can engineer new materials that possess user-prescribed properties. Over the last decades, many efforts have been made towards obtaining new materials with user-determined functionality. The combination of metal and metal-oxides with polymers are typical examples, leading to polymeric nanocomposites containing metallic additives. Nano-sized materials can have different properties compared to their bulk counterpart, originating from nano-crystals size. Nano-crystals measure a few nanometers containing few hundred atoms. In this way, nano-materials can show unique properties (thermal, electronic, magnetic, structural, and so on) depending on nano-structure size. Previous studies [1–6] have shown that the addition of a small fraction of nanoparticles to a solution can lead to a noticeable change in the overall thermal conductivity. Several studies, both of experimental and theoretical nature, have been conducted with the attempt of investigating and explaining the thermal intensification seen in materials loaded with nanoparticles of higher thermal conductivity. As observed from the literature, many of these studies are oriented towards thermal intensification of liquids [1–9], leading to the so-called nanofluids. There are also studies that investigate the thermal intensification resulting from adding nano-sized fillers to solid polymeric materials [10–14], as well as other studies focused on analyzing the thermal conductivity of polymer composites with larger-scale fillers [15–22]. The goal of this study is to experimentally determine how the effective thermal conductivity is influenced by the addition of alumina (Al_2O_3) and tenorite (CuO) nanoparticles to an unsaturated polyester resin (UPR) matrix, which has a lower thermal conductivity compared to the employed metal oxides. The UPR used in this study is commonly employed in the production of fiber-reinforced plastics or non-reinforced filled products for various applications and end-markets.

2. Nanocomposite fabrication

The nanocomposite materials used in this study are composed of a polymeric matrix and metal oxides (Al_2O_3 and CuO) nano-particles used separately as fillers. The properties and sources of the composite material components are described as follows.

The employed polymer was Polylite 10316-10 (provided by Reichold), an unsaturated polyester resin (UPR) diluted in 44% styrene. This resin is pre-accelerated by the manufacturer and the initiator used was methyl ethyl ketone peroxide (MEKP) in a proportion of 1.5 phr. The UPR properties are presented in Table 1.

The nano-particles, provided by NanoAmor (www.nanoamor.com), were alpha-alumina (containing 5–10% theta) and cupric oxide. The average particle size and other nanoparticle

* Corresponding author at: Laboratory of Theoretical and Applied Mechanics – LMTA, Universidade Federal Fluminense – UFF, Rua Passo da Pátria 156, Bloco E, sala 216, Niterói, RJ 24210-240, Brazil. Tel.: +55 21 2629 5576; fax: +55 21 2629 5588.
E-mail address: lasphaier@id.uff.br (L.A. Sphaier).

0894-1777/$ - see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.expthermflusci.2011.06.004