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Tensile Behavior of SiCNP and MWCNTs Filled Toughened Epoxy Nanocomposites: A Comparative Study

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Abstract

This study is conducted to evaluate the tensile properties of silicon carbide nanoparticles (SiCNP) and multiwalled carbon nanotubes (MWCNTs) filled toughened epoxy composites as a function of filler loading. The nanocomposites with different weight percentage of SiCNP and MWCNTs loading were fabricated by mechanical blending operation assisted with an ultrasonic cavitation technique. The loadings utilized were 0, 2, 4, and 6% of total composites weight. The result shows that the optimum filler loading of both systems were obtainable at 4% of SiCNP and MWCNTs of loadings. Composite with SiCNP filler achieved the highest value of tensile strength and Young's modulus at about 11% and 4%, respectively as compared to unfilled system. The enhancement pattern in MWCNTs nanocomposite systems were not significant as compared than SiCNP composite. The tensile strength and Young's modulus of MWCNTs composite were increased at only about 7% and 2%, respectively compared than unfilled system. The strain at break attribute for both filler system had shown reduction pattern at higher loading started from 2% loading and onwards. The variation in tensile properties were further supported by the tensile fracture morphologies and clearly shown that the filler-matrix plated an important role in affecting the tensile behavior of nanocomposite produced.

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Keywords: Toughened epoxy composite; tensile properties; nanofiller

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1. Introduction

Recently, the growing interest in the use of nanofiller in composite materials creates new innovations in many fields such as electronic devices, communication, defense and aerospace applications. Silicon carbide nanoparticles (SiCNP) and multiwall carbon nanotubes (MWCNTs) are considered to be the most two interesting nanofillers in the polymer matrix due to their outstanding characteristics. The usage of SiCNP has received great attention due to their advantages over the other nanofillers. Besides, SiCNP is among of the hardest materials that have high an oxidation and thermal resistance with excellent electrical and optical characteristics[1-3]. Higher demand on carbon nanotubes (CNTs) in various fields is due to superior characteristics such as lightweight materials and strong microwave absorption properties[4]. MWCNTs also known as stiffest materials with high tensile strength and modulus, therefore, the incorporation of this filler in epoxy is possible to improve mechanical properties of composite[5]. These inherent properties also make the nanofiller was extensively used for a high heat impact, radiation resistance, high chemical stability, strengthening, and enhanced super plasticity properties of materials[6]. However, according to Sun et al.[7], silicon carbide has better properties and wide application prospect at higher temperature than other dielectric absorbers such as carbon nanotubes, pyrolitic carbon and carbon black.

The mechanical properties of composite are largely depended to the filler and matrix composition. The tensile strength of polymer nanocomposites is influenced by a weight fraction and modification made to nanoparticles[8]. The effects of nanoparticles addition on mechanical behavior of SiCNP reinforced epoxy composites had shown that at 0-10 weight percent of the loading caused reduction in tensile strength and Young's Modulus[9]. Higher loading of nanoparticles led to the agglomeration phenomena in matrices due to their small size and Van de Waals interaction forces between the particles which causing a poor dispersion and weak bonding between the matrix and nanoparticles. Thus, become a major factor had in strength reduction of the produced nanocomposites. In addition, the efficiency of MWCNTs addition in epoxy matrix profoundly caused deterioration to the mechanical properties due to similar aggregation of CNTs[10]. Moreover, another support from the TEM images observation of poor distribution of nanoclays in epoxy matrix caused deterioration in mechanical properties at higher loading filler[11]. In this study, the effects of filler loading to the tensile behavior of two dissimilar composite systems of SiCNP and MWCNT filled was evaluated and further compared.

2. Experimental

Commercial grade of Morcote BJC 39 epoxy resin were mixed with liquid epoxidized natural rubber (LENR) by mechanical stirrer for 1 hour at 1300 rpm. After that the SiCNP or MWCNTs was added into the mixture and stirred for 1 hour at the same speed assisted with sonication cavitations. Then, the curing agent was added at ratio of 1:3 of the resin and further mixed for another 15 minutes. The mixture was degassed in vacuum oven for 5 minutes at a room temperature in the vacuum oven to ensure the release of entrapped air and bubbles in the mixture. The mixture was then transferred to the mould and leveled by the roller until uniformly filled the entire mold cavity. Preheating step was then conducted at 80°C and after 1 hour, the molded samples were removed from the mold and trimmed for an excess resin removal. Finally, the samples went through a post curing process by further heating in an oven at 140°C for 3 hours.

Tensile properties were measured by using a Testometric Universal Testing Machine (UTM) with a crosshead speed of 5 mm/min and 500 kN of applied load. The nanocomposites samples were prepared into a dumbbell shape in accordance to the ASTM D 638 type I test specimen with gauge length of 70 mm. At least about five samples of each different filler loadings were tested. Later, an observation of tensile fractured surface was performed through the field emission scanning electron microscope (FESEM). The fractured surface was carefully coated by a thin film layer of gold using the sputter coated model Polaron to enhance the quality of FESEM images and to eliminate the charging effects due to non-conductive nature of the composites samples.

3. Result and Discussion

Tensile strength of toughened epoxy filled with SiCNP and MWCNT at various loading compositions were tabulated as the Fig. 1. The tensile strengths were linearly increased with an addition of both fillers up to 4% of loading before further decreasing at subsequent higher loadings. The tensile strength for MWCNT filled toughened epoxy is slightly lower than SiCNP filled nanocomposites at all loading contents. The strength values were increased at about 11% and 4% respectively for both composites systems at 4% of optimum loadings in comparison to the unfilled matrices. The tensile strength of SiCNP composites increased when 4% filler is added to the toughened epoxy matrices with an optimum value of 49 MPa. Further loading at 6 % was not suitable for both composites systems and even worst for MWCNT nanaocomposite which was underrated than unfilled system.

A similar reduction trend for both particle and nanotubes toughened epoxy nanocomposites had explained that the nanocomposites are performed better at lower filler loading and the addition of higher loading led to the deterioration of strength properties. This scenario of enhancement in mechanical properties was due to a good distribution of nanofiller in the matrices, while the reduction of tensile strength attribute may possibly occur due to the worst dispersion and agglomeration which automatically induce the stress localization during load transfers.

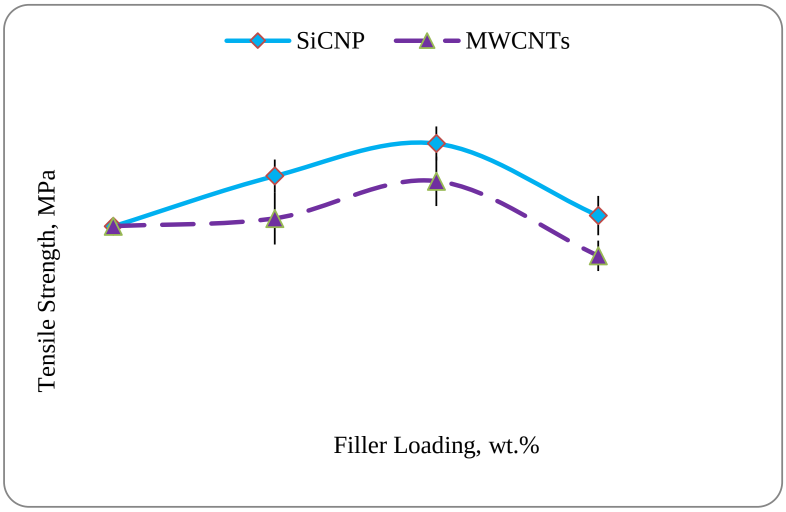

Fig. 1. Tensile strength of SiCNP and MWCNTs composite

Fig. 2 depicts the variation of Young's modulus for both epoxy filled systems as compared than an unfilled toughened epoxy matrix. In overall, the modulus performances are obviously similar to the tensile strength attribute whereas the SiCNP filled toughened epoxy are much better at all loadings as compared than the MWCNTs filled system. This can be explained by the presence of nanoparticles in toughened matrix which induces the brittleness. The SiCNP filled system exhibits greater stiffness behaviour due to the stiffer nature of SiCNP filler. There was no significant improvement at both tensile strength and Young's modulus properties with the present of MWCNTs in the toughened epoxy matrices. The presence of higher MWCNTs loadings had introduced an entanglement phenomenon which partially generates the microspaces during the load transfer, thus hindering the stress propagation between filler and matrix [12]. This situation diminished the capability of MWCNTs filled composites to sustain the loads transferred into the matrix and significantly lowered the stiffness behaviour of nanocomposites.

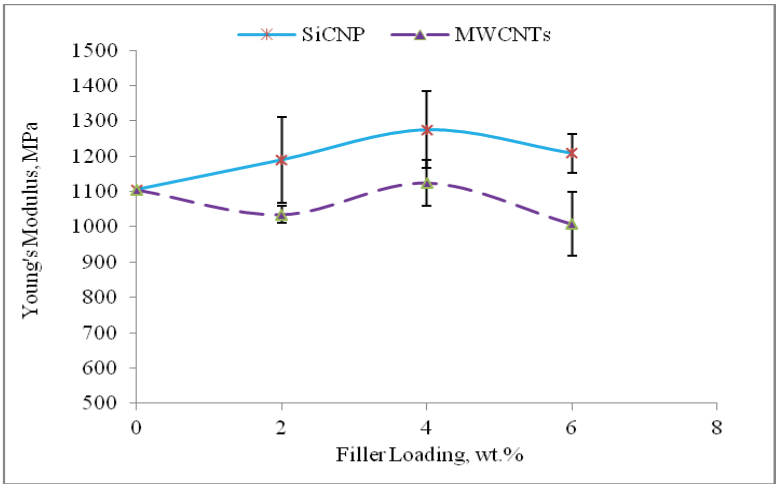

Fig. 2. Young's modulus of SiCNP and MWCNTs composites

The elastic behavior of SiCNP and MWCNTs nanocomposites are depicted as in the Fig. 3. An addition of SiCNP and MWCNTs were largely effected the reduction of matrix's tensile strain for both composites systems. The tensile strain was started to reduce as the filler added to the matrix for MWCNTs system while the SiCNP filled toughened epoxy system had shown fluctuating trend of the strain at break with regard of the filler loading even higher than unfilled system at 2% and 6% of filler loadings. This phenomenon further support the role of SiCNP dispersion which possibly may induce interfacial viscoelastic deformation and matrix yielding contributed to the higher value as compared to MWCNTs composites system[13].

The presence of nanoparticles was acted as a stress concentrator which has led to the plastic deformation of the matrix[14]. In addition, the stiffening effects that was introduced by inclusions with the increasing of the filler content has linearly improved the stiffness of a matrix system due to rigid filler[15]. The reduction in the tensile strain was attributed by the restriction of a molecular motion of segmental chain during the applied load[12].

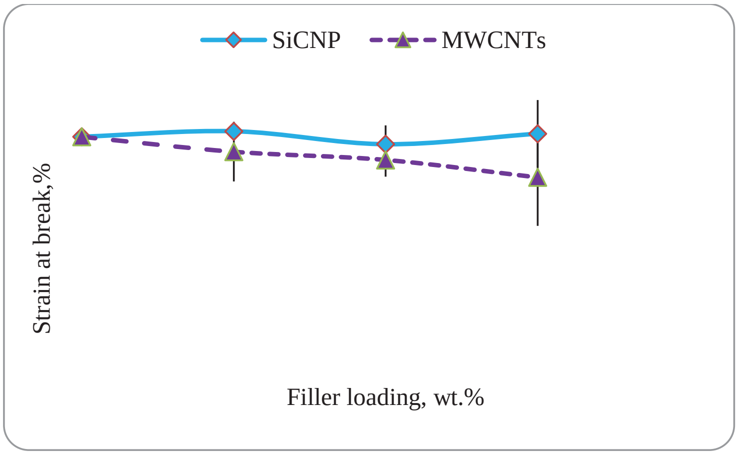

Fig. 3. Strain at break of SiCNP and MWCNTs composite

Fig. 4 show the FESEM morphology the tensile fractured surfaces of the LENR/epoxy matrix and their composites. It clearly can be seen that the smooth continuous phase of toughened epoxy matrix as represented in the Fig. 4(a), meanwhile SiCNP and MWCNTs were evenly distributed in the toughened epoxy matrix in Fig. 4(b) and (d). This observation further supports a significant improvement of tensile properties attributes in SiCNP and MWCNTs composites sample at 4% filler loading. An agglomeration and entanglements of MWCNTs in matrix are easily observed at a higher filler loading of 6% in MWCNTs composite as depicted in Fig. 4(d) supported the reduction phenomenon of tensile strength in MWCNTs composite at higher filler loading.

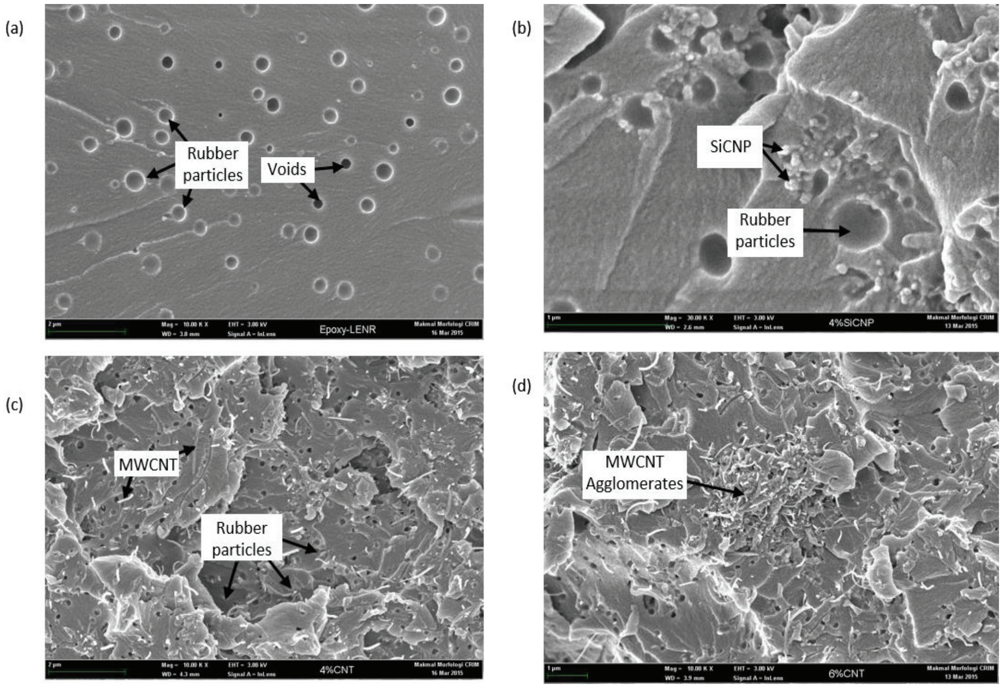

Fig. 4. Tensile fractured surface morphology of (a) toughened epoxy matrix (b) 4 wt% of SiCNPs (c) 4% MWCNT and (d) 6% MWCNTs

4. Summary

In conclusion, the optimum filler loading for both SiCNP and MWCNTs composites were achieved at 4%. SiCNP filled toughened epoxy composites had shown a higher tensile strength and modulus as compared to MWCNT filled toughened epoxy composite. The presence of two fillers had reduced the strain at break of toughened epoxy matrix. FESEM micrographs had showed better dispersion of the SiCNP filler and matrix than MWCNTs.

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