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THE EFFECT OF ACETIC ANHYDRIDE-TREATED SILICON CARBIDE ON MORPHOLOGICAL AND MECHANICAL PROPERTIES OF EPOXY/CARBON FIBER/SILICONE CARBIDE COMPOSITES

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Abstract – Epoxy is widely applied in various fields because of its excellent properties. The filler is needed to enhance the properties of the epoxy composite. The pretreatment of fillers can improve the mechanical properties of the composites. The objective of this study was to determine the influence of acetic anhydride (Ac_2O)-treated silicon carbide (SiC) on morphological and mechanical properties of epoxy/carbon fiber/SiC composites. The SiC was immersed in Ac_2O with the concentration of 0, 4, 8, 12, and 16 wt% for 5 hours at room temperature. The epoxy/carbon fiber/SiC composites were made using the hand lay-up method. The morphology, tensile strength, and flexural strength of the composite were investigated. The SEM images indicated that the Ac_2O affects the surface of SiC particles. The higher Ac_2O concentration provided the higher tensile and flexural strength of the composite. The 16% Ac_2O-treated SiC increased the composite's tensile strength (86 MPa) and flexural strength (65 MPa). The treated SiC using Ac_2O is suitable to improve the mechanical properties of epoxy/carbon fiber/SiC composites.

Keywords: epoxy; carbon fiber; silicon carbide; acetic anhydride; pretreatment.

1. Introduction

Epoxy is one of the most widely used materials because of its excellent properties. It has good mechanical properties, high temperature resistance, solvent resistance, corrosion resistance, and electrical properties. Epoxy can be applied in various fields such as protective coatings, adhesives, advanced composites, electrical insulating materials. Several methods have been proposed to improve the mechanical properties of the epoxy composites, such as mixing with reinforcing filler materials (Parbin *et al*., 2019; Matykiewicz, 2020), the addition of coupling agents such as maleic anhydride and phthalic anhydride (Silva *et al*., 2013; Wolok and Pakaya, 2020), size selection, and treatment of reinforcing filler materials (Jaafar *et al*., 2018; Premnath, 2019).

The addition of two or more reinforcing materials can produce a hybrid composite with better properties. The additional reinforcing filler material provides better load distribution throughout the matrix thereby improving the mechanical and compressive strength of the composite (Antil *et al*., 2018). In this study, carbon fiber and silicon carbide (SiC) fillers were used as filler. Carbon fiber is lightweight, has high tensile strength, good electrical, chemical and thermal resistance (Bharath *et al.*, 2018). SiC (silicon carbide) has high strength, hardness, good thermal conductivity, thermal stability, wear resistance and chemical resistance (Kiran, Govindaraju and Jayaraju, 2018). The epoxy/carbon fiber/SiC can be used for car body and helmet.

The composite's filler can be treated to improve the mechanical properties and the surface adhesion between the filler and the matrix. The treatment of filler can be done by chemical treatment such as immersion in acidic solutions such as hydrochloric acid (HCl) and acetic anhydride (Ac_2O) or in alkaline solutions such as NaOH and sodium bicarbonate. (Min *et al*., 2016; Camargo *et al*., 2020; Jaafar *et al*., 2018; Fiore *et al*., 2018). Acetic anhydride (Ac_2O) is a colorless liquid with a pungent odor with the structural formula $(CH_3CO)_2O$. The molecular structure of Ac_2O is shown in Figure 1. Some previous studies have shown that immersion of fibers and particles in acetic anhydride (Ac_2O) solution can improve the mechanical properties of the composite. The Ac_2O can improve the compatibility between the filler and matrix (Loong and Cree, 2018; Huner, 2018; Zhang *et al.*, 2019).

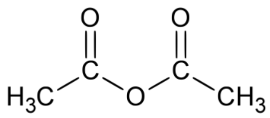


Fig. 1. The structural formula of acetic anhydride (Ac_2O).

Based on the author's knowledge, acetic anhydride has not been used for SiC pretreatment in epoxy/carbon fiber/SiC composites. In this work, the chemical treatment was carried out by immersing SiC in acetic anhydride (Ac_2O) solution at 0, 4, 8, 12, 16%. Composites are made using the hand lay-up method. The tensile strength and the flexural strength are studied to investigate the mechanical properties. The morphology of composites is studied by the scanning electron microscope (SEM). It is hoped that this research can provide information of the Ac_2O-treated SiC on the epoxy/carbon fiber/SiC composites to produce better mechanical properties composite.

2. Material and Method

The materials used in this research are diglycidyl ether of bisphenol A (DGEBA) epoxy (Justus Kimiaraya) and cycloaliphatic amine (CAA) / EPH 555 (Justus Kimiaraya) as hardener for the matrix. The matrix ratio was epoxy: hardener = 60: 40. The reinforcing filler materials used are carbon fiber HDC 542-3K (Justus Kimiaraya) and 180 grit silicon carbide (Sandblasting Tools). Acetic anhydride with pH of 3 and density 1.080 g/cm^3 (PT. Unilab). The formulation used in this work is shown in Table 1. Chemical treatment of SiC are carried out by immersing SiC in acetic anhydride solution with a concentration of 0,4,8,12,16% for 5 hours at room temperature. The tools used in this research are digital scales, aluminum cup, glass beaker, stirrer, silicon mold.

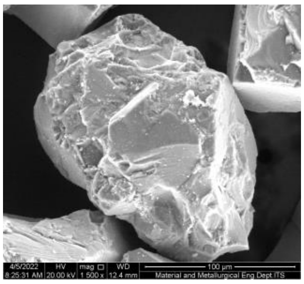
The tensile strength of the epoxy/carbon fiber/SiC composite is studied using universal testing machine UTM DTU-900 according to ASTM D638. The flexural strength of the composite is studied using UTM Llyod LFPlus. The morphology of silicon carbide was studied by scanning electromagnetic microscope FEI INSPECT S50 with magnification 1500x.

Table 1. Formulation of epoxy/carbon fiber/SiC composite

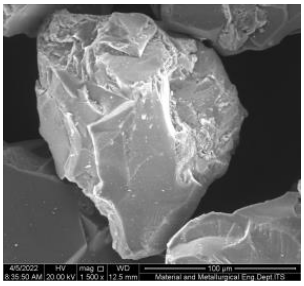
Composite	Materials			
	Ac_2O %	Epoxy matrix % wt	Carbon fiber % wt	SiC % wt
E	0	100	0	0
E/SK/S/A0	0	48	40	12
E/SK/S/A4	4	48	40	12
E/SK/S/A8	8	48	40	12
E/SK/S/A12	12	48	40	12
E/SK/S/A16	16	48	40	12

3. Results and Discussion

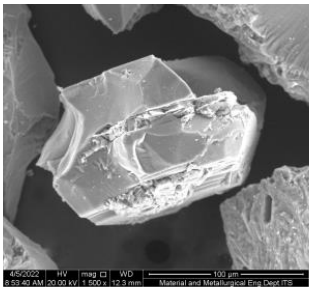
The morphology of SiC has been observed by SEM. The morphology of untreated SiC and treated SiC are shown in Figure 2. The SiC is a solid crystal with a rectangular and spherical shape. It is known that SiC color are dark (black) and bright because SiC is composed of carbon and silicon atoms. Figure 2 shows that SiC have flake shape.



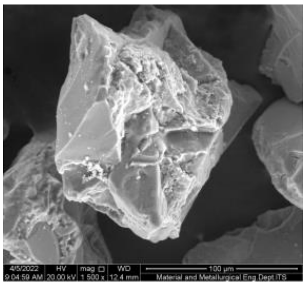
(a) Untreated SiC



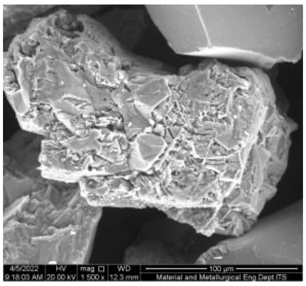
(b) 4% Ac_2O-treated SiC



(c) 8% Ac_2O-treated SiC



(d) 12% Ac_2O-treated SiC



(e) 16% Ac_2O-treated SiC

Fig. 2. The images of untreated and treated SiC (a) untreated SiC, (b) 4% Ac_2O-treated SiC, (c) 8% Ac_2O-treated SiC, (d) 12% Ac_2O-treated SiC, (e) 16% Ac_2O-treated SiC.

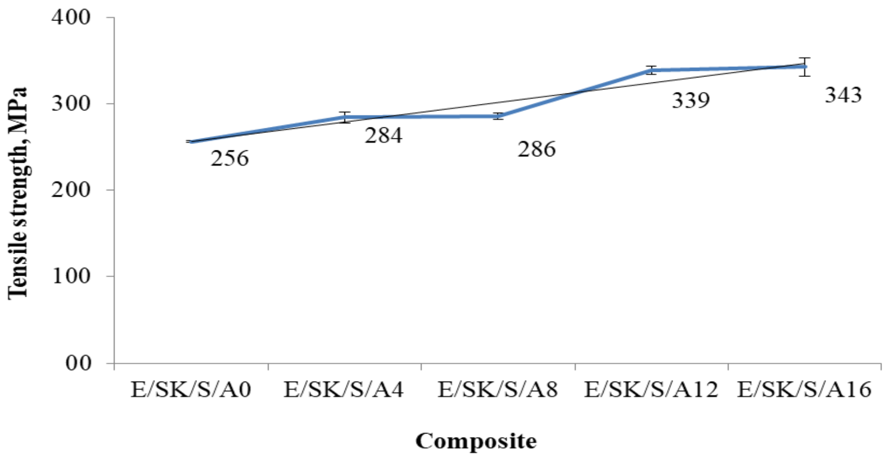


Fig. 3. Tensile strength of epoxy/carbon fiber/SiC composite.

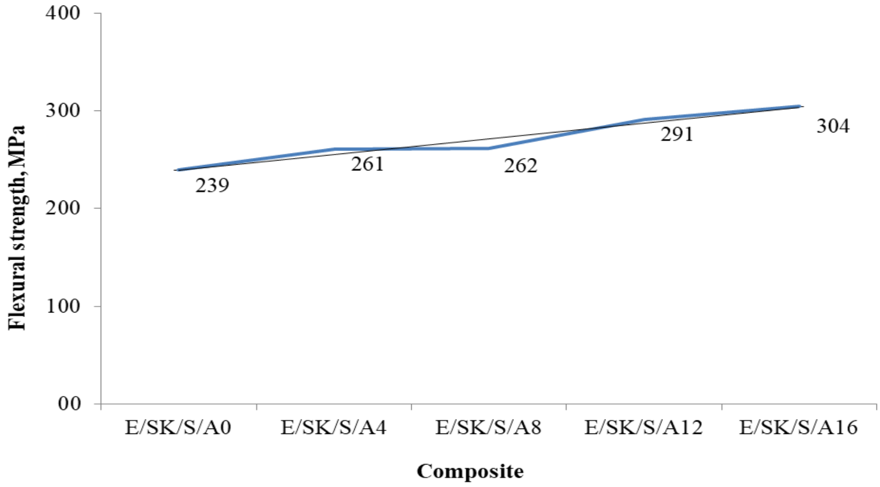


Fig. 4. Flexural strength of epoxy/carbon fiber/SiC composite.

The tensile and flexural strength of epoxy/carbon fiber/silicon carbide composite are shown in Figure 3 and Figure 4. Figure 3 shows that the tensile strength of the composites is relatively high, ranging from 256 to 343 MPa. The diglycidyl ether of bisphenol A (DGEBA) is a commonly used epoxy because of its good mechanical properties. The carbon fiber and SiC as the reinforcing filler gives significant improvement of mechanical properties.

The composite filled with treated SiC shows the higher tensile strength than composite filled with untreated SiC. The higher Ac_2O concentration provides the higher the tensile strength of the composite. Immersion of SiC in 16% Ac_2O increases the tensile strength up to 86 MPa. The Ac_2O treatment is able to remove the impurities materials from SiC, because it can dissolved the impurities more than other chemicals (Huner, 2018). It can lead to the increase in the miscibility of SiC in epoxy. The Ac_2O is an acidic solution that may erode the SiC surface and provides the stronger interlocking between particle and matrix that leads to the increase in the tensile strength.

Ac_2O is an acidic solution with a pH of 3. It has high electrical polarity so that can increase electrical interactions and increase the particles and matrix interactions. It leads to the good interfacial bonding and improvement of filler-matrix compatibility, hence the tensile strength is increases (Matykiewicz, 2020) (Antil et al., 2018).

Fig. 4 show that the addition of carbon fiber and SiC particles increases the flexural strength of the composite. The flexural strength of the epoxy/carbon fiber/SiC composite is relatively high, ranging from 239 to 304 MPa. The treated SiC increases the flexural strength of the composite. The higher the Ac_2O concentration, the higher the flexural strength. Immersion of SiC in 16% Ac_2O increases the flexural strength up to 65 MPa. The rougher SiC surface provide better SiC - matrix bonding that leads to the increase in flexural strength. Ac_2O can improve the mechanical properties of the composite (Loong and Cree, 2018; Haijuan *et al*., 2019; Zhang *et al*., 2019).

4. Conclusions

Ac_2O-treated SiC can increase the mechanical properties of the epoxy/carbon fiber/SiC composite. From the SEM analysis, the surface of Ac_2O-treated SiC is rougher than untreated SiC. The tensile strength and the flexural strength of the composite are 256 - 343 MPa and 239 - 304 MPa. The higher the Ac_2O concentration, the rougher the SiC surface and the higher the tensile and bending strength. The 16% Ac_2O-treated SiC can increase the tensile and bending strength up to 86 MPa and 65 MPa.

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References

Antil, P., Singh, S. and Manna, A. (2018), 'Effect of Reinforced SiC Particulates of Different Grit Size on Mechanical and Tribological Properties of Hybrid Polymer Matrix Composites', Materials Today: Proceedings. Elsevier Ltd, 5(2), pp. 8073–8079.

Bharath Kumar, T. et al. (2018), 'Influence of Sic on Mechanical, Thermal, Fire and Wear Studies of Vinylester/Glass Fibre Composites', Materials Today: Proceedings. Elsevier Ltd, 5(10), pp. 22675–22686.

Camargo, M. M. et al. (2020), 'A review on natural fiber-reinforced geopolymer and cement-based composites', Materials, 13(20), pp. 1–29.

Fiore, V., Scalici, T. and Valenza, A. (2018), 'Effect of sodium bicarbonate treatment on mechanical properties of flax-reinforced epoxy composite materials', Journal of Composite Materials, 52(8), pp. 1061–1072.

Haijuan, K. et al. (2019), 'Improvement of adhesion of kevlar fabrics to epoxy by surface modification with acetic anhydride in supercritical carbon dioxide', Polymer Composites, 40, pp. E920–E927.

Huner, U. (2018), 'Effect of Chemical Surface Treatment on Flax-Reinforced Epoxy Composite', Journal of Natural Fibers. Taylor & Francis, 15(6), pp. 808–821.

Jaafar, C. N. A., Rizal, M. A. M. and Zainol, I. (2018), 'Effect of kenaf alkalization treatment on morphological and mechanical properties of epoxy/silica/kenaf composite', International Journal of Engineering and Technology(UAE), 7(4), pp. 258–263.

Kiran, M. D., Govindaraju, H. K. and Jayaraju, T. (2018), 'Evaluation of Mechanical Properties of Glass Fiber Reinforced Epoxy Polymer Composites with Alumina, Titanium dioxide and Silicon Carbide', Materials Today: Proceedings. Elsevier Ltd, 5(10), pp. 22355–22361.

Loong, M. L. and Cree, D. (2018), 'Enhancement of Mechanical Properties of Bio-Resin Epoxy/Flax Fiber Composites using Acetic Anhydride', Journal of Polymers and the Environment. Springer US, 26(1), pp. 224–234.

Matykiewicz, D. (2020), 'Hybrid epoxy composites with both powder and fiber filler: A review of mechanical and thermomechanical properties', Materials, 13(8).

Min, L. et al. (2016), 'Influence of pretreatment of SiC on microstructure and properties of SiCp/A390', Emerging Materials Research, 5(1), pp. 81–87.

Parbin, S. et al. (2019), 'Mechanical properties of natural fiber reinforced epoxy composites: A review', Procedia Computer Science. Elsevier B.V., 152, pp. 375–379.

Premnath, A. A. (2019), 'Impact of surface treatment on the mechanical properties of sisal and jute reinforced with epoxy resin natural fiber hybrid composites', Journal of Natural Fibers. Taylor & Francis, 16(5), pp. 718–728.

Silva, L. J. et al. (2013), 'The effect of silica microparticles and maleic anhydride on the physic-Mechanical properties of epoxy matrix phase', Science and Engineering of Composite Materials, 20(3), pp. 203–208.

Wolok, E. and Pakaya, F. (2020), 'Experimental investigation of epoxy/poly(Amino amide)/phthalic anhydride: Mechanical properties and thermal stability', International Journal of Advanced Science and Technology, 29(5 Special Issue), pp. 1011–1021.

Zhang, X. et al. (2019), 'Surface Modification of Multi-Walled Carbon Nanotubes Using Acetic Anhydride and its Effects on Poly(butylenesadipate-co-terephthalate) Based Composite', Polymer Science - Series A, 61(6), pp. 897–905.