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Tensile modeling of composite epoxy modified with nanosilica particles

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ABSTRACT
The addition of nanosilica particles can enhance mechanical properties of epoxy based composite materials. Tensile behavior is very crucial properties to be investigated due to its appearance frequently in the application. The amount of nanosilica (SiO_2) particles was added in 2%, 5%,8 % and 10% of weight to epoxy resin Epikote 828. ***.*** *Dogbone tensile specimens of epoxy modified with nanosilica were tested using universal tensile machine. The results of tensile properties were further elaborated using available analytical model and finite element analysis. Analytical model and finite element analysis using computer can cut the time to market. As the result, the cost can be minimized compare to experiment based assessment. Tensile behavior improvement is revealed as the nanosilica particles added. A very good correlation among the results from experiment, analytical and finite element analysis has been revealed.*

Keywords: *Nanopsilica, Tensile Behavior, Finite Element Analysis.*

INTRODUCTION

It is well known, that fiber reinforced polymer (FRP) failure is often determined by matrix behaviour caused by indifferent loading conditions [1]. The first form of damage in laminates is usually matrix microcracks [2], which are intralaminar or ply cracks that transverse the thickness of the ply and run parallel to the fibres in that ply. The most common observation of microcracking is cracking in 90° plies during axial loading in the 0° direction [3]. One of the ways to enhance the mechanical properties of FRPs is to improve the properties of the polymer matrix by incorporating second phase fillers into the resin such as nanoparticles. The incorporating nanoparticles into polymeric matrix have shown great enhancements in mechanical properties, thermal properties, and electrical properties [4]–[9].

Predictive modelling based on the physics of composite material behavior is wealth generating; by guiding material system selection and process choices, by cutting down on experimentation and associated high costs; and by speeding up the time frame from the research stage to market [10]. The prediction of the macroscopic stress-strain response of composite materials related to the description of their complex micro-structural behavior exemplified by the interaction between the constituents and the overall property of a composite material is governed by the properties of its constituents and microstructures [11].

Incorporating nanosilica particles to the epoxy matrix system significantly enhances the tensile behavior of the epoxy-based composite. Finite element outcomes have discovered the effect of incorporating the interphase and interaction effect on the estimate of the elastic modulus of nanosilica epoxy composite. The developed multi-particle FE model with graded interphase also shows a very good correlation with experimental result [12]

In this work the modulus of elasticity from analytical model results proposed by Mulyadi et al [12] are utilized as input parameter in FEA modeling with regard to tensile test modeling. Tensile test results from FEA modeling are validated using experimental results.

RESEARCH METHODOLOGY

Materials

Epikote 828 epoxy, a diglycidyl ether of bisphenol-A (DGEBA) was used and cured with an alicyclic anhydride hardener. Epikote 828 is a low viscosity resin. Nanopox F400 is nanosilica (SiO_2) reinforced bisphenol-A based epoxy resin. It was supplied as a colloidal solution with 40 wt% in epoxy resin. This nanosilica is commonly used in fibrous composites. Evonik Hanse GmbH, Geesthacht, Germany supplied the spherical silica nanoparticles with average particle size about 20 nm and maximum diameter below 50nm. The silica phase has surface-modified with an extremely narrow particle size distribution.

The Fabrication of Composite Materials

The fabrication process of the pure Epikote 828 and Nanopox F400/Epikote 828 composite referred to work done by Jumahat et al [13].

Tensile test of the pure epoxy and composite

Five dogbone shape coupons were examined for each pure Epikote 828 and Nanopox F400/Epikote 828 composite system. Tensile tests were perfomed by using a Tinius Olsen universal testing machine at crosshead speed of 1 mm/min with wedge type grips. All the data were acquisitioned using computer interface for analysis. The tensile test was conducted according to British standard BS EN ISO 527-1 and -2: 1996 [14]. In this study, the tensile properties results from the work of Mulyadi et al [12] are utilized as input parameters in FEM modeling and also to validate tensile modeling results.

Finite Element Method Modeling

Dogbone specimen design as seen in Figure 1 was produced using Freecad software. Step file is exported and opened in Salome-Meca software for FEM modeling. Material data was based on research conducted by Mulyadi et al [12]. Modulus of elasticity from analytical model was applied in tensile FEM modeling in present work. One end of the test coupon was fixed and the other end was applied with 1% displacement load. Netgen 1D-2D-3D meshing hypothesis was utilized to generate the mesh. The stress results were assessed and compared to the result from tensile test.

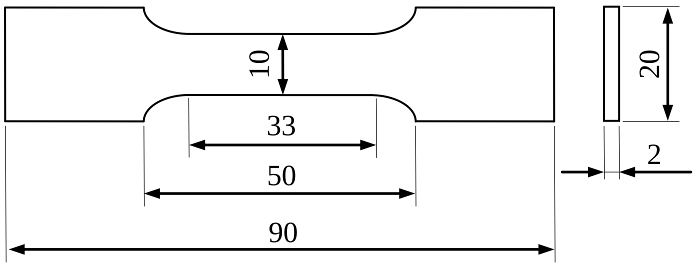

Figure 1. Dogbone shape specimen nomenclature.

RESULTS AND DISCUSSION

Figure 2 shows tensile test for composite epoxy modified with nanosilica with ten percent content by weight. Stress distribution along the gauge length provide a very good uniform as expected. Average stress on gauge length is 55 MPa with 1% of displacement load while 35 MPa based on experimental results [12]. The difference is due to in this tensile test modeling only consider the specimen with homogenous material with no interaction effect between the matrix and nanosilica filler despite the modulus of elasticity provided in this FEM extracted from analytical modeling which include the interaction effect in the assessment.

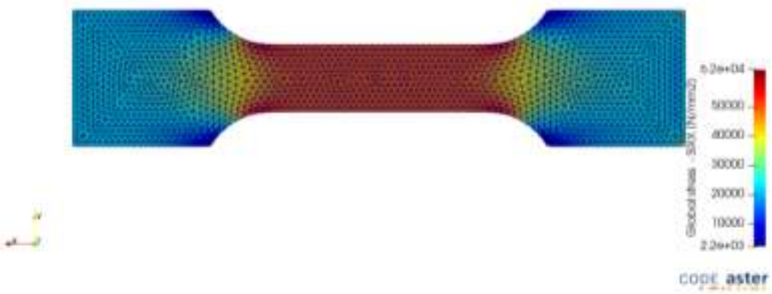

Figure 2. Global stress in x direction distribution of tensile test

Tabel 1. Modulus elasticity results (GPa)

Method	SiO$_2$ Content (% by weight)				
	0	2	5	8	10
Analytical Modeling [12]	2.75	3.06	3.34	3.58	3.73
Experiment [12]	2.75	3.41	3.54	3.66	3.78
Tensile test 3D FEM modeling	2.75	3.32	3.42	3.56	3.68

In addition, the modulus of elasticity in analytical model were extracted from 2D modeling method while in the present work 3D modeling was performed without in the presence of nanosilica physically. The method discrepancy between present work and previous analytical model influences the final results in the present work. FEM modeling in the present work should introduce nanosilica physically in the model to make everything more realistic and consistence. This can be done by proposing a proper method to obtain better result.

Modulus elasticity comparison among analytical, experiment and FEM is depicted in Figure 3. It can be seen that the results are in a very good correlation. This evidence confirmed that the modulus elasticity from analytical and FEM were well predicted using the method mentioned in this present work. According to Figure 3 it can be seen clearly that the modulus of elasticity is improved as the content of nanosilica increased. Modification of the epoxy matrix using nanosilica revealed a promising way to improved modulus elasticity of epoxy and the possibility other mechanical properties related to modulus elasticity of the material.

Optimizing nanosilica content should be done to find the limitation of the filler addition in the epoxy matrix system. This is very important so we know how far this can be to acquire the best material to implement in the real life application.

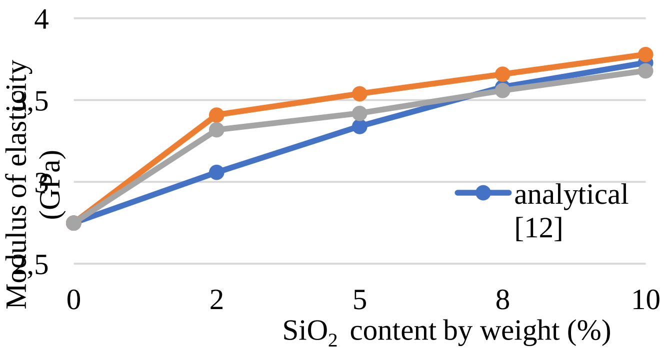

Figure 3. Composite Elastic modulus assessment of the Nanopox F400 (SiO$_2$) modified Epikote 828 composite among experimental, tensile FE modelling and micromechanics model.

CONCLUSION

This study revealed that analytical and FEM modeling results with regard to the modulus of elasticity of epoxy matrix modified with nanosilica particles are well predicted and in a good correlation with experimental result. The addition of nanosilica in epoxy matrix system up to 10% of nanosilica content by weight is increased the modulus elasticity.

SUGGESTION

FEM modeling of epoxy modified with nanosilica particle in 3D should be performed in order to minimize the deviation to with regard to extract modulus of elasticity. Furthermore, more mechanical behavior of epoxy nanosilica composite need to be done to get more insight regard to this composite material characteristics.

BIBLIOGRAPHY

[1] P. Drescher, M. Thomas, J. Borris, U. Riedel, and C. Arlt, “Strengthening fibre/matrix interphase by fibre surface modification and nanoparticle incorporation into the matrix,” *Compos. Sci. Technol.*, vol. 74, no. 0, pp. 60–66, 2013.

[2] J. A. Nairn and S. Hu, “Micromechanics of Damage: A Case Study of Matrix Microcracking,” in *Damage Mechanics of Composite Materials*, R. Talreja, Ed. Amsterdam: Elsevier, 1994, pp. 187–243.

[3] J. A. Nairn, “Comprehensive Composite Materials,” Z. A. K. and Carl, Ed. Oxford: Pergamon, 2000, p. 403.

[4] A. Jumahat, C. Soutis, S. A. Abdullah, and S. Kasolang, “Tensile Properties of Nanosilica/Epoxy Nanocomposites,” *Procedia Eng.*, vol. 41, no. 0, pp. 1634–1640, 2012.

[5] M. Zappalorto, A. Pontefisso, A. Fabrizi, and M. Quaresimin, “Mechanical behaviour of epoxy/silica nanocomposites: Experiments and modelling,” *Compos. Part A Appl. Sci. Manuf.*, vol. 72, no. 0, pp. 58–64, 2015.

[6] H. Zhang, Z. Zhang, K. Friedrich, and C. Eger, “Property improvements of in situ nanocomposites with reduced interparticle particle at high nanosilica content,” *Acta Mater.*, vol. 54, pp. 1833–1842, 2006.

[7] Z. Gao and L. Zhao, “Effect of nano-fillers on the thermal conductivity of epoxy composites with micro-Al2O3 particles,” *Mater. Des.*, vol. 66, Part A, no. 0, pp. 176–182, 2015.

[8] A. K. Guin, B. P. Mallik, and S. Shreepathi, “Electrochemical and mechanical studies on influence of curing agents on performance of epoxy tank linings,” *Prog. Org. Coatings*, vol. 78, pp. 340–347, 2015.

[9] S. Chandrasekaran, C. Seidel, and K. Schulte, “Preparation and characterization of graphite nano-platelet (GNP)/epoxy nano-composite: Mechanical, electrical and thermal properties,” *Eur. Polym. J.*, vol. 49, no. 12, pp. 3878–3888, 2013.

[10] C. Soutis and P. W. R. Beaument, “Multi-scale modeling of composite material systems: the art of predictive damage modeling.” Woodhead, Cambridge, 2005.

[11] B. Klusemann and B. Svendsen, “Homogenization methods for multi-phase elastic composite: Comparison and benchmarks,” *Tech. Mech.*, vol. 30, no. 4, pp. 374–386.

[12] Mulyadi, I. Gitman, C. Pinna, and C. Soutis, “Modelling Interaction Effect of Nanosilica Particles on Nanosilica / Epoxy Composite Stiffness,” in *16 Th European Conference on Composite Material*, 2014, no. June, pp. 22–26.

[13] A. Jumahat, C. Soutis, F. R. Jones, and A. Hodzic, “Effect of silica nanoparticles on compressive properties of an epoxy polymer,” *J. Mater. Sci.*, vol. 45, no. 21, pp. 5973–5983, 2010.

[14] “British Standard ISO 527-5:1997. Plastic determination of tensile properties. art 5: Test conditions for unidirectional fibre-reinforced plastic composite.” 1997.