www.amlett.com, www.vbripress.com/aml, DOI: 10.5185/amlett.2015.5835 Published online by the VBRI Press in 2015

An experimental and numerical investigation of tensile properties of stone wool fiber reinforced polymer composites

Sivaraos[1*], S.T. Leong[1], Y. Yusof[2], C.F. Tan[3]

[1]*Faculty of Manufacturing engineering, Universiti Teknikal Malaysia Melaka, Malaysia*
[2]*Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn, Malaysia*
[3]*Faculty of Mechanical engineering, Universiti Teknikal Malaysia Melaka, Malaysia*

[*]Corresponding author. Tel: 06 - 3316869; E-mail: sivarao@utem.edu.my

Received: 04 February 2015, Revised: 27 July 2015 and Accepted: 28 July 2015

ABSTRACT

The present work focuses on determination of tensile properties of stone wool fiber reinforced high density polyethylene composites by two methods: experimental and finite element analysis. Four weight percentage of stone wool (SW) fiber 10 – 40 wt. % were chosen. The samples of composites were made by using the hot press technique. ASTM D638 was used to test the composite samples. Scanning electron microscopy analysis was carried out on the fractured surface to observe the interaction between matrix and fiber in the composites. Significant improvement of tensile properties was observed and recorded from the composites with SW weight percentage of 20 wt. %. The yield strength, tensile strength and tensile modulus increased by 8.1%, 23.0% and 37.8% over pure HDPE. ANSYS tensile models were then established to understand better the processing and behavior phenomenon. The numerical results obtained were in good agreement with the experimental results, with an accuracy of more than 90%. Copyright © 2015 VBRI Press.

Keywords: Pr (OH)$_3$; Pr_6O_{11}; nanorods; dielectric properties; gate dielectric.

Introduction

Composites are a combination of two or more constituent materials that consist of phases like reinforcement and matrix phase. They are considered as one of the most adaptable and advanced engineering materials **[1-2]**. Composites are categorized by either the geometry of reinforcement (particulate, flake, fibers) or by the type of matrix (metal, ceramic, polymer). Most composites have been created to optimize the mechanical properties and are designed to be stronger and lighter to apply through environments of high temperature and to resist corrosion. This is because reinforced fibers are the principal load-carrying constituents while matrix is the load transfer medium between them. It also acts as a role of desired location and an orientation keeper **[3]**. The geometrical arrangement of the fibers such as the orientation angles of fiber, the volume fraction, the fiber aspect ratio and the fiber spacing parameters strongly affect the optimized properties **[4]**. Thermoplastic composites which is reinforced with different types of fibers such as long fibers, short fibers and mat of natural and synthetic fibers like coconut, oil palm, hemp, glass, carbon and etc. are used in a variety of applications such as in the automotive industry, sports equipments, aircraft structural components, ballistic, tires and etc. They are used because of their improved properties such as stiffness, toughness, ambient and high temperature strength, creep resistance, and corrosion resistance **[5]**. Many researchers have investigated the mechanical properties of thermoplastic composites and discovered that there is improvement in its mechanical properties **[6-8]**. High density of polyethylene (HDPE) is a polymer that has a low degree of branching in a long chain of repeated atoms, thus having strong intermolecular force **[9]**. Enhanced of mechanical properties of HDPE composites have been observed and reported in many investigations [**10-12**].

Mineral fibers such as carbon fiber (CF) and glass fiber (GF) are widely used as the reinforcements of polymer composites. Many researchers have investigated the mechanical properties of mineral fiber reinforced composites and discovered that there is improvement in the mechanical properties [**13-16**]. All results have shown that mechanical properties of the composites strongly depend on the fiber content. CF and GF can improve the mechanical properties of thermoplastic composites but they suffer from several drawbacks such as high density and high cost. As a result, new mineral fiber reinforced materials are currently studied. Stone wool fibers as one of the mineral fibers are not new, but their suitability as reinforcement in polymer composites is a relatively new issue. These rising mineral fibers are natural, safe and easy to process at the recycling stage **[17]**. Stone wool is a manufactured byproduct of volcanic activity which has the characteristic of typical wool insulation. Pre-mixture of stone wool is heated to about 1400-1500 ^{o}C in order for it to be in lava form. After that, the resin is combined with fibers which will produce a mass of intertwined fibers. These fibers are a promising alternative for fiber reinforced composites due to their lightweight, excellent heat resistance, sound insulation, sustainability and environmental friendliness **[18]**.

Cheng *et al.* **[19]** studied the properties of cement-based composites with addition of stone wool. The results showed that compressive strength, splitting tensile strength, abrasion resistance of cement-based composites had improved in this composite. According to a study by Manikandan *et al.* [**13**], the performance of stone wool composites was superior to the glass fiber reinforced composites. Another study also presented the high performance of stone wool composites in terms of young modulus, impact force, compressive and bending strength [**15**]. These good properties enable the applications of stone wool fibers in fields where glass composites are nowadays widely applied.

Tensile test is an engineering test that can test material strength. A sample is subjected to a pulling force from both sides until the sample fractures. This test method is used to produce properties of tensile data for the material and to predict the reaction of the material when it is under tension load. The selection of material engineering applications depends on the tensile result obtained. For fiber reinforced HDPE composites, large increment of tensile strength occurred on the composites with a 20 percentage weight of fiber **[20-21]**. This indicates that fiber content in composites strongly affects the mechanical properties of the composites **[22]**. Han-Seung Yang *et al.* **[23]** presented the effect of different compatibilizing agents on the mechanical properties of lingo-cellulosic material filled polyethylene bio-composites. The results reveal that the incorporating maleated PE has better tensile strength and modulus.

Structural calculation software based on finite element analysis (FEA) is a common practice when designing new industrial products processed from thermoplastic materials. By using the finite element analysis, engineers can reduce the amount of prototype testing. This helps in cost and time saving for an organization as it allows the creation of more reliable and better quality designs. There are many types of FEA tools such as Abaqus, Ansys, Catia, Cosmos, LS-DYNA etc. For this research, ANSYS will be used to get the simulation result of tensile test. ANSYS is a complete FEA software package used by engineers worldwide in virtually all fields of engineering. These include structural, thermal, fluid, computational fluid dynamics, electrical, electrostatics and electromagnetics. Some researchers have presented the experimental and numerical investigation of mechanical properties of mineral fiber reinforced polymer composites **[24-28]**. Those experiments showed that with the increase in weight fraction of reinforcement, the tensile strength and flexural strength increases over the pure polymer.

The improvement in mechanical properties of mineral fiber reinforced composites from previous literatures have become the motivating factor for the current study on the influence of stone wool fiber and the mechanical properties of HDPE since stone wool has been to be safer for used in comparison to carbon and glass fiber **[29]**. Besides, stone wool fiber has properties such as being lightweight, having excellent heat resistance, sound insulation, is sustainable and environmental friendly **[18]**. Research on tensile properties of stone wool-polymer composites (SWPC) has been conducted where HDPE has been used as the matrix and stone wool as the reinforced fibers. In this study, the tensile modulus of SWPC has been studied using two methods: experimental and finite element analysis. Tensile properties have been evaluated at different weight percentage (10 – 40 wt. %). Equivalent finite element analysis models have been designed and the results have been compared with the experimental results by considering the isotropic behavior. Error percentage of these results have been calculated and observed.

Experimental

Material

Highly Polyethylene Malaysia Sdn. Bhd. supplied the general purpose high density polyethylene (HDPE) in pellet form with melting point of 180 ^{o}C and density of 958.5 kg/m^{3}for this study. Firstly, HDPE pellets underwent treatment through the Memmert drying oven for 24 hours at 70 ^{o}C to constantly remove the moisture content of the pellets. Rockwool Malaysia Sdn. Bhd. provided fibers with density of 222 kg/m^3. Compositions of stone wool are summarized in **Table 1 (supplementary information)**. First, Stone wool fibers were cleansed through the utilization of ultrasonic cleaner using distilled water for 90 minutes to ensure the removal and separation of wax and impurities. The stone wool was then dried using Lab Tech vacuum drying oven for 8 hours continuously at 105 ^{o}C **[30-31]**. This was to ensure that the stone wool had constant density while drying out trapped moisture and had better bonding in a steady state.

Fabrication of composites

Composite formulation for different weight percentage was then taken down and is as shown in **Table 2 (supplementary information)**. An internal mixer, Haake Polymer Lab OS Rheodrive 16 was used to mix the matrix and fiber together. The standard processing temperature for HDPE composite is 165 ^{o}C with rotor speed 50 revolutions per minute (rpm). The duration of the mixing process was 10 minutes in which the matrix was put into the mixer within a 30 second time frame. This allowed the matrix to melt for the first 5 minutes. Once done, remaining fiber was added into the mixture. Matrix and fiber were then mixed and processed together uniformly for 5 minutes. Motorized Hydraulic Hot Molding Machine (Go Tech Testing Machine Inc GT-7014-A, Taiwan) was used for post mixing batches which was then hot pressed to form composite sheets. Through the initial melting in the hot molding machine within 10 minutes, it was found that no pressure is applied whereby the mold assembly slightly touched the upper mold of the hot molding machine. Another 10 minutes of hot pressing time was applied to the mixed material after they have been fully melted. Pressure applied was gradually increased to 70 kg/cm^3 to squeeze out air bubbles formed in the composite sheet. Upon completion, cooling down was done by taking out the mold assembly and placing it into the lower press plate for 10 minutes in a pressure free condition. This parameter control was obtained from the previous study **[11, 28]**. The composite with different weight percentage was removed from the mold cavity.

Specimentation

The SWPC specimens were prepared based on ASTM D638 into 165mm x 19mm x 4mm rectangular bars, as used by other researchers in the field [**27, 33**]. A total of 15 specimens were profiled according to the ASTM standard of dimension from the finished composite to fulfil the study.

Test apparatus and procedures

The tensile test was conducted using an ASTM D638 at room temperature through a universal testing machine (Shimadzu AG-1 100KN, Japan). The crosshead speed was set at 2 mm/min while a load cell capacity of 100 kN was used throughout the test. Values of yield strength, tensile strength and tensile modulus were observed to be the response of the tests. Three replications were performed for each weight percentage configuration and the average values were determined as final.

Finite element modeling

Finite element analysis has become one of the most important tool to solve engineering problems by complex analysis **[34]**. The general procedures involved in the analysis are input for the model material properties, built of model, selection of the element type of material, mesh for the model, fiber reinforcing section for the model, applicable boundary conditions, solution of the mathematical representation and post processing which is the study result for the solution **[35]**. For the linear static stress analysis, software package ANSYS Parametric Design Language (APDL) was used. During the finite element analysis conducted in this research, the material used is considered isotropic in nature. The boundary conditions applied were similar to the experimental condition as shown in **Fig. 1**. The element type used for this analysis work was solid 20-node 186 because it was one of the valid element base to be used to present the REINF 265 element in the reinforced composites. **Table 3** shows the input of data used for this reinforcing section form. Model for pure HDPE material, stone wool reinforced HDPE composite and meshed material are shown in **Fig. 2 (supplementary information)**. **Table 4** shows the input value for materials modeling such as Young's modulus, Poisson ratio and density for HDPE matrix and stone wool fiber. At section 3.6, the validation between FEA and experimental will be discussed.

Results and discussion

Fig. 3 shows the stress-strain curve for pure HDPE and 10-40 wt. % SWPC. Results such as yield stress, yield strain, tensile strength and fracture strain or ductility of the material can be obtained from the stress-strain curve. It can be observed that fracture happens on composite reinforced with 10 wt. %, 30 wt. % and 40 wt. % SW fiber. 20 wt. % SW fiber reinforced HDPE has higher ductility than other composites as shown in the curve. Mechanical properties of the composite are highly dependent on the matrix and fiber properties, reinforcement shape and alignment to the load.

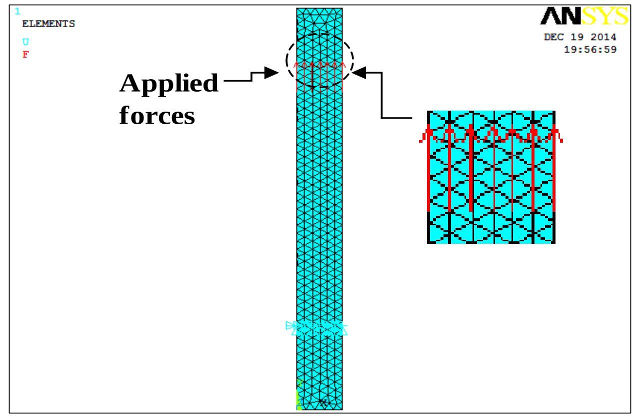


Fig. 1. Boundary conditions for finite element model.

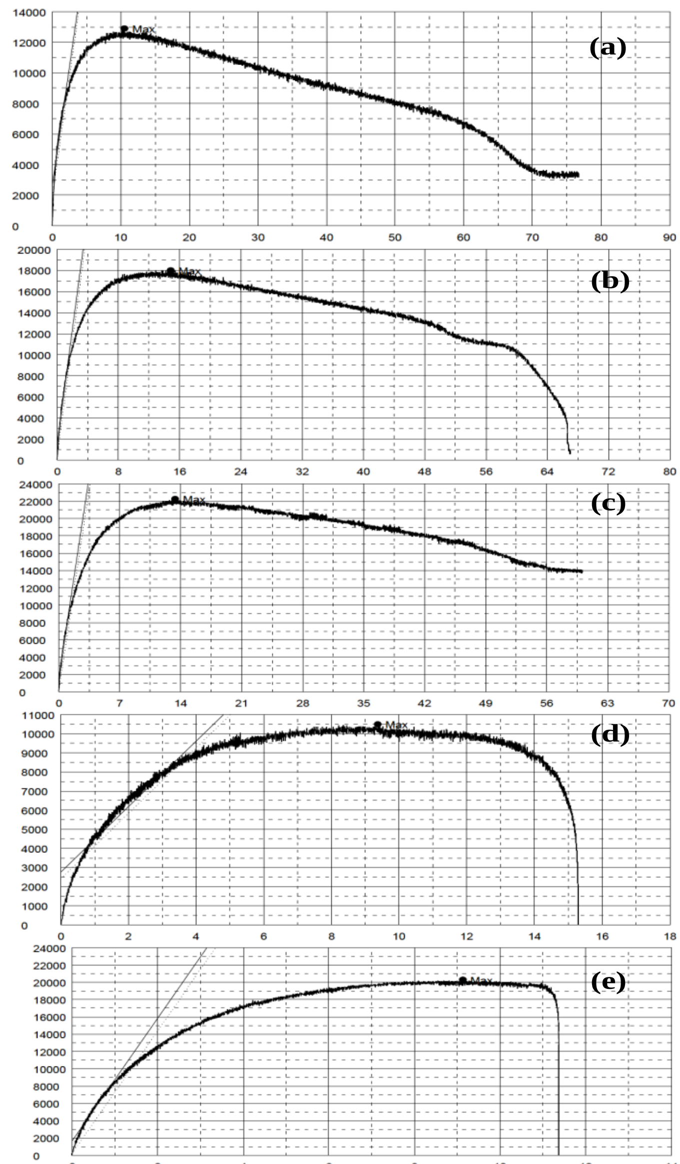


Fig. 3.Stress-strain curve of stone wool reinforced HDPE composites with different filler weight percentage (a) pure HDPE (b) 10 wt.% (c) 20 wt.% (d) 30 wt.% (e) 40 wt.%.

Tensile strength

Tensile strength also known as ultimate tensile strength is actually the maximum tensile stress that the material can support while being pulled or stretched before having failure **[2]**. The experimental result is shown in **Table 5** and plotted in a graph as **Fig. 4(a)**. Result shows that the 20 wt. % SWPC composite has recorded the highest tensile strength which is 29.82% higher than the tensile strength of pure HDPE. Besides, pure HDPE and 10 wt. % SWPC have tensile strength of 18.050 MPa and 16.767 MPa respectively, and their difference is only 7.10%. The 30 wt. % SWPC has recorded the lowest average tensile strength. Tensile strength decreased with the increased of fiber content may due to agglomerations of fibers happened in some points which caused by inefficient SW fibers dispersion inside matrix. This phenomena cause fibers easily pull-out which may be visualized as friction like action arising from the geometrical contact of between fiber and matrix [**36**]. With this, the results show an agreement with the study done by J.R. Araujo *et al.* **[21]**, where the interfacial strength between 20 wt. % of SW reinforcement and 80 wt. % of HDPE matrix is the strongest, resulting in the highest tensile strength.

Yield strength

Yield strength can be defined as the stress of a material which can withstand before it starts to deform plastically. Once passed the yield point, it will deform plastically where the deformation will be permanent **[2]**. **Table 5** and **Fig. 4(b)** showed the yield strength for each filler weight percentage where 20 wt. % SWPC has the highest yield strength when compared to all other composites of different weight percentage. Its value of yield strength is 8.79% higher than the pure HDPE. The 30 wt. % SWPC has the lowest yield strength which is 16.90% lower than that of pure HDPE. It is significant that the 20 wt. % SWPC has the greatest performance in the data analysis of yield strength. Material of high yield strength is crucial in the designation stage, as it helps the design engineer to understand the stress level a material can withstand before plastic deformation takes place.

Tensile modulus

Tensile modulus, also known as Young's modulus is a measurement of the stiffness of an elastic material or the resistance of material to elastic deformation under load **[2]**. Experimental results are shown in **Table 5** and plotted in a graph as in **Fig. 4(c)**. The values of tensile modulus dropped when it was increased beyond 20 wt. %, proving that it has the highest value of tensile modulus. As compared to pure HDPE, its tensile modulus is 60.83% higher. The lowest tensile modulus is recorded for 30 wt. % SWPC, a difference of 41.93% from the pure HDPE. The drop of tensile modulus happened maybe due to the void occurred in the specimens which promoted a poor interaction and adhesion between matrix and fibers [**25**]. Higher properties value cannot be achieved when there is no sufficient adhesion bonding was present [**37**]. The 20 wt. % has the highest stiffness, as stiffness is determined by the binding forces between atoms. Thus proving that the binding forces of 20 wt. % SWPC is the strongest among the pure HDPE and other composites.

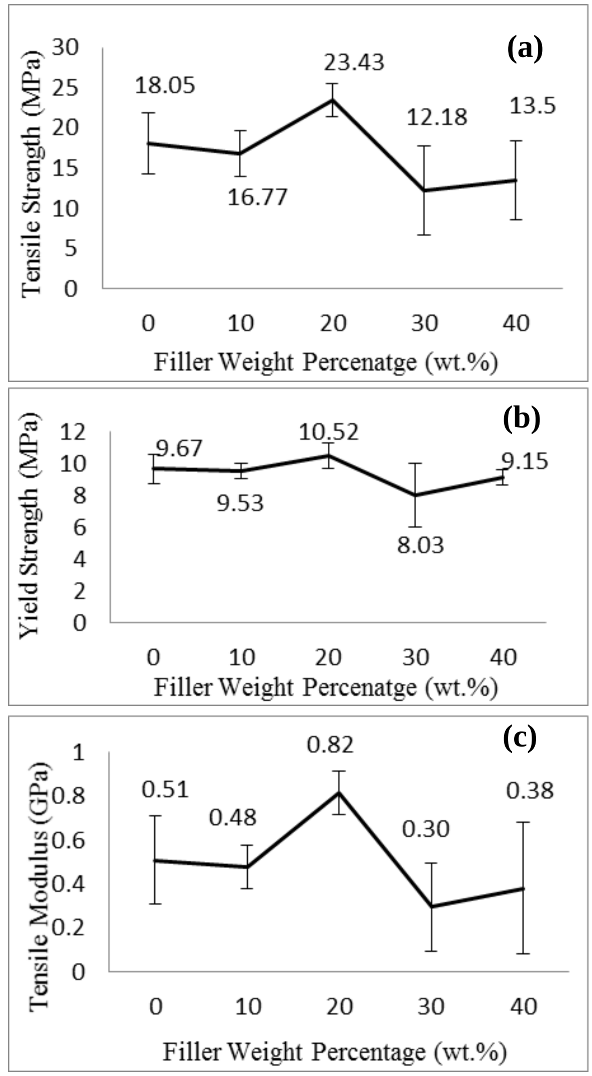


Fig. 4. The effect of fiber weight percentage of stone wool fiber reinforced high density polyethylene (a) on tensile strength (b) on yield strength and (c) variation of tensile modulus.

As for mathematical modeling, some of the material properties such as elastic modulus (E), Poisson's ratio (*v*) and relative volume fractions (V) are employed to predict the properties of composites. The simplest model used to predict the elastic properties for a composite material is the rule of mixture (ROM). The ROM equations to predict the tensile modulus of the composites were derived as Eq. (1) **[38],**

$$E_1 = E_f V_f + E_m V_m \quad (1)$$

where E_f, E_m, V_f and V_m are the moduli and volume fractions of the fibre and matrix materials respectively.

From Eq. (1), the parameter V_f was given as Eq. (2),

$$V_f = (W_f/\rho_f) \,/\, [(W_f/\rho_f) + (W_m/\rho_m)] \quad (2)$$

where, W_f, W_m, ρ_f, ρ_m are the weight percentage and density of the fiber and matrix materials respectively.

From Eq. (2), Vm can calculate from Eq. (3),

$$V_f + V_m = 1 \tag{3}$$

Morphology study

Some fracture surfaces of SW loaded tensile specimens are as shown in **Fig. 5**. Ductile failure can be observed in the matrix region of 20 wt. % and 30 wt.% SW loaded specimens as shown in **Fig. 5(a)** and **Fig. 5(c)**. It can be clearly seen from 20 wt. % SW composites that the wedges are long and are pulled away (separated) from the surrounding matrix. Wedging is one of the modes of deformation in polyethylene. It is supported by R.D.K. Misra *et al.* [**39**] that, wedging is the dominant mode of surface deformation for ductile polymeric material. For 30 wt. % SW composites, wedges and micro-void occurred on the fracture surface of the specimen. Micro-void or bubble represents one of the factors that form cracks towards fracture with little deformations on the specimen thus correlating the ductile fracture phenomenon [**40**], thus, proves that 30wt.% have the lowest tensile properties.

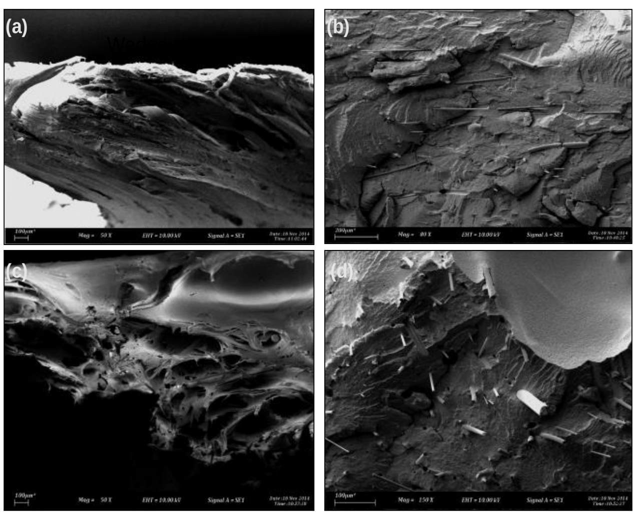


Fig. 5. SEM micrograph of loaded tensile specimen with (a), (b) 20 wt.% (c), (d) 30 wt.%.

From **Fig. 5(b)** it can be observed that SW fibers embedded well with the HDPE matrix is seen to improve the interfacial bonding between the fiber and the matrix. This phenomenon increased the efficiency of load transfer between fiber and matrix which also leads to an increase in the tensile properties [**41**]. Moreover, **Fig. 5(d)** reveals that the concentration of fiber caused by micro-void coalesces and fiber pull-out phenomena from the HDPE matrix when a fracture happens [**42**]. This indicates that, weak interfacial bonding occurred in 30 wt. % composites due to the poor wetting between fiber and matrix. This causes inefficient load transfer between fiber and matrix to happen. Therefore, 20 wt. % composites have the highest tensile properties while 30wt. % yields the lowest.

Finite element analysis

The stress and strain from the result of ANSYS nodal solution are calculated by using some of the mathematic analytical finite element analysis solution which is applied in the ANSYS. The analytical solution for maximum strain and maximum stress are given in Eq. (4) and Eq. (5) **[43]**.

$$\int_v \sigma_{ij}\delta e_{ij} dV = \int_s f_i^B \delta u_i dV + \int_s f_i^S \delta u_i ds \tag{4}$$

where, σ_{ij} = Cauchy stress component
$e_{ij} = \frac{1}{2}\left(\frac{\partial ui}{\partial xj} + \frac{\partial uj}{\partial xi}\right)$ = deformation tensor
u_i = displacement
x_i = current coordinate
f_i^B = component of body force
f_i^S = component of surface fraction
V = volume of deformed body
S = surface deformed body on which tractions are prescribed

$$\sigma_{ij} = \sigma'_{ij} - \delta_{ij}\bar{P} = \sigma_{ij} + \delta_{ij}P - \delta_{ij}\bar{P} \tag{5}$$

where, δ_{ij} = Kronecker delta
σ_{ij} = Cauchy stress from constitutive law

Fig. 6 shows the deformed shape after the finite element analysis. The nodal solution are results of tensile test for pure HDPE and stone wool reinforced HDPE composites by using ANSYS are shown in **Fig. 7**. From these figures, it is evident that the maximum stress (red color zone) occurs at the point where the load is applied. This is indicative of the fact that failure starting point for these two methods matched **[27]**. Tensile modulus (E_p) can be calculated by Eq. (6) by applying the maximum stress and maximum strain obtained from finite element analysis (FEA). Maximum stress, maximum strain and calculated tensile modulus of tensile test from ANSYS are shown in **Table 6**.

$$E_p = \frac{\sigma_f}{\epsilon_f} \tag{6}$$

where, σf is maximum stress; ϵf is maximum strain.

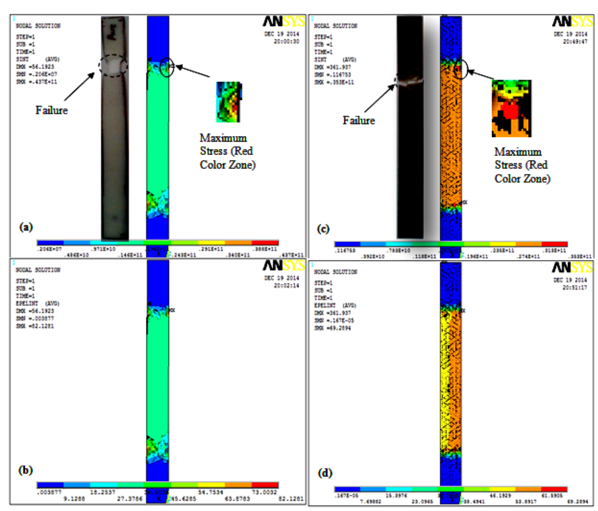


Fig. 7. Nodal solution of tensile test for pure HDPE material (a) maximum stress, (b) maximum strain and for 20wt. % reinforced HDPE composites, (c) maximum stress and (d) maximum strain.

Comparison between FEA and experiment

The finite element analysis tensile modulus of every fiber weight percentage composites were compared with the experimental tensile modulus as shown in **Fig. 8**. Error percentages of these results were calculated and are as shown in **Table 7**.

Table 7. Comparison of experimental and ANSYS analysis tensile modulus and error percentage.

Fiber Weight Percentage (wt. %)	Experimental (GPa)	ANSYS analysis (GPa)	Error (%)
0	0.508	0.532	4.5
10	0.477	0.532	10.3
20	0.817	0.891	8.3
30	0.295	0.266	9.9
40	0.381	0.413	7

According to Velmurugan *et al.* [**44**], the acceptable error percentage for model validation is within 20%. This is an important step to verify the effectiveness of the model that is created by the software ANSYS. The range of error percentage for this study is between 4–10 wt. % which is considered to be within the acceptable range. The trend of the tensile modulus results between experimental and finite element analysis is similar. As observed in the **Fig. 8**, the trend of the results predicted by FEA is in agreement with those obtained by experimental. 20 wt. % SWPC has the highest tensile modulus for experimental and FEA. From the comparison, FEA obtained higher values and the results show that finite element analysis is better than experimental. This deviation happened due to the manufacturing defects of the composites (porosity, bubbles, void), discontinuities in the test specimen material, uncertainties in the experimental setup and etc. Besides that, isotropic behavior of the material is assumed for the modeled material in analysis but it is difficult to achieve isotropic behavior in the fabricated randomly oriented fiber composite due to stress concentrations at the fiber ends **[27]**. Mesh limitations used in the analysis can also cause the deviation of results between analysis and experimental results **[35]**.

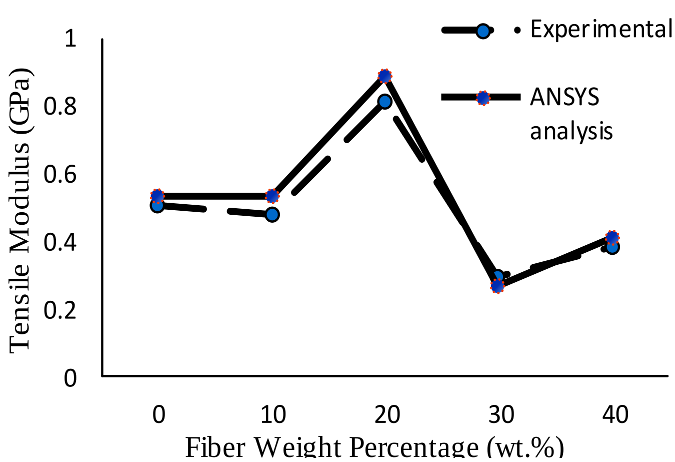


Fig. 8. Comparison of experimental and ANSYS analysis tensile modulus.

Conclusion

A stone wool reinforced HDPE that had been prepared by varying weight percentage and tensile properties was investigated in accordance to ASTM D638. The result indicates that 20 wt % SWPC yielded the highest value for tensile strength, yield strength and tensile modulus as compared to all the other composites of different weight percentages tested. This proves that 20 wt% stone wool fiber has the best dispersion of fiber in the matrix which allows the load transfer between fiber and matrix to be more efficient. The good interfacial bond, absence of void and good adhesive between matrix and fiber are also the reasons as to why the 20 wt. % is able to achieve the highest tensile properties. Micro-void which occurred on the fracture surface of 30 wt. % composites specimen is one of the factors that causes cracks thus leading into premature failure. Therefore, fracture which is propagated and little deformation on the specimen correlates with the ductile fracture phenomenon causes 30 wt. % to have the lowest tensile property. A model of finite element analysis was designed and analyzed under similar boundary conditions. The trend of tensile modulus obtained from the analysis was very much similar to the experimental results. Model accuracy of 90% was found, hence, proving a good agreement between the results of these two methods. Therefore, the model which can be considered robust reveals almost exact processing and behavior phenomenon of SWPC. Thus, the potential of stone wool fiber as reinforced materials for polymer composites, particularly HDPE has proven to yield better mechanical properties especially tensile.

Acknowledgements

First and foremost, the authors would like to thank the Ministry of Higher Education Malaysia for awarding a Fundamental Research Grant Scheme [Grant number: FGGS/1/2013/TK01/UTEM/03/1]. The authors would also like to extend their appreciation to Zamalah scholarship which succeeded the completion of this research. We are highly in debt and would like to specially thank the top level management of the Universiti Teknikal Malaysia Melaka, Centre for research and Innovation Management and Faculty of Manufacturing Engineering for providing continuous technical and moral support.

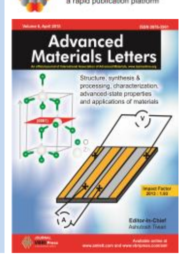
Author contribution

Conceived the plan: Sivaraos, S.T.Leong; Performed the expeirments: Sivaraos, S.T.Leong; Data analysis: Sivaraos, S.T.Leong, Y.Yusof, C.F.Tan; Wrote the paper: Sivaraos, S.T.Leong, Y.Yusof, C.F.Tan. Authors have no competing financial interests.

Reference

1. Nazareth, S.A.L.; Teixeira, S.C.S.; Widal, A.C.C.; Coutinho, F.M.B. *Polymer Testing*, **2001**, *20*, 895.
   DOI: 10.1016/S0142-9418(01)00018-6
2. Callister, W.D.; Rethwisch, D.G. *Materials Science and Engineering*, John Wiley & Sons Pte Ltd, United States, **2011**.
   ISBN: 978-0-470-50586-1
3. Kaw, A.K. *Mechanics of Composite Materials*, Chapter 1, CRC Press: Taylor & Francis Group, USA, **2006,** 2nd ed.
   ISBN: 0-8493-1343-0
4. Ghassemieh, E.; Nessehi, V. *Polymer Composites*, **2001**, *22*, 528.
   DOI: 10.1002/pc.10557
5. Chandra, R.; Singh, S.P.; Gupta, K. *Composite Structures*, **1999**, *46*, 41.
   DOI: 10.1016/S0263-8223(99)00041-0
6. Castro, D.O.; Ruvolo-Filho, A.; Frollini, E. *Polymer Testing*, **2012**, *31*, 880.
   DOI: 10.1016/j.polymertesting.2012.05.011

7. Juhasz, J.A.; Best, S.M.; Brooks, R.; Kawashita, M.; Miyata, N.; Nakamura, T.; Bonfield, W. *Biomaterial*,**2004**, *25*, 949. **DOI:** 10.1016/j.biomaterials.2003.07.005
8. Agunsoye, J.O.; Talabi, S.I.; Sanni, S. *Journal of Mineral and Materials Characterization and Engineering*, **2012**, *11*, 774. **DOI:** 10.4236/jmmce.2012.118066
9. Rassiah, K.; Mohd, A.C.; Mohd, Y.Y.; Sihombing, H. *International Journal of Integrated Engineering*, **2011**, *33*, 63. **DOI:** penerbit.uthm.edu.my/ojs/index.php/ijie
10. Panthapulakkal, S.; Mohini, S. *Composites: Part A – Applied Science and Manufacturing*, **2007**, *38*, 1445. **DOI:** 10.1016/j.compositesa.2007.01.015
11. Tong, J.Y.; Royan, N.R.; Ng, Y.C.; Ab Ghani, M.H.; Ahmad, S. *Advanced in Materials Science and Engineering*, **2014**, *1*. **DOI:** 10.1155/2014/938961
12. Gungor, A. *Materials and Design*, **2007**, *28*, 1027. **DOI:** 10.1016/j.matdes.2005.11.003
13. Manikandan, V.; Winowlin Jappes, J. T.; Suresh Kumar, S. M.; Amuthakkannan, P. *Composites: Part B*, **2012**, *43*, 812. **DOI:**10.1016/j.compositesb.2011.11.009
14. Poyyathappan, K.; Bhaskar, G. B.; Pazhanivel, K.; Venkatesan, N. *International Journal of Engineering and Technology*, **2014**, *6*, 83.
15. Lopresto, V.; Leone, C.; Iorio, I. D. *Composites: Part B*, **2011,** *42*, 717. **DOI:**10.1016/j.compositesb.2011.01.030
16. Agarwal, G.; Patnaik, A.; Sharma, R. K. *Journal of Engineering Science and Technology*, **2014**, *9*, 590.
17. Carmisciano, S.; DeRosa, I.M.; Sarasini, F.; Tamburrano, A.; Valente, M. *Materials and Design*, **2011**, *32*, 337. **DOI:** 10.1016/j.matdes.2010.06.042
18. Karamanos, A.; Hadiarakou, S.; Papadopoulus, A.M. *Energy and Building*, **2008**, *40*, 1402. **DOI:** 10.1016/j.enbuild.2008.01.004
19. Cheng, A.; Lin, W.T.; Huang, R. *Materials and Design*, **2011**, *32*, 636. **DOI:** 10.1016/j.matdes.2010.08.014
20. Suaraz, J.C.M.; Elzubair, A. *Materials Science and Engineering A*, **2012**, *55*, 29. **DOI:** 10.1016/j.msea.2012.06.051
21. Araujo, J.R.; Teixeira, G.M.; Spinace, M.A.S.; Paoli, M.A.D. *Composites Science and Technology*, **2010**, *70*, 1637. **DOI:** 10.1016/j.compscitech.2010.06.006
22. Szabo, J.S.; Czigany, T. *Polymer Testing*, **2003**, *22*, 711. **DOI:** 10.1016/S0142-9418(03)00005-9
23. Yang, H.S.; Wolcott, M.P.; Kim, H.S.; Kim, S.; Kim, H.J. *Composite Structure*, **2007**, *79*, 369. **DOI:** 10.1016/j.compstruct.2006.02.016
24. Aitor, A.; Rikardo, P.; Ane, M.Z.; Alicia, C.; Michael, O. *Polymer Testing*, **2010,** *29*, 170. **DOI:** 10.1016/j.polymertesting.2009.10.007
25. Dong, C.; Davies, I.J. *Materials and Design*, **2014**, *54*, 893. **DOI:** 10.1016/j.matdes.2013.08.086
26. Sai, V.S.; Satyanarayana, M.R.S.; Murthy, V.B.K.; Rao, G.S.; Prasad, A.S. *Advances in Materials Science and Engineering*, **2013**, 648, 6 pages. **DOI:** 10.1155/2013/648527
27. Singh, S.; Kumar, P.; Jain, S.K. *Advanced Materials Letters*, **2013**, *4*, 567. **DOI:** 10.5185/amlett.2012.11475
28. Ali, H.; Rafic, Y.; Farouk, F.; Samer, N. *Composite Structure*, **2012**, *94*, 3009. **DOI:** 10.1016/j.compstruct.2012.03.019
29. Roser, C.; Ramon, O. *Arch Bronconeumol*, **2012**, *48*, 12. **DOI:** 10.1016/j.arbr.2012.04.004
30. Joseph, K.; Thomas, S.; Pavithran, S. *Polymer*, **1995**, *37*, 5139. **DOI:** 10.1016/0031-3861(96)00144-9
31. Conzatti, L.; Giunco, F.; Capobianco, P.; Castellano, M.; Marsano, E. *Composites: Part A – Applied Science and Manufacturing*, **2012**, *43*, 1113. **DOI:** 10.1016/j.compositesa.2012.02.019
32. Ahmad, S.; Ab Ghani, M.H. *Advances in Materials Science and Engineering*, **2011**, 1. **DOI:** 10.1155/2011/406284
33. Kumar, A.; Batra, N.K.; Khanna, R. *International Journal of Engineering Research and Applications*, **2013**, *3*, 557. **DOI:** 10.1.1.419.2672
34. Matter, M.; Gmuer, T.; Cugnoni, J.; Schorderet, A. *Computer & Structure*, **2010**, *88*, 902. **DOI:** 10.1016/j.compstruc.2010.04.008
35. Chaudhary, V.; Gohil, P. *International Journal Metallurgical & Materials Science and Engineering*, **2013**, *3*, 15. **DOI:** 1271636691-2
36. Charoenvai, S. *Energy Procedia*, **2014**, *56*, 539. **DOI:** 10.1016/j.egypro.2014.07.190
37. Li, Y. *International Journal of Polymeric Materials and Polymeric Biomaterials*, **2012**, *61*, 882. **DOI:** 10.1080/00914037.2011.617338
38. Angelo, G.F.; Mark, T.K.; Ning, Y. *Composites: Part A*, **2006**, *37*, 1660. **DOI:** 10.1016/j.compositesa.2005.10.006
39. Misra, R.D.K.; Nerikar, P.; Bertrand, K.; Murphy, D. *Materials Science and Engineering A*, **2004**, *384*, 284. **DOI:** 10.1016/j.,sea.2004.06.047
40. Sivaraos; Mallisi; Ali, A; L.S. Teng. *Materials Testing*, **2014**, *56*, 150. **DOI:** 10.3139/120.110539
41. Sivarao; Mohd Rizal Salleh; Kamely, A; Tajul, A; Taufik. *Advanced Materials Research*, **2011**, *871*, 264-265. **DOI:** 10.4028/www.scientific.net/AMR264-265.871
42. Lei, H.S.; Wang, Z.Q.; Tong, L.Y.; Zhou, B.; Fu, J. *Composite Structure*, **2013**, *101*, 301.
43. Peter K. Theory reference for the mechanical APDL and mechanical applications. **2009.**
44. Velmurugan, G.; Vadivel, D.; Arravind, R.; Vengatesan, S. P.; Mathiazhagan, A. *International Journal of Mechanical and Industrial Engineering*, **2012**, *2*, 56.



Supporting Information

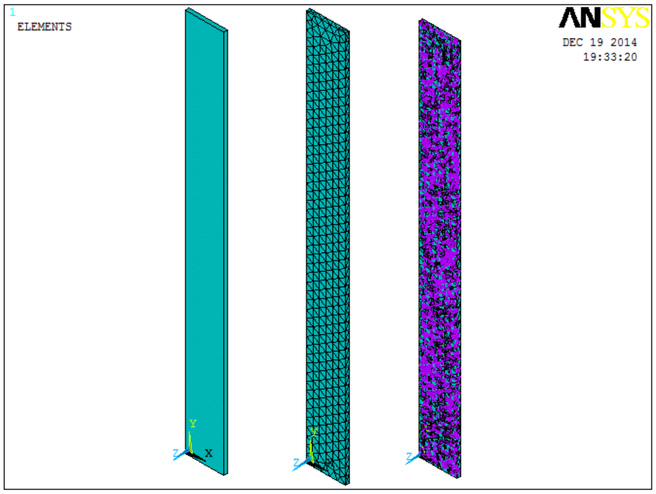


Fig. 2. Finite element model of (a) pure HDPE (b) meshed Material (c) stone wool reinforced composite.

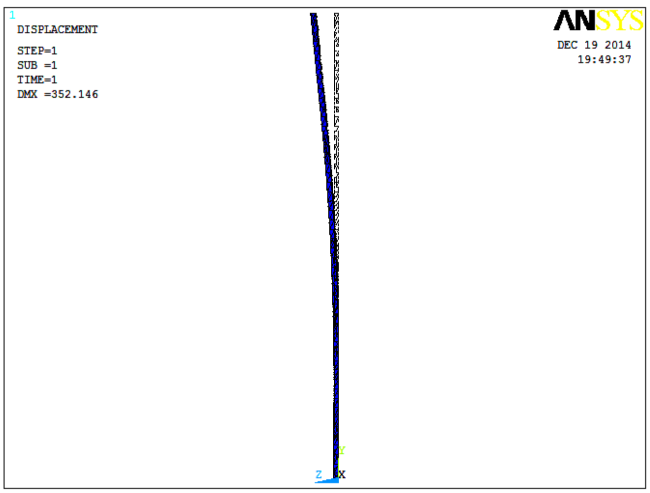


Fig. 6. Deformed shape for finite element model after tensile testing.

Table 1. Stone wool composition (wt.%).

Rock	Percentage
Basalt	58-80
Dolomite	10-30
Briquette	0-40
Limestone	0-5
Coke	13.5

Table 2. Composite formulation in weight percentage (wt. %) for tensile test.

Filler weight percentage (wt.%)	Tensile test	
	Filler (g)	Matrix (g)
0	-	280.358
10	3.428	126.163
20	6.496	112.144
30	9.740	98.126
40	12.987	84.108

Table 3. Data input for reinforcing section form.

Filler weight percentage (wt.%)	Distance between fiber (µm)
10	62.63
20	46.38
30	40.75
40	25.73

Table 4. Input value material properties of model composite material.

Mechanical Properties	Input value	
	Matrix	Fiber
Young's Modulus (Pa)	$7.587e^{8}$	$7e^{4}$
Poisson Ratio	0.4260	0.0001
Density (kg/m^3)	958.5	222

Table 6. ANSYS analysis tensile properties.

Fiber Weight Percentage (wt.%)	Tensile properties		
	Maximum Stress (Pa)	Maximum Strain	Tensile Modulus (GPa)
0	0.533e11	100.147	0.532
10	0.637e11	119.749	0.532
20	0.521e11	58.4874	0.891
30	0.151e11	56.7942	0.266
40	0.774e11	18.7427	0.413