Journal of Mechanical Engineering and Sciences (JMES)
ISSN (Print): 2289-4659; e-ISSN: 2231-8380; Volume 6, pp. 940-948, June 2014

DOI: http://dx.doi.org/10.15282/jmes.6.2014.20.0090

FEASIBILITY STUDY OF NATURAL FIBER COMPOSITE MATERIAL FOR ENGINEERING APPLICATION

R. S. Taufik*, Nurul Farah Adibah M., M.R. Muhamad and H. Hasib

Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
*Email: taufik@utem.edu.my
Phone : +606-331-6899 ; Fax : +606-331-6411

ABSTRACT

This paper presents a feasibility study of natural fiber-tin lead alloy composite material for engineering application. The specimen aluminum mold plate was made using a laser cutting machine. Rice husk was selected for introduction to the tin-lead alloy composite. Sand casting techniques and a hot press molding machine were used to produce the specimen. Three types of testing were used in these studies: tensile test, flexural test and hardness test. A new technique for preparing a natural fiber and metal matrix composite material using a manual mixer has been developed to stir the mixture uniformly during the solidification phase. The SiC particulate and rice husk as a natural fiber were introduced to the tin-lead alloy for engineering applications to maintain the hardness of the material. It was found that the mechanical properties of the fabricated composites increased through reinforcement with SiC and rice husk in the material matrix of Sn, particularly for flexural and hardness properties. However, the result shows the tensile strength not significantly improved as the tensile strength for the composite is lower than that for tin-lead alloy (60-40). The experiment also obtained better performance for the tensile modulus and flexural modulus. There is potential to use rice husk in Sn composite material for engineering applications.

Keywords**:** Feasibility study; natural fiber; composite material; engineering application.

INTRODUCTION

Natural fiber composite is widely discussed in various manufacturing industries due to its impact in reducing the material cost and overall production cost, and increasing design requirements, and customer satisfaction(Adebisi, Maleque, & Rahman, 2011; Balcı & Gündoğdu, 2013; Hariprasad, Dharmalingam, & Praveen Raj, 2013; Jeffrey, Tarlochan, & Rahman, 2011). There are various applications in order to increase strength ratios and flexibility in design of products. Natural fiber composite is one of the accepted approaches. These natural fibers have many properties which make them an attractive alternative to traditional materials. Many researchers have described the highly specific properties and advantages of natural fiber, such as stiffness (Sherman, 1999), impact resistance (Aeyzarq Muhammad Hadzreel & Siti Rabiatull Aisha, 2013; Sydenstricker, Mochnaz, & Amico, 2003), flexibility (Ibrahim, Sapuan, & Faieza, 2012; Nair, Diwan, & Thomas, 1996), modulus (Balcı & Gündoğdu, 2013; Eichhorn et al., 2001) and renewable. Natural fibers can be grouped into three categories; bast, seed and leaf (Sgriccia, Hawley, & Misra, 2008). The design of natural fiber composites involves fabricating physical specimens for analysis of the microstructures of the natural fiber product and studying their mechanical behavior (Bachtiar, Sapuan, &

Hamdan, 2010; Brahmakumar, Pavithran, & Pillai, 2005; Du, Wu, Yan, Kortschot, & Farnood, 2014; Ihueze, Okafor, & Okoye, 2013; Jacob, Thomas, & Varughese, 2004; Mohammed, Salmiaton, Wan Azlina, & Mohamad Amran, 2012; Shan, Ghazali, & Idris, 2013). Most researchers have presented the use of natural fiber composites for particular purposes. The thermal conductivity of natural fiber composites has attracted researchers. The most recent and relevant works discuss the use of fiber epoxy composites to study the anisotropy thermal conductivity properties (Liu, Yang, & Takagi, 2014; Umar, Zainudin, & Sapuan, 2012) and the use of coupling agents with natural fiber and polypropylene composites to study the adhesion between natural fiber and thermoplastic matrix (El-Sabbagh, 2014).

The application of design for sustainability faces various challenges in manufacturing. The most outstanding challenges to be resolved include contributing to the transition towards a sustainable society by integrating social, economic, environmental and institutional aspects and by offering opportunities to get involved, and express one's own identity beyond consuming standardized mass-market products. Several design methodologies have recently been proposed to study the feasibility of use, from the angles of design, sustainability science and sustainable consumption analysis, developing tools and rules (the SCALES principles) to support (Design for Sustainability (DfS) (Spangenberg, Fuad-Luke, & Blincoe, 2010) and a systems analysis perspective that extends the traditional process design framework to a green process design, green energy and industrial ecology leading to sustainability (Diwekar & Shastri, 2010). Green process design involves starting with design decisions as early as the chemical and material selection stages at one end, and managing and planning decisions at the other end. However, uncertainties and multiple and conflicting objectives are inherent in such a design process. Uncertainties increase further in industrial ecology. A method and application of manufacturing processes in producing natural fiber composite to introduce to metal matrices will be proposed. The characterization of natural fiber-tin composite will be performed based on mechanical and physical properties. In order to produce the natural fiber-tin composite, preparation using the sand casting process is selected.

Rice husk (RH) is an agro-waste material of which approximately 100 million tons is produced per year. Approximately, 20kg of rice husk is obtained for 100kg of rice. Rice husks contain organic substances and 20% inorganic material (Hardinnawirda & SitiRabiatull Aisha, 2012; Hariprasad et al., 2013; Tashima, Silva, J.L., & M.B., 2004). The reasons for using RH in the construction industry include its high availability, low bulk density (90-150kg/m3), toughness, its abrasive nature, resistance to weathering and unique composition. The main components in RH are silica, cellulose and lignin. Rice husk contains a high concentration of silica in amorphous and crystalline (quartz) forms. The presence of amorphous silica determines the pozzolanic effect of RH. The pozzolanic effect exhibits cementitious properties that increase the rate at which the material gains strength. The extent of the strength development depends on the chemical composition of the alumina and silica in the material. The external surface of the husk contains a high concentration of amorphous silica which decreases inwards and is practically non-existent within the husk. At the moment, green manufacturing can be described as aiming to prevent pollution and save energy through the discovery and development of new knowledge, which reduces the use or generation of hazardous substances in the design, manufacture and use of chemicals or in processes. Based on a literature review, there is still potential to explore the use of natural fiber composite materials and what type of natural fiber composite needs to be further investigated properly for engineering application. This has motivated the authors to study the feasibility of introducing natural fiber composites to metal alloys for engineering applications. The main reason for selecting tin (Sn) alloy as the composition material is because it is easy to recycle as a result of the casting process The waste material used in the study was taken from sprues and risers in sand casting molds. The objective of this research was to study the feasibility of using rice husk in tin-lead alloy and SiC as a particulate reinforced for further engineering application.

MATERIALS AND METHOD

In this study, tin (Sn) was chosen as a core material and as recycled material, and silicon carbide (Keating & Nesic) and rice husk as reinforced materials. Silicon carbide (SiC, carborundum), is made by fusing sand and coke at 2200^{o}C, and is the grit on high quality sandpaper. It is very hard and maintains its strength to temperatures of 1400^{o}C, has good thermal shock resistance and excellent abrasion resistance, but, like all ceramics, is brittle. It has the highest corrosion resistance of all advanced ceramics. As the hardness for SiC up to 2600 Hardness Vickers, it was chosen as the supported material for making the specimen. Because SiC is a ceramic element, it cannot stand alone for making clamps, but needs to be combined with other metals. In this project, important features such as as combination materials must be taken from recycled materials and tin (Sn) has been chosen as that material. Sn is very ductile material which has a maximum value of only 18MPa tensile strength and maximum melting point of only 232^{o}C. In this project, all three materials will be combined in the casting process in which SiC and rice husk is mixed into molten Sn. Tin was used as the main material for this project because it is one of the metals that can be recycled. Tin was first used as an element for alloying copper to bronze, which is easily castable for copper molds and allows the creation of complex castings. It is a soft metal of shiny silver and is resistant to corrosion in air and water. Tin corrosion resistance worked in bronze and tin alloy as a component of long-term electric welding, and as a protective coating for other metals. Tin is a very ductile metal at room temperature, and is also flexible. This is also much less ductile thin skin descending on 392^{o}F. Through the literature review it was found that tin is also low in strength. Tin is easy to bend or crash and cannot stand at high load force. If tin is used for making the clamp, the combination of material needs to increase its strength.

Silicon Carbide (Keating & Nesic) is used for this project in powder phase. The weight of SiC used was an average of 10mg. Silicon carbide is also known as carborundum, its black (and green) hexagonal crystal is hard and sharp, and its physical and chemical properties are good. Silicon carbide has good heat resistance, thermal conductivity, aseismatic properties, wear resistance, high and low ductility. It is also a semi-conductor with non-linear electrical resistance. Silicon carbide is very chemically stable. It is an antacid and antalkali and does not respond to the fuming of nitric acid, sulphuric acid, boiling, hydrochloric acid or hydrofluoric acid. Sodium silicate is on the attack 1300A°C, calcium and magnesium oxide and attack on copper oxide reacts 1000A and 800 °C to form a metal silicates. Slow oxidation occurs in air above 1000°C. Silicon carbide is also dissociates raised or cast iron and silicon oxides react with the metal in the melt whist, exothermic energy carbon provides furnace. Before proceeding with the specimen making, the drawing process needs to be performed for the mold. The mold size was based on the ASTM specimen standard of ASTM E 8 for tensile test specimen, ASTM E 855 for flexural test specimen and ASTM E 18 for hardness test specimen. The mold was designed using SolidWorks and needs to be saved as a DXF file for a laser cutting machine. The mold plate is made by using aluminum material because the melting point for aluminum is higher than that for tin. Figure 1 shows the model of specimen mold.

Laser cutting is a cutting process that melts the material in the beam's path using a laser. Materials that are heat treatable will be case hardened at the cut edges. This may be beneficial if the hardened edges are functionally desirable in the finished parts. However, further machining operations such as finishing are required, because the bottom surface if rough. Aluminum is used because the melting point is higher than tin, which is up to 658^{o}C. Once designing the mold using SolidWorks is complete, the DXF file is transferred to a diskette to be read by the laser cutting machine. The file is edited to specify the dimensions of the raw aluminum plate and inserted in the machine's task panel. The laser cutting machine will then read the file and run the program, following the shape of the drawing. During the cutting process, the assist gas serves primarily to blow the molten material from the cut zone. This helps to produce an edge quality that is generally superior to that produced by a band saw. However, the melted material tends to flow along the edge and cling to the backside of the cut. While this slag is easily removable, there are inter-granular cracks emanating from the cut surface on some alloys.

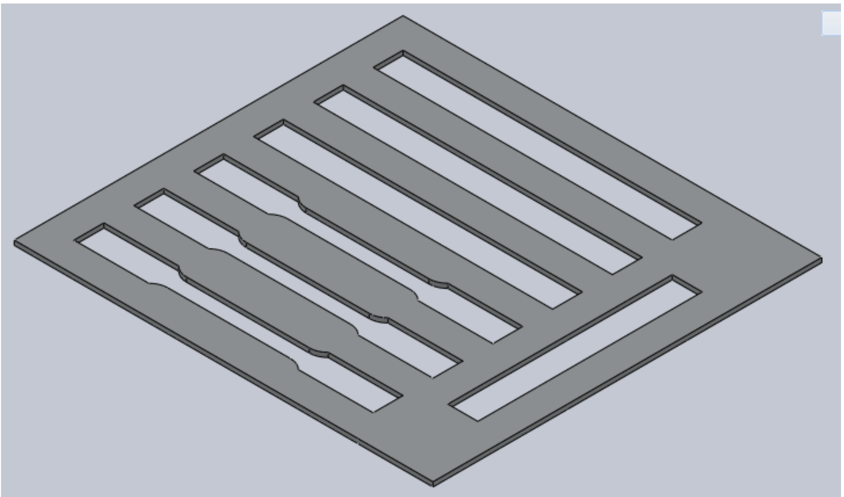

Figure 1. Model of specimen mold.

After the materials have been solidified, the next process is hot pressing. The hot press machine can set the temperature up to 300^{o}C. Basically, this small hot press is used for polymer materials. This is because the melting point for polymer is lower than metal. In this project, tin only required 237^{o}C to melt. The machine was switched on and the temperature set for 280^{o}C. The temperature is set higher than the melting point of tin to make sure it is easier for the tin to melt. The tin with the mold is mounted on the flat mild steel plate, and on the machine's lower mold. When the temperature at upper mold and lower mold is met, the lower mold is compressed until it touches the specimen mold by pushing the compress button. The return button is then pushed to turn down the lower mold. The specimen mold is taken out of the lower mold and solidified at room temperature.

RESULTS AND DISCUSSION

Three specimens were prepared for tensile testing to obtain a more accurate result. Table 1 shows the specimen dimensions referring to ASTM E 8M, which are the standard test methods for tension testing of metallic materials. A thickness of 12.5mm and width of 19mm were used for the test specimen in specimen preparation.

Table 1. Specimen dimension.

	Thickness (mm)	Widthb(mm)	Gauge length (mm)
Specimen 1, 2, 3	3.0	12.5	50

Specimen 1 shows a fracture in the center, Specimen 2 fractured at the top and Specimen 3 fractured below the center. In a tensile test, the material fractures at the weakest region. All three specimens have their plastic region where the material irreversible and deformed to another shape and stretch. The plastic region was between the end of the elastic region and the fracture point. It was found that Specimen 2 fractured at the top of the gauge length whereas Specimen 1 and Specimen 3 fractured at the center of the gauge length. It was found that the rice husks can be introduced into the tin silicon carbide using a hot press machine. The results show that the process of the molten metal and natural fiber of the mold affected the shape of the specimen. In addition, the uniformity of the natural fiber and metal matrix composites allows the specimen characteristic during testing. The tensile tests resulted in average maximum force being achieved at 1355.33N.

Figure 2 shows the tensile test result and presents the stress-strain graph for Specimens 1, 2, and 3. The average maximum tensile strength was achieved at 36MPa. The composite material tested resulted in a strength lower than that of the tin-lead alloy (60-40 solder) at 55MPa (Cambridge Engineering Selector, 2011), and shows a less linear-elastic region in the stress-strain curve. Compared to the tin-lead alloy (60-40 solder), the composite material was more ductile because the mixture of the composite was not uniform in the mold. Natural fiber composites were found in the specimen, however, the result shows of the potential for natural fiber composite to be applied in engineering.

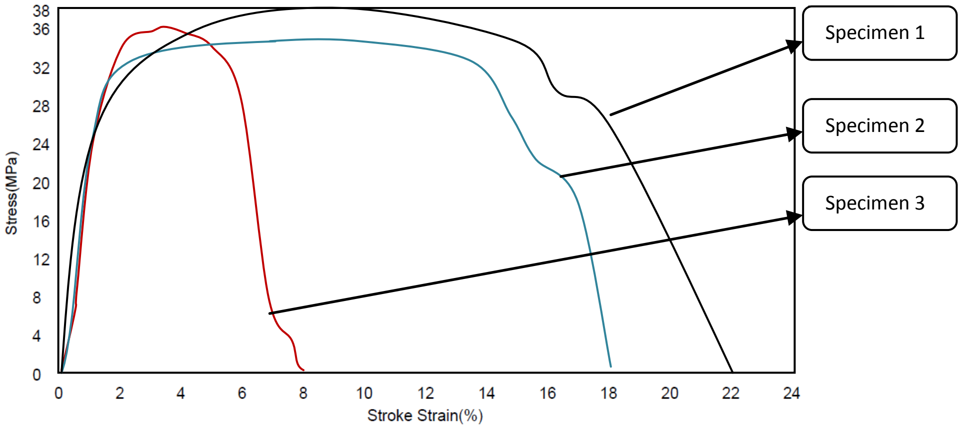

Figure 2. Stress-strain graph for Specimen 1, 2, and 3.

The elastic limit value was achieved at an average of 27.8MPa. All three specimens had a value of yield strength (elastic limit) less than the elastic limit for tin-lead alloy (60-40 solder) of 30MPa minimum. It was found that the elastic limit point was lower and the composite material starts to deform plastically after less than 30MPa. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible. The low elasticity characteristic is good for this composite material because while the strap clamp is clamped on the machining table, it can withstand the force applied. The yield strength force required to achieve the elastic limit was presented at an average of 1030.33N. There is therefore suitable yield strength to allow consideration for further engineering application. Table 2 shows the dimension characteristics used for flexural tests. Figure 5 shows the specimen result after finishing the flexural test. All three specimens show the almost same resultant shape.

Table 2. Dimension for flexural test specimen.

	Thickness	Width	Lower support
Units	mm	mm	mm
Specimen flexural 1	3.00	20.00	74.00

Figure 5. Specimen result for flexural test.

Figure 6 shows the force-stroke graph for the specimen. It was determined that the average maximum force required for a flexural test for the composite materials was achieved at 117.7N. The testing was conducted by setting the speed at 2mm/min and deflection at 35mm. In addition, flexural testing found the average maximum stress at 72.60MPa.

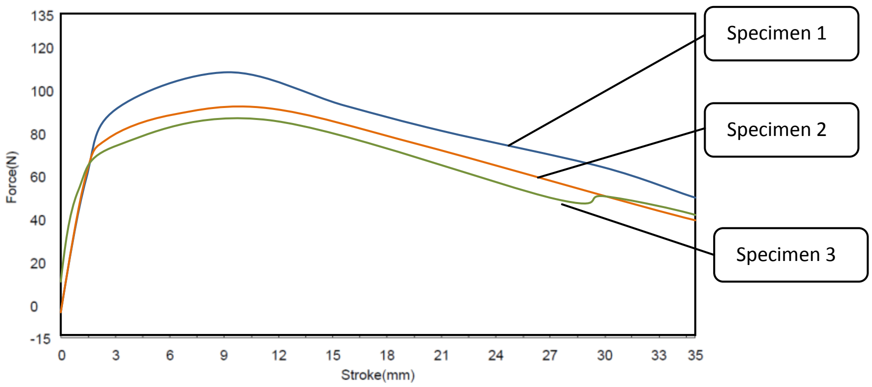

Figure 6. Force-stroke graph.

Flexural Test 1 shows the highest maximum stress since the force required was also the highest value. The highest elastic strength resulted at flexural testing on average at 6342MPa. The parameters of the elastic region used was 10mm for the stroke and 80N for the force. The maximum flexural strength for tin-lead alloy (60-40 solder) was 40MPa which was lower than the experimental result for the composite material. The material properties for the composite material were more brittle than the tin-lead alloy (60-40 solder). A hardness test was conducted using a Rockwell hardness machine, with the value unit in HRB. Because the specimen has less flatness, Vickers hardness testing cannot be used. The test was conducted 30 times to get more accurate values. The material hardness property of tin-lead alloy (60-40 solder) was 25 HV. Figure 7 shows the chart of hardness values for HRB and HV. The average of the hardness tests was achieved at 88.4HRB, equivalent to 177HV (Vickers Hardness).

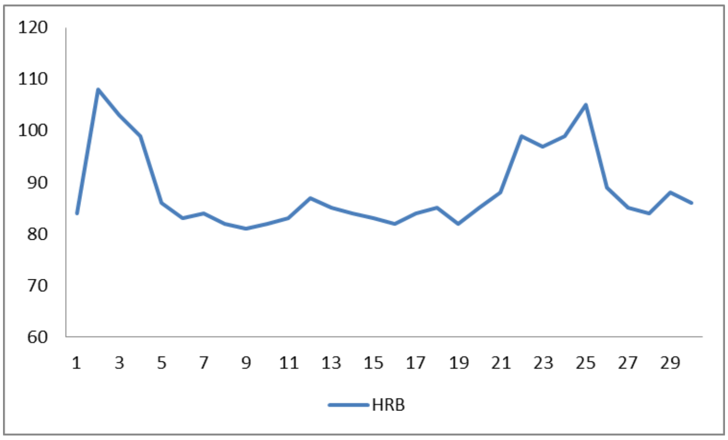

Figure 7. Hardness result in HRB.

CONCLUSIONS

A new technique for preparing a natural fiber and metal matrix composite material using a manual mixer was developed to lead the mixture uniformly during the solidification phase. SiC material and rice husk as a natural fiber can be introduced to the tin-lead alloy material matrix for engineering applications, to maintain the hardness of the material. It was found that the mechanical properties of the fabricated composites increased by reinforcing SiC and rice husk in the material matrix of tin-lead alloy. The testing shows a significant improvement in flexural and hardness properties. However, tensile strength was not significant improved, and was lower than that for tin-lead alloy (60-40). Food performance was obtained for the tensile modulus and flexural modulus. As a result, it is feasible to introduce rice husk to metal matrix composite material for further engineering applications.

ACKNOWLEDGEMENTS

The authors would like to thank the MTUN COE Research Grant Scheme, MTUN/2012//UTeM-FKP/12 M00020 and the Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, UTeM.

REFERENCES

Adebisi, A. A., Maleque, M. A., & Rahman, M. M. (2011). Metal matrix composite brake rotor: Historical development and product life cycle analysis. *International Journal of Automotive and Mechanical Engineering,* 4, 471-480.

Aeyzarq Muhammad Hadzreel, M. R., & Siti Rabiatull Aisha, I. (2013). Effect of reinforcement alignment on the properties of polymer matrix composite. *Journal of Mechanical Engineering and Sciences,* 4, 548-554.

Bachtiar, D., Sapuan, S. M., & Hamdan, M. M. (2010). Flexural properties of alkaline treated sugar palm fibre reinforced epoxy composites. *International Journal of Automotive and Mechanical Engineering,* 1, 79-90.

Balcı, M., & Gündoğdu, Ö. (2013). Determination of physical properties of laminated composite beam via the inverse vibration problem method. *Journal of Mechanical Engineering and Sciences,* 5, 611-622.

Brahmakumar, M., Pavithran, C., & Pillai, R. (2005). Coconut fibre reinforced polyethylene composites: Effect of natural waxy surface layer of the fibre on fibre/matrix interfacial bonding and strength of composites. *Composites Science and Technology,* 65(3), 563-569.

Cambridge Engineering Selector. (2011). Ces edupack. Cambridge, UK Granta Design Ltd.

Diwekar, U. M., & Shastri, Y. N. (2010). Green process design, green energy, and sustainability: A systems analysis perspective. *Computers & chemical engineering,* 34(9), 1348-1355.

Du, Y., Wu, T., Yan, N., Kortschot, M. T., & Farnood, R. (2014). Fabrication and characterization of fully biodegradable natural fiber-reinforced poly (lactic acid) composites. *Composites Part B: Engineering,* 56, 717-723.

Eichhorn, S., Baillie, C., Zafeiropoulos, N., Mwaikambo, L., Ansell, M., Dufresne, A.et al.Groom, L. (2001). Review: Current international research into cellulosic fibres and composites. *Journal of Materials Science,* 36(9), 2107-2131.

El-Sabbagh, A. (2014). Effect of coupling agent on natural fibre in natural fibre/polypropylene composites on mechanical and thermal behaviour. *Composites Part B: Engineering,* 57, 126-135.

Hardinnawirda, K., & SitiRabiatull Aisha, I. (2012). Effect of rice husks as filler in polymer matrix composites. *Journal of Mechanical Engineering and Sciences,* 2, 181-186.

Hariprasad, T., Dharmalingam, G., & Praveen Raj, P. (2013). Study of mechanical properties of banana-coir hybrid composite using experimental and fem techniques. *Journal of Mechanical Engineering and Sciences,* 4, 518-531.

Ibrahim, M. S., Sapuan, S. M., & Faieza, A. A. (2012). Mechanical and thermal properties of composites from unsaturated polyester filled with oil palm ash. *Journal of Mechanical Engineering and Sciences,* 2, 133-147.

Ihueze, C. C., Okafor, C. E., & Okoye, C. I. (2013). Natural fiber composite design and characterization for limit stress prediction in multiaxial stress state. *Journal of King Saud University-Engineering Sciences*.

Jacob, M., Thomas, S., & Varughese, K. (2004). Mechanical properties of sisal/oil palm hybrid fiber reinforced natural rubber composites. *Composites Science and Technology,* 64(7), 955-965.

Jeffrey, K. J. T., Tarlochan, F., & Rahman, M. M. (2011). Residual strength of chop strand mats glass fiber/epoxy composite structures: Effect of temperature and water absorption. *International Journal of Automotive and Mechanical Engineering,* 4, 504-519.

Keating, A., & Nesic, S. (1999). *Prediction of two-phase erosion-corrosion in bends.* Paper presented at the Second International Conference on CFD in the Minerals and Process Industries, CSIRO, Melbourne, Australia.

Liu, K., Yang, Z., & Takagi, H. (2014). Anisotropic thermal conductivity of unidirectional natural abaca fiber composites as a function of lumen and cell wall structure. *Composite structures,* 108, 987-991.

Mohammed, M., Salmiaton, A., Wan Azlina, W., & Mohamad Amran, M. (2012). Gasification of oil palm empty fruit bunches: A characterization and kinetic study. *Bioresource Technology,* 110, 628-636.

Nair, K., Diwan, S., & Thomas, S. (1996). Tensile properties of short sisal fiber reinforced polystyrene composites. *Journal of applied polymer science,* 60(9), 1483-1497.

Sgriccia, N., Hawley, M., & Misra, M. (2008). Characterization of natural fiber surfaces and natural fiber composites. *Composites Part A: Applied Science and Manufacturing,* 39(10), 1632-1637.

Shan, C. W., Ghazali, M. I., & Idris, M. I. (2013). Improved vibration characteristics of flexible polyurethane foam via composite formation. *International Journal of Automotive and Mechanical Engineering,* 7, 1031-1042.

Sherman, L. M. (1999). Natural fibers: The new fashion in automotive plastics. *Journal Pastic Technology,* 45(10), 62-68.

Spangenberg, J. H., Fuad-Luke, A., & Blincoe, K. (2010). Design for sustainability (dfs): The interface of sustainable production and consumption. *Journal of Cleaner Production,* 18(15), 1485-1493.

Sydenstricker, T. H., Mochnaz, S., & Amico, S. C. (2003). Pull-out and other evaluations in sisal-reinforced polyester biocomposites. *Polymer testing,* 22(4), 375-380.

Tashima, M. M., Silva, C. A. R., J.L., A., & M.B., B. (2004). *Influence of rice husk ash in mechanical characteristics of concrete*. Paper presented at the International Conference on Quality of Concrete Structures and Recent Advances in Concrete Materials and Testing XII (08).

Umar, A. H., Zainudin, E. S., & Sapuan, S. M. (2012). Effect of accelerated weathering on tensile properties of kenaf reinforced high-density polyethylene composites. *Journal of Mechanical Engineering and Sciences,* 2, 198-205.