Influence of Rice Husk and Composition Ratio on Mechanical Performance of Polypropylene Composite

Kannan Rassiah
Department of Mechanical Engineering, Politeknik Port Dickson
E-mail: kannan@polipd.edu.my

Haeryip Sihombing
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka

Mohd Yuhazri Y.
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka

C.M.R. Prabhu
Faculty of Engineering and Technology, Multimedia University, Melaka

Abstract

In this study, the surface modification techniques were performed on rice husk flour (RH) in polypropylene (PP) matrix and consolidated to improve the mechanical properties. The rice husks were formed with the granular size composite with such as untreated, boiled, and boiled-sodium hydroxide (NaOH) treated fiber. An internal mixer machine is set for four different composites compositions ratio and the samples produced by hot press machine. The analysis was carried out using a 2- factor and 3- level design of experiment (DOE). An analysis conducted based on variance (ANOVA) is to determine on how the formed of three type rice husk and the composition of the rice husk ratio affected the mechanical properties of the composites. It was proven that both the rice husk type and the composition demonstrated significantly different results in terms of the tensile test, impact test and hardness test. The overall results indicated that the boiled-sodium hydroxide (NaOH) treated rice husk fiber composite exhibited the highest performance.

Keywords: Rice Husk, Composition, Treatment

1. Introduction

Agriculture composite in a more realistic case refers to natural fiber reinforced composite. A good agreement between various alternatives of products design and materials, in fact, makes natural fibers as reinforcing components with petroleum and thermoplastics as well as thermosets to become more potential reinforcing filler in plastics. Here, thermoplastics such as polyethylene (PE), polystyrene, polypropylene (PP), and polyvinyl chloride are generally incorporation with the natural fiber composites in order to produce outstanding performance applications.

The reason of using natural fibers as a reinforce material are, now, receiving more consideration of scholars due to their environmental benefits and that natural fiber composites can replace tropical hardwood. There were several studies on polymer and natural fibers as a reinforce material such as:

- Starch (Gupta *et al.*, 2008; Tena-Salcido *et al.*, 2008),
- Kenaf (Tajeddin *et al.*, 2009; Cho *et al.*, 2009; Rashdi *et al.*, 2010; Westman *et al.*, 2010),
- Banana (Samal *et al.*, 2009 ; Srinivasababu *et al.*, 2009; El-Meligy *et al.,* 2010 ; Majhi *et al.*, 2010)
- Palm Oil (Anuar *et al.*, 2006; Abdul Khalil *et al.*, 2007; Ahmadzadeh *et al.*, 2008),
- Rice husk (Yang *et al.*, 2004; Panthapulakkal *et al.*, 2005; Rozman *et al.*, 2005; Rosa *et al.*, 2009),
- Sugarcane baggase (Stael *et al.*, 2001 ; Bilba *et al.*, 2003; Cao *et al.,* 2007 ; Ishak *et al.,* 2009; Vilakati *et al.,* 2010),
- Bamboo (Vasoya *et al.*, 2007; Suharty *et al.*, 2008; Kittinaovarat & Suthamnoi, 2009).

Among the natural fiber, rice husk is one of the major agro-waste products, which contains cellulose 32.7%, hemicellulose 20.5%, lignin 21.8%, silica 15.1%, solubles 2.8%, and moisture 7.5% (Stefani & Jiménez, 2003). The rice husk is the outermost layer of the paddy grain that is separated from the rice grains during the milling process. It is expected that lignocellulosic composites have several advantages over the composites produced from synthetic fibres. The utilization of rice husk ash as a reinforcement of a polymeric material is provided excellent performance in characteristics that combine the positive attributes of each constituent component such as durability properties and improved strength, environmental benefits related to the disposal of waste materials, reduced materials costs, and to reduce carbon dioxide emissions (Yussuf et al., 2010).

The main issue of the using natural fiber composite is the fiber matrix adhesion. Among the effective parameters, properties of matrix and fiber and also their processing condition are very important for gaining sufficient mechanical properties of composite (Zampaloni et al., 2007). It was shown that the strength parameter is sensitive to matrix properties, whereas the modulus is dependent on the fiber properties. For improving the mechanical properties of the composite, the main parameters are the bonding level, fiber length, and geometry of the parts (Hull & Clyne, 1996). The chemical and physical surface adaptation studies on a variety of natural fibers have been committed to understanding and enhancing the interface strength between the natural fibers and the polymer matrix. However, the performance and properties of composite materials depend on the properties of the individual components and their interface compatibility. Therefore, this study conducted the work to identify the factors that affect rice husk/ polypropylene composites using untreated, boiled, and boiled- NaOH treated rice husk.

2. Experimental

2.1. Experimental Design

The focus of this work is on two parameters; the type of rice husk flour and its composition ratio. Because the levels of each factor used were determined referring to the manufacturing capability and its competency, three levels were chosen for the composition of the rice husk and its composition. The 2- factor with 3-levels for the design of experiments (DOE) was then used by utilizing the Design-Expert software.

2.2. Material

The research use polypropylene as the matrix material in the form of pallet with a density 0.9 g/cm^3 and melting temperature at 230^{o}C. This compound consists of carbon, hydrogen and some additives designed for general purpose applications. The rice husk fiber was obtained from the rice field Alor Star, Kedah, (Malaysia). The dimension of the granular sizes ranged are from 500 to 1000 μm, while moisture content is 13 wt. %.

2.3. Materials preparation

For untreated RH, the raw material was sun dried for three days. This process have to be carried out before they were fed into a blender in order to obtain short fibers at lower than 1000 μm in length. While for the boiled and treated RH, the preparation carried out is by washing process of the 120 grams of untreated RH and then it is boiled in the 100 ^{o}C boiling water for about 1 hour. Thus, they are forwarded to soaking process for 2 hours with 2 % concentration of Sodium Hydroxide (NaOH), then the compound was stirred. The compound was left in the environmental chamber for 3 hours followed by cleaning process using normal pipe water. The washing process was repeated for 4 times to ensure no more NaOH residual at rice husk. The next process is drying the rice husk under sunlight for 72 hours.

2.4. Composite Fabrication

The Polypropylene and rice husk is weighed according to selected ratio. A thermal mixing process was carried out using a Thermo Haake Rheomix 600 OS internal mixer at a temperature of 175 ^{o}C and a rotor speed of 50 rpm for 10 minutes. Through this process, the mixture of substances will be found better and more uniform overall. After this process, the material goes to crusher machine to produce a standard particle size 2 mm x 2 mm. The final stage of the composite preparation process in this research is the hot pressing. Hot pressing was carried out at a temperature of 175 ^{o}C for 8 minutes, and the mixture was then cooled under room temperature. The final products were in the form of plates with dimensions of 200 mm x 200 mm x 2 mm and prepared to cut into ASTM standard and conduct mechanical testing.

2.5 Testing Standards

The tensile, impact and hardness test were performed according to ASTM D638, ASTM D6110 and ASTM E-384 respectively. The specimen positioning and the operating conditions were 25±3°C with 50 % of humidity (Figure 1 to 3).

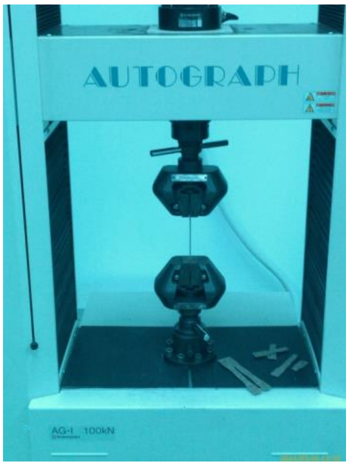

Figure 1: Tensile

Figure 2: Charpy Impact

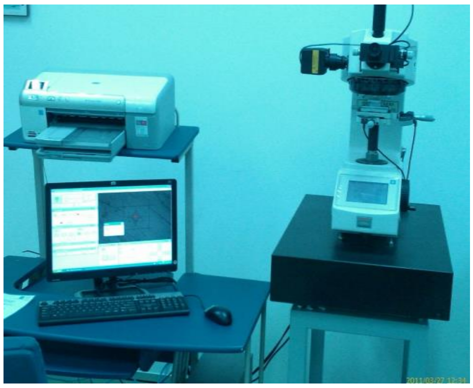

Figure 3: Hardness

3. Results and Discussion

Table 1 shows the factor and level of the rice husk flour and composition variables, while Table 2 show the ANOVA results for the tensile strength, impact strength and hardness.

Table 1: Factor and Level

Factor	Level 1	Level 2	Level 3
Rice Husk (RH)	Untreated	Boiled	Boiled & Treated
Composition Ratio (PP: RH)	90:10	90:10	90:10
	80:20	80:20	80:20
	70:30	70:30	70:30

Table 2: Anova for Mechanical Testing Results of different Rice Husk

Mechanical Properties	Source	Sum of Squares	Degree of Freedom	Mean Square	F (Value)	P (Value)
Tensile Stress	A= Rice Husk	0.32	2	0.16	32.67	0.0033
	B= Composition	0.97	2	0.48	98.63	0.0004
Tensile Modulus	A= Rice Husk	0.32	2	0.16	11.95	<0.0001
	B= Composition	0.97	2	0.48	65.88	<0.0001
Impact Strength	A= Rice Husk	0.27	2	0.14	908.11	<0.0001
	B= Composition	2.23	2	1.12	635.56	<0.0001
Hardness	A= Rice Husk	0.56	2	0.28	1291.44	<0.0001
	B= Composition	2.54	2	1.27	45.60	<0.0001

3.1. Tensile Properties

In normal probability plot shown in Figure 4 and 5, the residuals tensile stress and modulus demonstrated a stable of variability for tensile test samples where the value of R^2 is 0.9850 and 0.9990. Based on analysis of variance (Table 2), all mean values for each group is significantly different (p-value<0.05). It is proven that each variable gives significant effects towards tensile strength performance of the composites.

The results of interaction plot for tensile stress and modulus on the different rice husk and composition are as presented in Figure 6 and 7. A tensile test was done to determine the strength and modulus of PP/RH composite, which was fabricated using the untreated, boiled, boiled-NaOH treated fibers. It can be seen that the tensile strength Figure 6 and modulus strength Figure 7 of boiled-NaOH treated rice husk increasing in PP/RH composite. The different concentration of natural fiber with matrix can effect and it make facture if stress is applied and easy to slip off (Santiagoo et al., 2011; Nouri et al., 2006; Maziad et al., 2009 ; Ramasamy 2012). The boiled-NaOH treated rice husk composite can improve tensile strength and modulus compared to boiling and untreated composite.

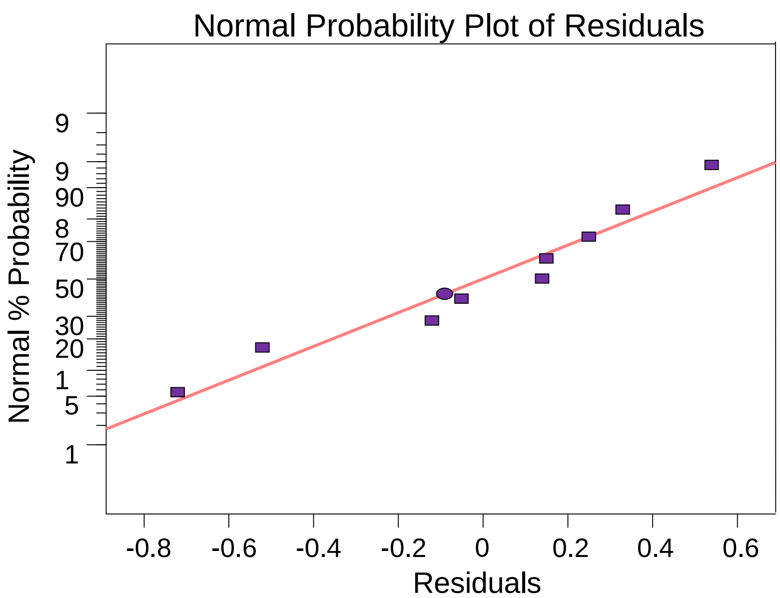

Figure 4: Normal plot of residuals for Tensile Stress

Politeknik & Kolej Komuniti Journal of Engineering and Technology, Vol.1, 2016
eISSN 0128-2883

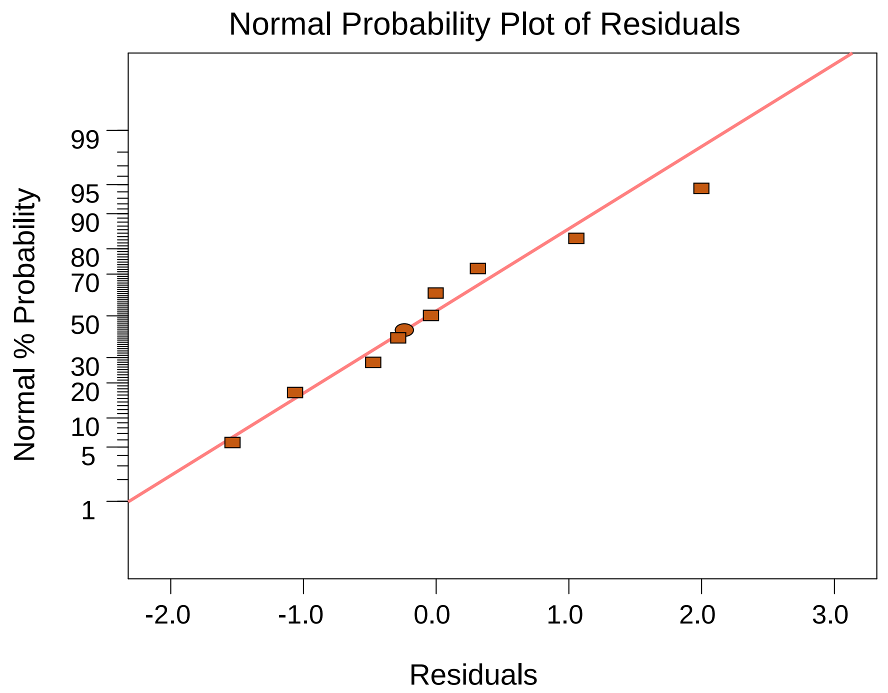

Figure 5: Normal plot of residuals for Tensile Modulus

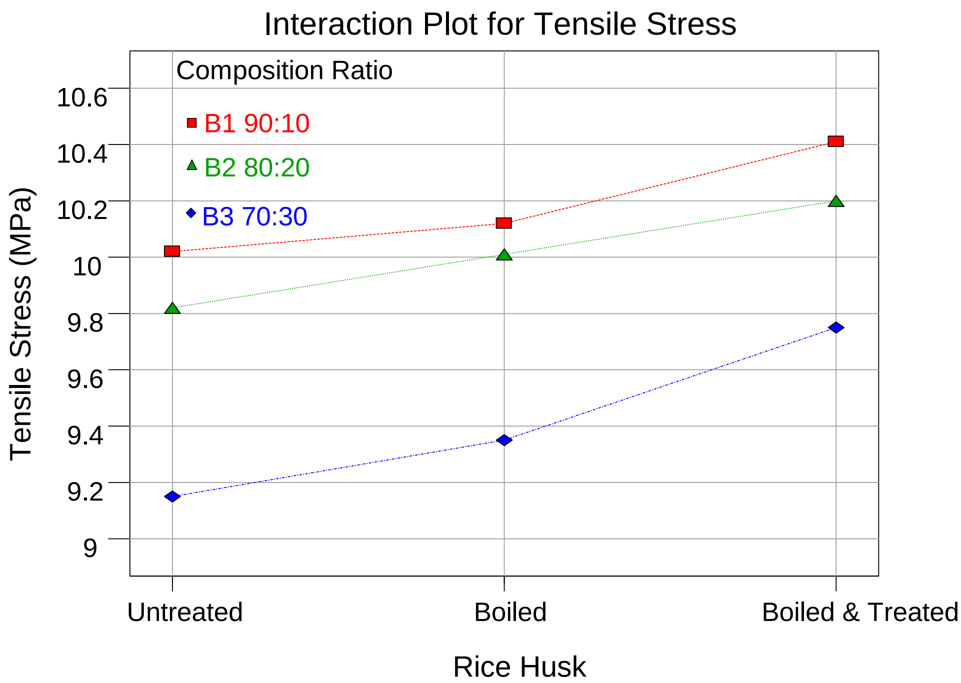

Figure 6: Interaction plot for Tensile Stress

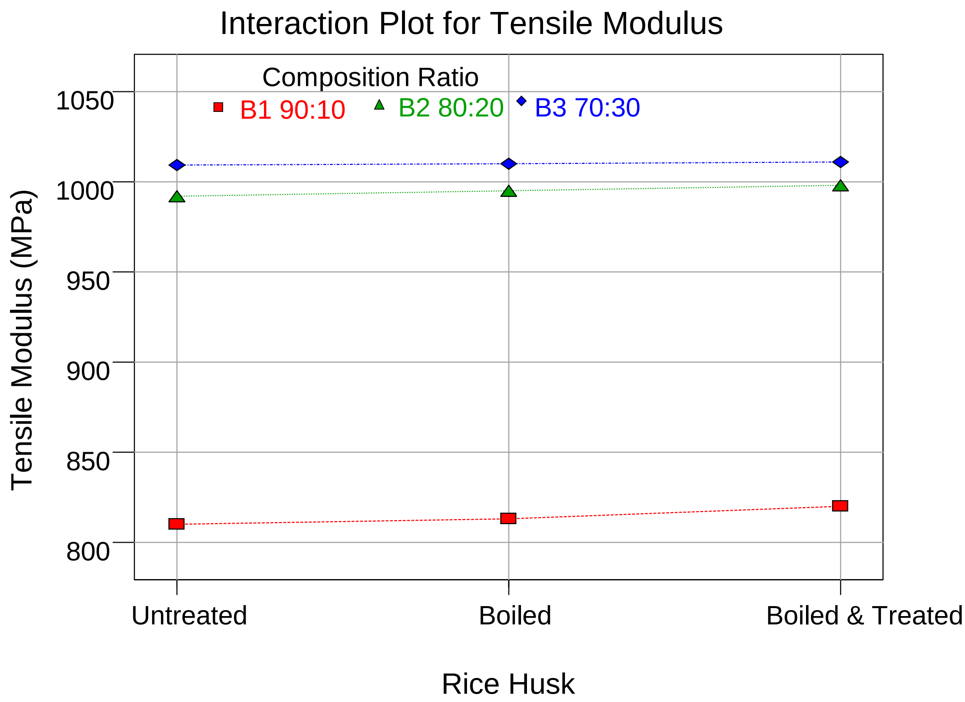

Figure 7: Interaction plot for Tensile Modulus

4.2. Hardness Properties

Figure 8 demonstrates the normal probability plot for hardness strength, where the R^2 value is 0.9983. The interactions between each variable, rice husk types, and composition gives a significant effect towards the hardness strength performance. It is proven that each variable gives significant effects towards hardness strength performance of the composites (Tale 2).

The results of interaction plot for hardness strength on the different rice husk and composition are as presented in Figure 9. It is showed the effect of adding Sodium Hydroxide (NaOH) on the hardness property of PP/RH composite. Based on the result obtained, the hardness of boiled-NaOH treated composite of PP/RH is better than boiled or untreated composite. Besides, the response between boiling and treated rice husk with Sodium Hydroxide (NaOH) in PP/RH composition increases the stiffness property of composite. According to Ahmad et al., (2009), the addition of rice husk and clay into the thermoplastic will increase the hardness properties. Ismail et al., (2009) reported that by increasing rice husk ash loading in natural rubber/linear low density polyethylene, the hardness will increase. Generally, the using of rice husk fibers will increase the value of hardness composites in thermoplastic (Maziad et al., 2009). The significant difference in the value shows that the composition ratio of rice husk will increase the hardness of the material as the bonding between the molecules.

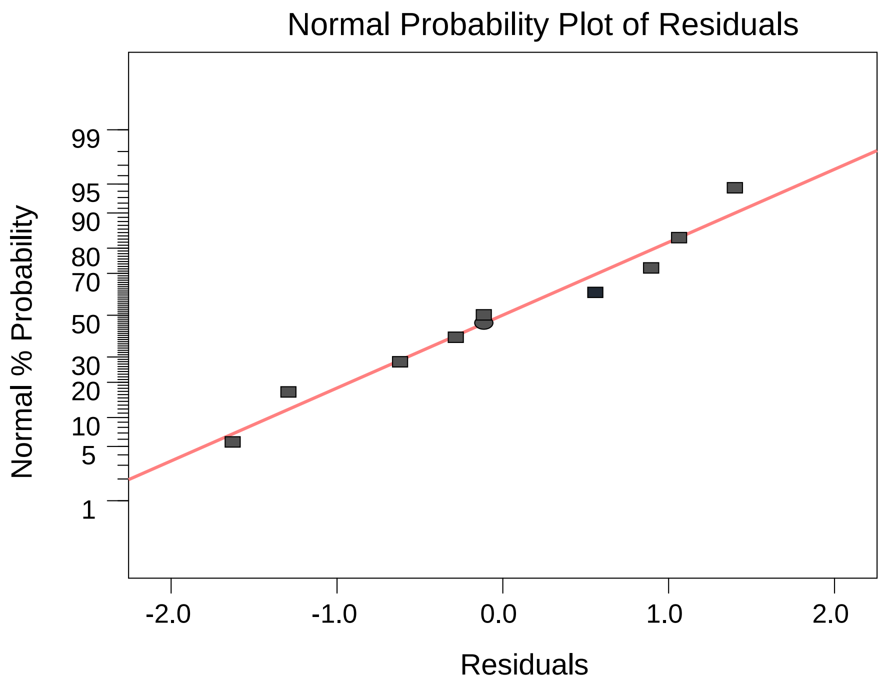

Figure 8: Normal plot of residuals for Hardness Strength

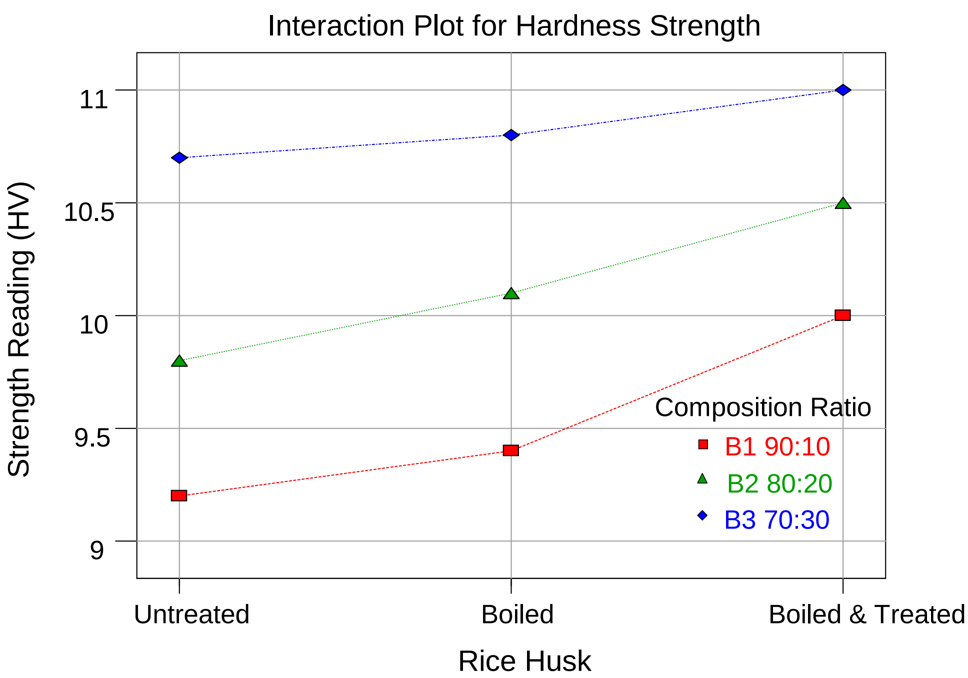

Figure 9: Interaction plot for Hardness Strength

4.3 Impact Properties

In a normal probability plot shown in Figure 10, the residuals impact strength demonstrated a stable data plot for impact test samples where the R^2 value is 0.9962. Based on analysis of variance (Table 2), all mean values for each group is significantly different (p-value<0.05). It is proven that each variable gives significant effects towards impact strength performance of the composites.

Figure 11 shows the interaction plot for impact strength results of rice husk for different composition. Based on this graph, boiled and treated rice husk composites show outstanding result as a best composition. The impact value of the untreated, the boiled rice husk is lower than the boiled-NaOH treated rice husk. Besides, the untreated, boiled, and boiled-NaOH treated composite of PP/RH is decreased when fiber loading increased. The impact strength decreases when the higher ratio of rice loading in PP/RH composition. The less percentage of boiled-NaOH treated rice husk is excellent properties. The similar trend is also observed by Jamil et al., (2006) where the weak filler loading in matrix interaction resulting in poor filler dispersion and decrease the properties.

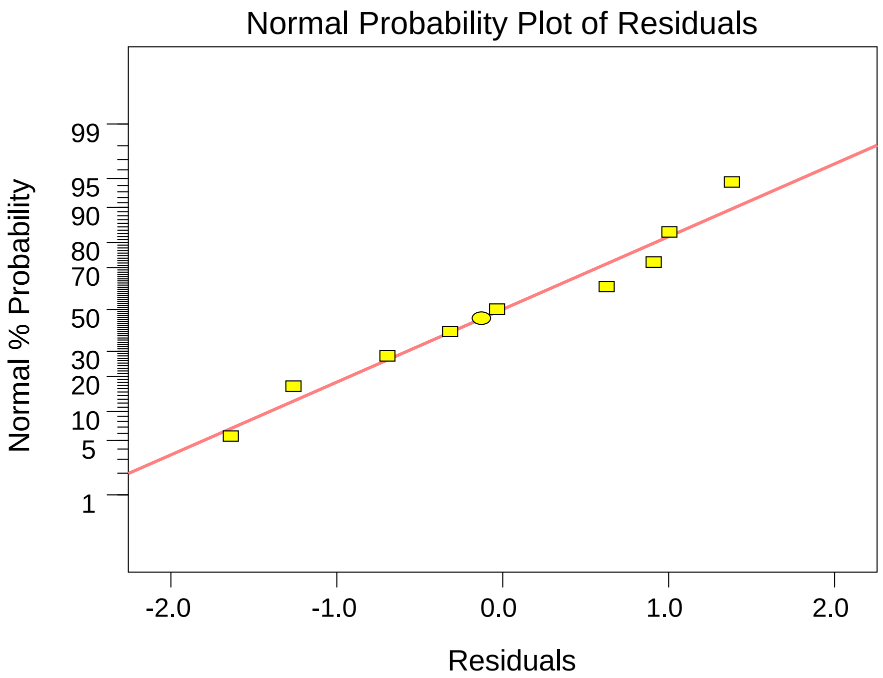

Figure 10: Normal plot of residuals for Impact Strength

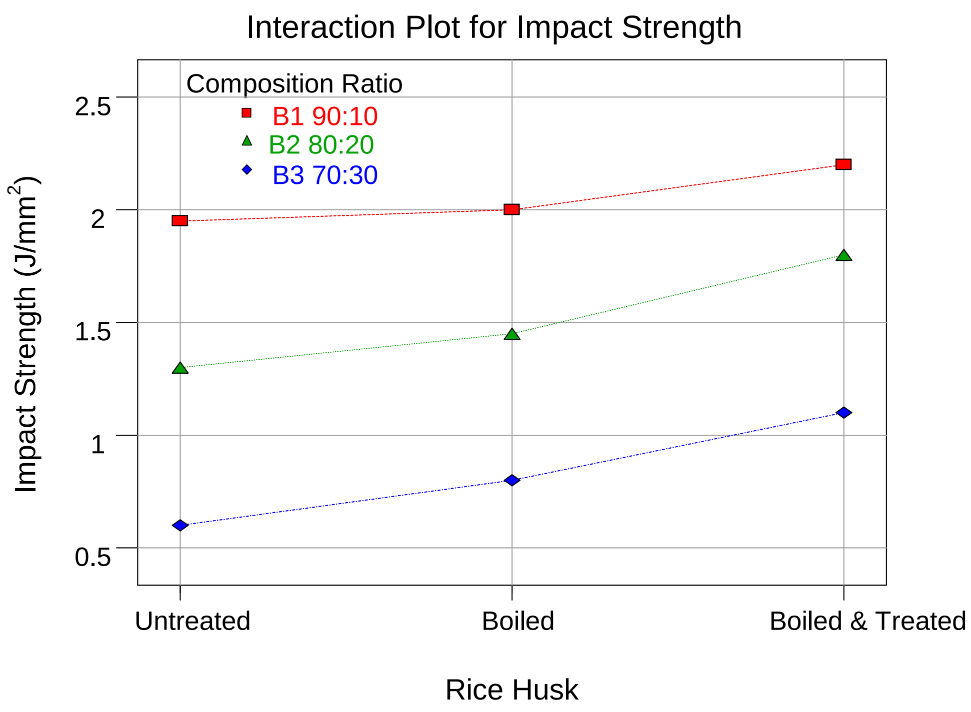

Figure 11: Interaction plot for Impact Strength

5. Conclusions

In these studies, the rice husk flour type and composition are identified as the factors that are important in improving the mechanical properties. The analysis, which used a design of experiments (DOE) and analysis of variance (ANOVA), shows that the optimum results were achieved when the boiled-sodium hydroxide (NaOH) treated rice husk was used. Thus, the ANOVA analysis outcome had established correctly that the rice husk types and composition used have significant effects on the mechanical. The boiled and sodium hydroxide (NaOH) treated rice husk was shown to have better tensile, charpy, and hardness strengths. The measurement of composite characteristics indicated that more ratio of rice husk composition in polypropylene composite displayed greater tensile modulus and hardness performance compared to a tensile strength and impact strength, especially for boiled-sodium hydroxide (NaOH) treated rice husk.

Acknowledgment

The authors acknowledge Jabatan Pendidikan Politeknik (JPP) for supporting the research work, as well as The Mechanical Engineering Department Polytechnic Port Dickson Negeri Sembilan and The Coordinator of Composite Engineering Laboratory (FKP/UTeM) for granting permission to use all available equipment.

References

Anuar, H., Ahmad, S. H., Rasid, R., & Daud, N. N. (2006). Tensile and impact properties of thermoplastic natural rubber reinforced short glass fiber and empty fruit bunch hybrid composites. *Polymer-Plastics Technology and Engineering*, 45(9), 1059-1063.

Abdul Khalil, H. P. S., Kumar, R. N., Asri, S. M., Nik Fuaad, N. A., & Ahmad, M. N. (2007). Hybrid thermoplastic pre-preg oil palm frond fibers (OPF) reinforced in polyester composites. *Polymer-Plastics Technology and Engineering*, 46(1), 43-50.

Ahmed, K. S., & Vijayarangan, S. (2008). Tensile, flexural and interlaminar shear properties of woven jute and jute-glass fabric reinforced polyester composites. *Journal of materials processing technology*, 207(1), 330-335.

Ahmad, I., Jamil, M. S. M., & Abdullah, I. (2009). Pengisian sekám padi dan tanah liât ke dalam matriks polietilena berketumpatan tinggi-getah asli-getah asii cecair. *Sains Malaysiana*, 38(3), 381-386.

Bilba, K., Arsène, M. A., & Ouensanga, A. (2003). Sugar cane bagasse fibre reinforced cement composites. Part I. Influence of the botanical components of bagasse on the setting of bagasse/cement composite. *Cement and concrete composites*, 25(1), 91-96.

Cho, D., Lee, H. S., & Han, S. O. (2009). Effect of fiber surface modification on the interfacial and mechanical properties of kenaf fiber-reinforced thermoplastic and thermosetting polymer composites. *Composite Interfaces*,16(7-9), 711-729.

Cao, Y., Goda, K., & Shibata, S. (2007). Development and mechanical properties of bagasse fiber reinforced composites. *Advanced Composite Materials*, 16(4), 283-298.

El-Meligy, M.G. , Mohamed, S. H. & Mahani, R. M. (2009). Study Mechanical, Swelling and Dielectric Properties of Prehydrolysed Banana Fiber – Waste Polyurethane foam Composites. *ICCM-17* Edinburgh, Scotland July 27-31, 2009.

Gupta, A. P., Sharma, M., & Kumar, V. (2008). Preparation and characterization of potato starch based low density polyethylene/low density polyethylene grafted maleic anhydride biodegradable polymer composite.*Polymer-Plastics Technology and Engineering*, 47(9), 953-959.

Hull, D., & Clyne, T. W. (1996). *An introduction to composite materials*. Cambridge university press.

Ishak, M. R., Leman, Z., Sapuan, S. M., Salleh, M. Y., & Misri, S. (2009). The effect of sea water treatment on the impact and flexural strength of sugar palm fibre reinforced epoxy composites. *International Journal of Mechanical and Materials Engineering (IJMME)*, *4*(3), 316-320.

Ismail, H., Nizam, J. M., & Khalil, H. A. (2001). The effect of a compatibilizer on the mechanical properties and mass swell of white rice husk ash filled natural rubber/linear low density polyethylene blends. *Polymer Testing*, 20(2), 125-133.

Jamil, M. S., Ahmad, I., & Abdullah, I. (2006). Effects of rice husk filler on the mechanical and thermal properties of liquid natural rubber compatibilized high-density polyethylene/natural rubber blends. *Journal of Polymer Research*, 13(4), 315-321.

Kittinaovarat, S., & Suthamnoi, W. (2009). Physical properties of polyolefin/bamboo charcoal composites. *Journal of Metals, Materials and Minerals*, 19(1), 9-15.

Maziad, N. A., El-Nashar, D. E., & Sadek, E. M. (2009). The effects of a silane coupling agent on properties of rice husk-filled maleic acid anhydride compatibilized natural rubber/low-density polyethylene blend. *Journal of materials science*, 44(10), 2665-2673.

Majhi, S. K., Nayak, S. K., Mohanty, S., & Unnikrishnan, L. (2010). Mechanical and fracture behavior of banana fiber reinforced Polylactic acid biocomposites. *International Journal of Plastics Technology*, 14(1), 57-75.

Nouri, R, M., Jafarzadeh-Dogouri, F., Oromiehie, A., & Langroudi, A. E. (2006). Mechanical properties and water absorption behaviour of chopped rice husk filled polypropylene composites. *Iranian Polymer Journal*, 15(9), 757-766.

Panthapulakkal, S., Sain, M., & Law, S. (2005). Effect of coupling agents on rice-husk-filled HDPE extruded profiles. *Polymer international*, 54(1), 137-142.

Ramasamy, V. (2012). Compressive strength and durability properties of rice husk ash concrete. *KSCE Journal of Civil Engineering*, 16(1), 93-102.

Rashdi, A., Abdalla, A., Salit, M. S., Ahmad, M., Hamdan, M. M., & Abdan, K. (2010). Combined effects of water absorption due to water immersion, soil buried and natural weather on mechanical properties of kenaf fibre unsaturated polyester composites (KFUPC). *International Journal of Mechanical and Materials Engineering*, 5(1), 11-17.

Rozman, H. D., Musa, L., & Abubakar, A. (2005). Rice husk–polyester composites: the effect of chemical modification of rice husk on the mechanical and dimensional stability properties. *Journal of applied polymer science*, 97(3), 1237-1247.

Rosa, S. M. L., Santos, E. F., Ferreira, C. A., & Nachtigall, S. M. B. (2009). Studies on the properties of rice-husk-filled-PP composites: effect of maleated PP. *Materials Research*, 12(3), 333-338.

Samal, S. K., Mohanty, S., & Nayak, S. K. (2009). Banana/glass fiber-reinforced polypropylene hybrid composites: Fabrication and performance evaluation. *Polymer-Plastics Technology and Engineering*, 48(4), 397-414.

Srinivasababu, N., Rao, K. M. M., & Kumar, J. S. (2009). Experimental determination of tensile properties of okra, sisal and banana fiber reinforced polyester composites. *Indian Journal of Science and Technology*, 2(7), 35-38.

Stael, G. C., Tavares, M. I. B., & d'Almeida, J. R. M. (2001). Impact behavior of sugarcane bagasse waste–EVA composites. *Polymer Testing*, 20(8), 869-872.

Suharty, N. S., Wirjosentono, B., Firdaus, M., Handayani, D. S., Sholikhah, J., & Maharani, Y. A. (2008). Synthesis of degradable bio-composites based on recycle polypropylene filled with bamboo powder using a reactive process. *Journal of Physical Science*, 19(2), 105-115.

Santiagoo, R., Ismail, H., & Hussin, K. (2011). Mechanical properties, water absorption, and swelling behaviour of rice husk powder filled polypropylene/recycled acrylonitrile butadiene rubber (PP/NBRr/RHP) biocomposites using silane as a coupling agent. *BioResources*, 6(4), 3714-3726.

Stefani P. M, Jimenez A (2003) Thermal degradation of rice husk and other biomass materials in international perspectives on chemistry and biochemistry research. Nova Sci Publisher, New York

Tena-Salcido, C. S., Rodríguez-González, F. J., Méndez-Hernández, M. L., & Contreras-Esquivel, J. C. (2008). Effect of morphology on the biodegradation of thermoplastic starch in LDPE/TPS blends. *Polymer bulletin*, 60(5), 677-688.

Tajeddin, B., Abdul Rahman, R., Abdullah, L. C., Yusof, Y. A., & Ibrahim, N. A. (2009). Effect of PEG on the biodegradability studies of Kenaf cellulose-polyethylene composites. *International food research journal*, 16(2), 243-247

Vasoya, P. J., Mehta, N. M., & Parsania, P. H. (2007). Mechanical, electrical and water absorption study of jute / glass / jute-bamboo / glass – bamboo – bisphenol – C – formaldehyde -acrylate a value added composites. *Polymer-Plastics Technology and Engineering*, 46(6), 621-628.

Vilakati, G. D., Mishra, A. K., Mishra, S. B., Mamba, B. B., & Thwala, J. M. (2010). Influence of TiO2-modification on the mechanical and thermal properties of sugarcane bagasse–EVA composites. *Journal of Inorganic and Organometallic Polymers and Materials*, *20*(4), 802-808.

Westman, M. P., Fifield, L. S., Simmons, K. L. , Laddha, S. G. & Kafentzis, T. A. (2010). *Natural Fiber Composites: A Review*. Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830 Pacific Northwest National Laboratory Richland, Washington 99352.

Yang, H. S., Kim, H. J., Son, J., Park, H. J., Lee, B. J., & Hwang, T. S. (2004). Rice-husk flour filled polypropylene composites; mechanical and morphological study. *Composite Structures*, 63(3), 305-312.

Yussuf, A. A., Massoumi, I., & Hassan, A. (2010). Comparison of polylactic acid/kenaf and polylactic acid/rise husk composites: the influence of the natural fibers on the mechanical, thermal and biodegradability properties. *Journal of Polymers and the Environment*, 18(3), 422-429.

Zampaloni, M., Pourboghrat, F., Yankovich, S. A., Rodgers, B. N., Moore, J., Drzal, L. T., & Misra, M. (2007). Kenaf natural fiber reinforced polypropylene composites: a discussion on manufacturing problems and solutions. *Composites Part A: Applied Science and Manufacturing*, 38(6), 1569-1580.