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Mechanical properties evaluation of single and hybrid composites polyester reinforced bamboo, PALF and coir fiber

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Abstract. This study aims to determine the composition fiber natural of bamboo, pineapple leaf and coir in single and hybrid composite to see the best characteristics of tensile strength and flexural test by using a Universal Testing Machine (UTM) and observe the effect on the microstructure of the composite through optical and scanning electron microscopy. Bamboo, Palf and coir have synthesis from natural fiber was used as reinforcement in polyester composite using hand lay up or a hot-compression moulding while filler:matrix was used (45%:55wt.%, 70%:30wt.% and 15%:85wt.%). From the variation of the volume fraction between filler and matrix show that mechanical properties of composites increased with increasing amount of filler in the matrix. This is evidenced by the high mechanical properties A:B:C/Ps in compositions 45%: 55wt.% 136 Mpa while flexural strength 93 N and good structure surface morphology. This research has produced a hybrid composite materials that have high mechanical properties and bending compared with conventional synthetic fibers and other materials.

1. Introduction

Regardless of environmental benefits, the availability of abundant raw material resources and renewable instead of fossil resources, low cost and high specific strength while due low density [1,2] when compared to the classic mineral filler / plastic composite. Plastic reinfored fibers have been widely used in various industries such as the aircraft industry, automobile, recreational, electronic, medical and furniture. Composites industry is always looking for alternative sources of low cost, which can decrease overall manufacturing costs. Natural fiber polymer composite hybrid produces a variety of designs to customize and achieve cost-effective composite properties as compared to a single fiber as filler dispersed in the matrix. merging two or more fibers in a matrix called a hybrid composite [3].

The advantages of natural fibers joined to form hybrid composites have been reported previously. Therefore, the natural fiber is now a new alternative materials that can replace petroleum-based products either alone or combined with other ingredients to produce green composites such as bambooa fast-growing plants, bio abundant resources included in the family bambusae, under the genus Gramineae. Variations of structural, mechanical properties, fiber extraction, chemical modification, and thermal properties that make it a versatile material for composite applications-industries has been investigated [4,5], Pineapple leaf fibers rich cellulose content, are relatively cheap and abundant availability and potential for polymer reinforcement filler. Currently pineapple leaf fiber is a waste product of cultivation of pineapple and therefore relatively inexpensive. Coir fibers lies between the skin and the outer shell of the coconut [6] the use of coconut fiber, including its use as reinforcement in polymer composites have been investigated [7],

Advantages of natural fibers, such as low cost, low density, availability, sustainability, recycling and biodegradability, making it an area of research that is interesting and great effort is made to exploit the potential of the source of reinforcing material polymer in the form of bamboo, pineapple leaf and coconut fiber to be used as filler to development of fiber as a renewable natural materials in polymer composites. Therefore, in this study the synthesis of the fiber of bamboo, pineapple leaf and coconut fiber as filler in fiber-reinforced polymer single and hybrid to be seen also compares the characterization of the mechanical properties of tensile strength, flexural and morphology by scanning electron microscopy for each material composites.

2. Methodelogy/Experimental

A. *Samples*

In this study the bamboo fiber (namely the first fiber = A) and pineapple leaf fiber fiber / PALF is collected from Bener meriah (it was namely the second fiber = B) while coir was called C). Matrix used is polyester resin (Ps) from Sigma Aldrich with etyl methyl ketone peroxide as a hardener. Physical, mechanical, and thermal natural fiber is strongly influenced by the composition of chemical constituents. Cellulose as the major structural component gives strength to the walls of plant and fiber [8]. Preparations of Bamboo, PALF and Coir describes in figure 1.

B. *Fabrication of the composite*

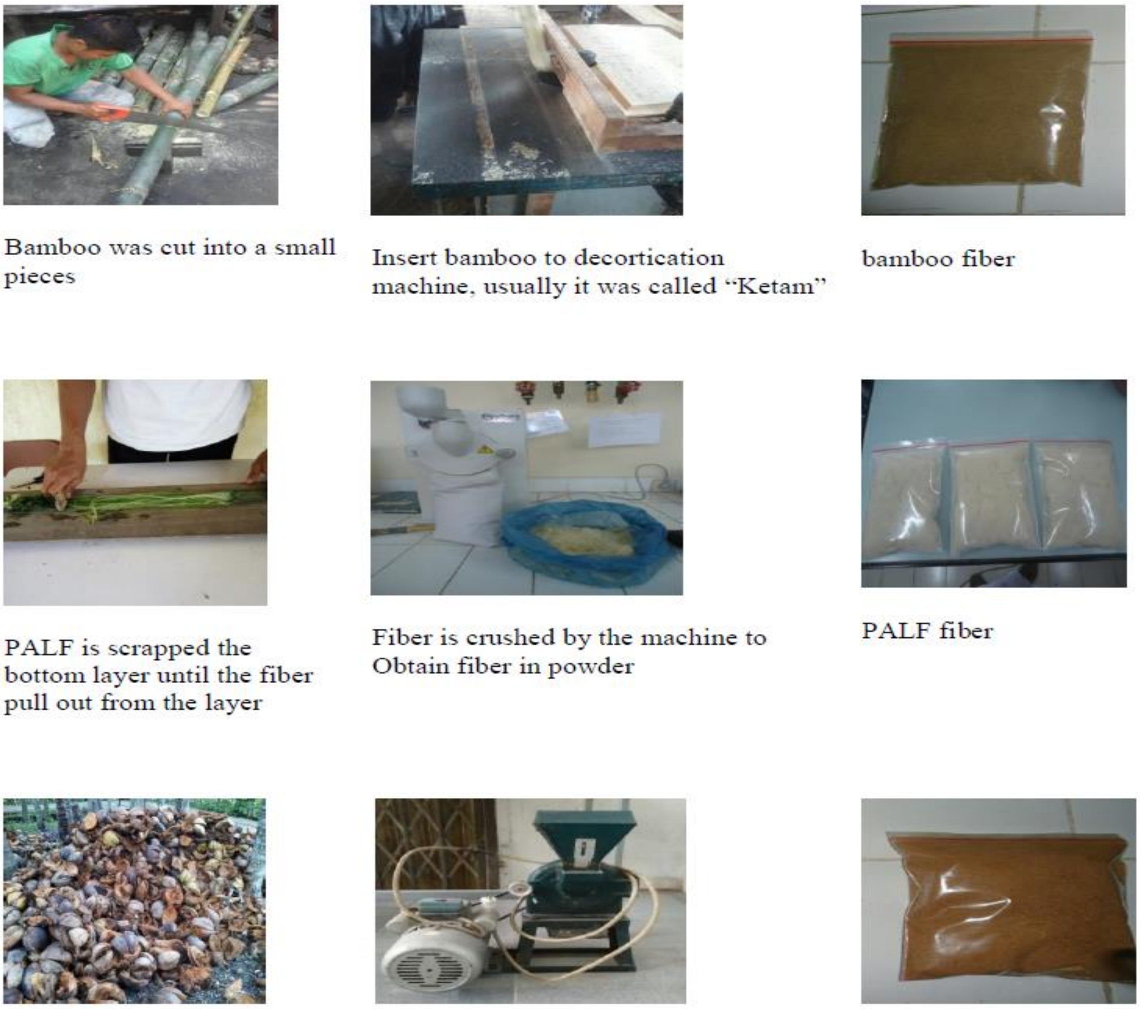
Reinforced polyester composite material of natural bamboo fiber, PALF and coir is fabricated by hand lay-up method and hot compression molding. the mixture of raw material bamboo, PALF and coir as filler in Isothalic polyester resin according with volume fraction and added 1% catalyst Methyl Ethyl Ketone Peroxide (MEKP) from the total weight of the matrix in 25cm × 5cm × 0,32cm.. the rule of mixtures such as bamboo-PLF-coir fiber, each fiber type consisted of (45%: 55 wt.%, 30%: 70wt.% and 15%: 85wt.%) for single fiber in polyester resin, during the hybrid composites while combination three fibers in polyester resin is consisted of (15%: 15%: 15%: 55.% wt, 10%: 10%: 10%: 70wt.%, 5%: 5%: 5%: 85wt .%), the composite is molded by a hot compression with a temperature of 85^{0}C [9] for 15 minutes. Specimens have been removed from the mold were cutting According with ASTM D 638 for tensile and flexural strength D 790 standard method.

C. *Tensile and flexural test*

Fig 2 (a) and (c) testing the tensile properties of the hybrid composite material refers to standard ASTM D 638. The tensile strength is measured using by universal testing machine (UTM) Exceed Model E43. Dimensions, gauge length and cross-head speed selected according to standard ASTM D-638. Fig 4 (a) and (b) flexural tests are performed in the same instrument According to ASTM D790 at a cross head speed of 0,8 mm / min and a gauge length of 25 mm.

D. *Scanning electron microscopy*

Scanning electron microscopy (SEM) was performed on a microscope JEOL-T20(Japan), operating at 20 kV accelerating voltage, in high vacuum mode, to study the morphology of the fracture surface of a sample. Fractures hybrid composite sample surface was observed using SEM to investigate the adhesion of the interface between the fiber and matrix hybrid composites. For this purpose, the sample is mounted on bronze stubs, using double-sided tape, and coated with a layer of gold (40-50 nm).



Bamboo was cut into a small pieces

Insert bamboo to decortication machine, usually it was called "Ketam"

bamboo fiber

PALF is scrapped the bottom layer until the fiber pull out from the layer

Fiber is crushed by the machine to Obtain fiber in powder

PALF fiber

Coir fiber is collected from various local source

Fiber is separated from the shell of coconut insert in crusher machine

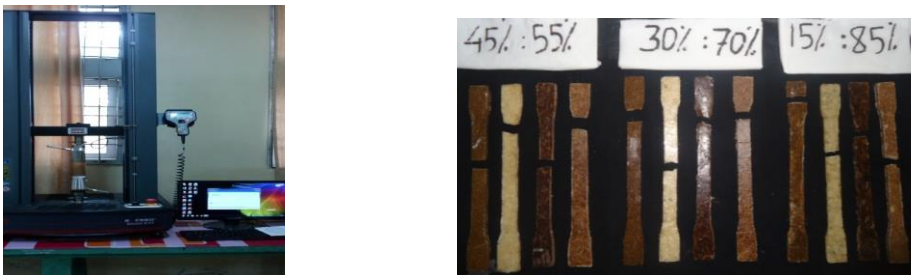
Coir fiber

Figure 1. Preparations of Bamboo, PALF and Coir

3. Results and Discussions

a. Tensile strength

Tensile testing of fiber reinforced composite material nature ployester analyzed using a Universal Testing Machine (UTM) Model E43 with a specimen sample used is ASTM D-638 is shown in Figure 1. Samples to be tested are clamped with a clamp located on the tool and the sample is pulled up to drop out at a rate of time t is 0.8 mm / s. The results are shown in graphical form when the sample experienced a tensile strain or stress vs. strain values at the break.



II. (b)

Figure 2. (a) Equipment sample test, (b) sample specimens ASTM D-638

Data from a composite material tensile test are compared with the theoretical data it shown in figure 2. Theoretical calculations for single fiber in matrix can be calculated using by equation (1) [10], during the hybrid composites consisting of a mixture of two or three fibers in the matrix is calculated using equation (2). The result of test composite polyester is presented in Table 1.

$$\sigma c = \sigma m V m + \sigma f V f \quad \text{.....................} \quad (1)$$
$$\sigma H = \sigma a V f a + \sigma b V f b + \sigma c V f c + \sigma m\,(1 - V f a - V f b - V f c) \quad \text{.....................} \quad (2).$$

Table 1. Result of Tensile Strength Test

The volume fraction (Filler: Matrix)	Tensile strenght (Mpa)				Flexural strength (KN)			
	A/Ps	B/Ps	C/Ps	A: B: C/Ps	A/Ps	B/Ps	C/Ps	A: B: C/Ps
45%: 55%	255	116	92	136	91	74	47	93
30%: 70%	183	81	58	103	79	62	33	89
15%: 85%	129	61	30	90	68	45	24	83

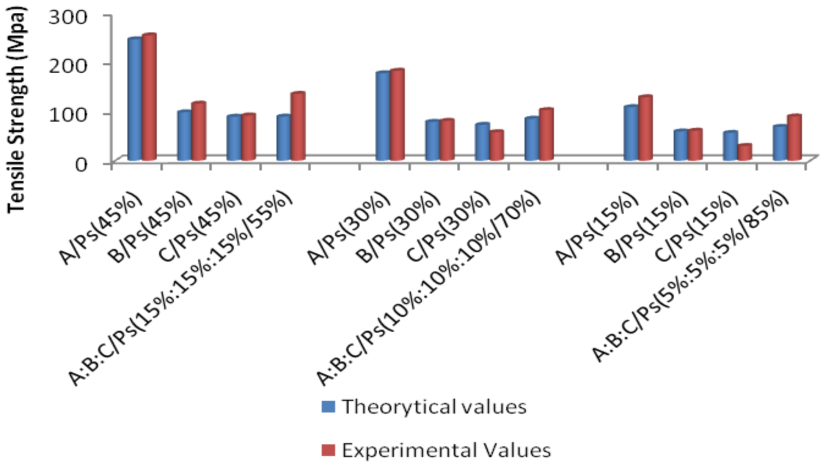


Figure 3. Comparison of experimental and theoretical tensile strength (MPa) versus Natural fiber loading (wt.%).

Based on Figure 3. of testing the tensile strength of the hybrid composite material polyester reinforced bamboo, PALF and coir fiber while the ratio of 45% fiber and 55% matrix has a tensile strength of 136 MPa. The tensile strength of 103 MPa produced from the hybrid composite ratio of 30%: 70% and 90 MPa for a ratio 15%: 85. This shows that hybrid composites are capable of producing the tensile strength values are better than the single fiber mixture of coconut coir (C: Matrix) and PALF fibers (B: Matrix) in the polyester matrix.

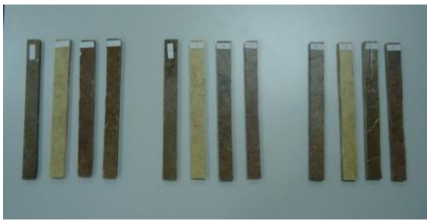
Disadvantages of the single fiber composites which is less properties than optimal characteristic can be improved by combining two or more types of fibers in the matrix so that it will produce a composite that has properties better mechanical characteristics. This effect is due to the good mechanical properties of bamboo fiber is associated with the natural fiber composition as shown in Table1[11] its will being hybrid composite polyester has tensile strength with a value of 136 MPa.

However, the tensile properties of hybrid composite polyester under the price of bamboo/ Polyester (A / Ps) and its because of difference volume fraction between mixing the three fibers (A: B: C / Ps) is less than the volume fraction of a single fiber as reinforcement matrix polyester indicating differences between the tensile strength properties of single fiber composites with hybrid composite. Recent studies have produced promising results with hybridization of natural fibers as a reinforcement of the mechanical properties and the impact strength of hybridization bamboo, PALF and coir fiber as reinforcement of polymer composites is very influential as shown in Table 2. Evaluation of the effect of hybridization on the mechanical performance of hybrid bamboo, PALF and coir fiber reinforced polyester composites found the tensile properties of NFCs increased with the addition of bamboo fiber. The mechanical properties of natural fiber is highly dependent on cellulose content results. The different cellulose content affects the mechanical properties of natural fibers [12].

b. flexural strength

Bending is a test to see durability due to loading application of a material is strongly influenced by the physical and mechanical properties of material. The Physical and mechanical properties of a material can be seen when they are done testing. The purpose of doing a mechanical testing is to determine the response material of a construction, component or assembly fabrication when subjected to a load or deformation from the outside [13]. The flexural strength of composite determined from 3-point bend test or with three point bend test on a sample of which is shown in Figure 4. The flexural strength for a variety of single and hybrid fiber composites are presented in Table 2.

(a)



(b)

Figure 4. (a) Example flexural test, (b) flexural test samples ASTM D-790

Flexural properties of fiber reinforced composite samples were single and hybrid obtained optimum results at the composition of the mixture A: B: C/Ps. show directly from testing using Exceed UTM machine Model E43 during the loading of bending to the best samples of hybrid composites.

Comparison of flexural strength of single fiber composite and hybrid polyester are presented in Figure 5. From the figure, confirmed that the bending load hybrid composite is better than single fiber-reinforced polyester composites A/Ps, B/Ps and C/Ps. Increased load bearing capability of composite materials increased significantly with the addition of fiber volume fraction in the mixing to form a composite.

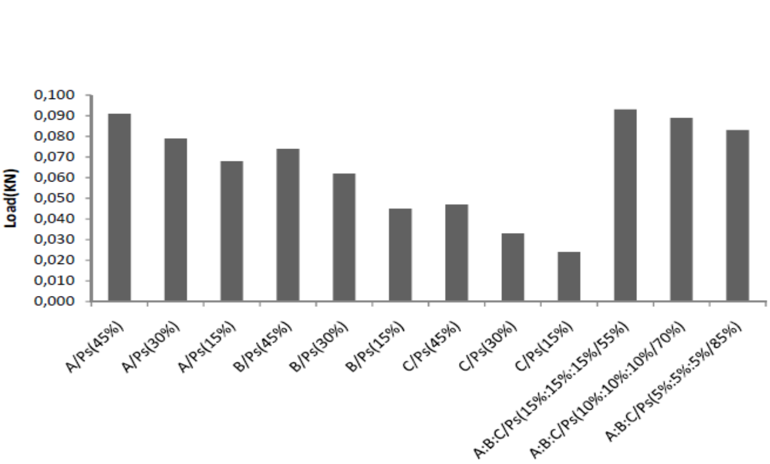
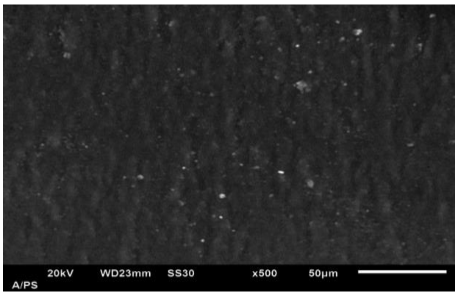
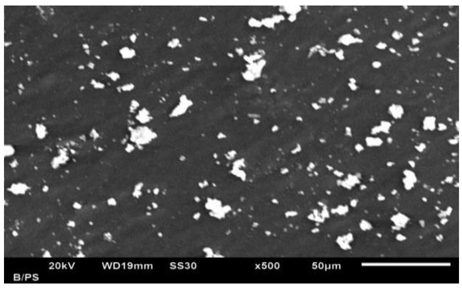


Figure 5. Comparison of Bending Strength of Single Fiber Reinforced Composites

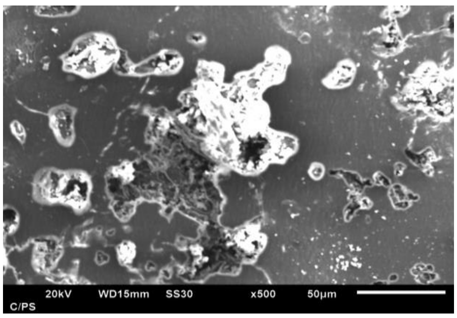
The results showed flexural optimum value for hybrid composite (A: B: C / Ps) is 0.093 KN. As for the single fiber (A/Ps) is 0091 KN, (B/Ps) and (C/Ps) each are having flexural optimum of 74 N and 47 N. Research on hybrid polyester composite bending properties was also investigated by[11], That mixing sisal-jute-GFRP / Ps produces a maximum of 3 KN flexural strength than mixing between the sisal-GFRP / Ps and jute-GFRP / Ps. From these experiment results that the hybrid composite play a role in shaping a composite material that has a value and a better flexural characteristics and this is evidenced by scanning electron microscopy analysis of the results contained in Figure 6. which shows the hybrid composite A:B:C/ Ps have a better surface structure [14].



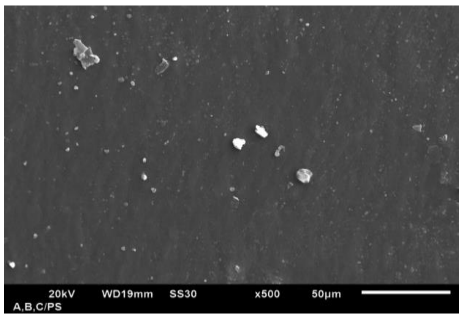
(a)



(b)



(c)



(d)

Figure 6. Analysis of scanning electron microscopy (a) A/Ps 500x, (b) B/Ps 500x, (b) C / Ps 500x and (d) A:B:C/Ps 500x.

From the results of the analysis are shown in Figure 6. (a) that (A/Ps) has a good dispertions fiber in surface structure than fig 6. (b) (B/Ps), which contains a lot of impurities on the surface of the fiber and fig 6. (c) (C/Ps) coir fiber reinforced polyester composites showed some void between fiber and matrix composites that influent interfacial bond and will not be effective when the transfer voltage from the matrix to the fiber, where the maximum usage in the composite fiber strength is achieved and these interactions affect the mechanical properties of composites that have been confirmed by the results of tensile tests in previous discussions [15].

While in Figure 6. (d) hybrid composite (A:B:C/Ps) it is apparent that fibers evenly dispersed into the matrix and provide a flatter surface properties. This shows the interface better adhesion properties, where there is a better interpenetration at the interface with the polyester fiber. This could be due to the high levels of delamination on the outer surface of polyester.

4. Conclusions

Comparison of bamboo fiber, PALF and coir in a matrix of polyester discovered that bamboo / polyester generate the highest characteristic value of 255 MPa compared PALF/ polyester and coir fiber / polyester. The addition of bamboo in the hybrid composite polyester can increases mechanical properties of the composite is 136 MPa.. The structure of the composite morphology indicating the presence of the number of voids and the interlocking matrix interfacial filler thus affecting the mechanical properties of the composite.

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References

[1] Alireza Ashori. 2017. Hybrid Thermoplastic Composites Using Plant Fibers Nonwood. *Hybrid Polymer Composite Materials*, pages: 39-56.

[2] Rihayat, T., Suryani., 2010. Synthesis and properties of biobased polyurethane/clay nanocomposites. *World Academy of Science, Engineering and Technology*. **65**, 918-922

[3] John, MJ, Thomas, S., 2008. Biofibres and Biocomposites. *Carbohydr Polym*.Vol **71**, pages: 343-364.

[4] Okubo, K., Fujii, T., Yamamoto, Y., 2004. Development of Bamboo-Based Polymer Composites and Their Mechanical Properties. *Compos. Part A Appl. Sci. Manuf*. Vol.**35**, pages: 377-383.

[5] Rihayat, T., Suryani, S., Zaimahwati, Z. 2014. Effects of heat treatment on the properties of polyurethane/clay nanocomposites paint. *Applied Mechanics and Materials*. 525, 97-100.

[6] Emad Omrani, Menezes Pradeep L., Pradeep K., Rohatgi. 2016 State Of The Art on the tribological Behavior of Polymer Matrix Composites Reinforced With Natural Fibers in The Green Materials World: Review. *Engineering Science and Technology, an International Journal.* Vol **19**, pages: 717-736.

[7] Yashwanth, MK, Easwara Prasad, GL, and N. K, Akshay. 2016. Comparative Study on the Properties of Coir And Sisal Fiber Reinforced Composites. *Inovative International Journal of Research in Science, Engineering and Technology*. Vol.**5**, Special Issue 9, pages: 992-926.

[8] Ahmed Edhirej., Sweep SM, Jawaid Mohammad., 2017. Cassava / Sugar Palm Cassava Starch Hybrid Fiber Reinforced Composites: Physical, Thermal and Structural Properties. *International Journal of Biological Macromolecules*. Vol.**101**, pages: 75-83.

[9] Akil, HM, Omar, M. F., Mazuki, A. A. M., Safiee. S., Isaac, ZAM, Abu Bakar, A. 2011. Kenaf Fiber Reinforced Composites: A review. *Materials and Design*. Vol.**32**, pages: 4107-4121.

[10] Yusoff, BR, Takagi, H., Nakagaito, AN 2016. Tensile and Flexural Properties of Polylactic Acid-Base Hybrid Green Composites Renforced by Kenaf, Bamboo And Coir Fibers. Industrial Crops and Products. Vol.94, pages: 562-573.
[11] Ramesh. M., Palanikumar. K., Reddy, Hemachandra, K ,. 2013. Evaluation of Mechanical Property-Jute Sisal-Glass Fiber Reinforced Polyester Composites. Composites: Part B. Vol.48, pages: 1-9.
[12] Easwara Prasad, GL, B. S, Gowda Keerthi., Velmurugan, R. 2017. A Study on Impact Strength Characteristics of Coir Polyester Composites. *Procedia Engineering* , Vol.**173**, Pages: 771-777.
[13] Kasim, AN, Congratulations, M. Z, David, MAM, Yaakob, MY, Son, A., Sivakumar, D., 2016. Mechanical Properties of Polypropylene Composites Reinfprced Alkaline Treated with Pineapple Leaf Fiber from Josapine Cultivar. *International Journal of Automative and Mechanical Engineering*. Vol.**13**, pages: 3157-3167.
[14] Umar Nirmal, JH. 2015. A Review on the tribological Performance of Natural Fiber Polymeric Composites. *Tribology International*. Vol 83, pages: 77-104.
[15] Rihayat, T., Suryani. 2013. Morphology properties of polyurethane/clay nanocomposites base on palm oil polyol paint. Advanced Materials Research. 647, 701-704