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# Review on Natural Fiber Reinforced Polymer Composites

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**ABSTRACT:** The use of natural fibers as a substitute for synthetic fibers in the polymer composites has gained an escalating importance in the recent years due to environmental concerns and growing cost of synthetic materials. These natural fibers are found to have outstanding properties like high specific strength, high tensile strength, very resilient, durable, bio-degradable resulting an eco-friendly natural composite material. The critical thing in the formation of natural fiber reinforced composites is to maintain an even homogeneity throughout the material and the factors affecting these things mainly are process of material formation (moulding process) and fiber distribution. Since the distribution of fibers, arrangement pattern has increased the scope of results. However different additives like hardner and accelerator are also used in natural composite to strengthen and enable fast epoxy hardening. This review is to study the natural polymer composites formed using different natural fibers. Addition of natural fiber to the base polymer matrix incorporates more performance properties like strength, stiffness, hardness and toughness. Hence different tests are carried out to evaluate failure analysis of each and every composite material and a relative study is made from the results to increase the performance properties. To further put steps in improving the compatibility of fiber matrix interface the natural fiber reinforced polymer matrix is visualized under Scanning Electron Microscope (SEM) and Fourier Transform Infra-Red (FTIR) spectroscopy to reveal the internal chemical bond in molecule.

**Keywords:** Natural fiber, fiber dispersion, polymer composite, tensile strength.

## 1. INTRODUCTION:

Materials always have been the fundamental part of design which determines performance, life and reliability of the final product. Properties that mainly determine the performance of materials are strength, stiffness, hardness and toughness. Materials like wood, fiber, building materials are typically used for furniture, construction purpose. However due to more degradation of trees, uses of polymer composites has been increased. In order to increase the performance properties of the material composites, processed synthetic material is added in the base matrix. However, the use of synthetic polymer composites has been increased because of fulfilling reliable properties.

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On the contrary these synthetic fibers have also increased environmental concerns. But for enhancement of properties, reduction in manufacturing cost, increasing waste management and creating biodegradable and eco-friendly materials much attention has been paid in the past decade to a new type of composite material i.e. natural fiber reinforced polymer composites [4]. These natural composite materials have natural fibers of plants, fruits and trees suspended in the base polymer matrix. Natural materials have unique advantages like easy availability, low cost over synthetic materials in which macro sized particles are dispersed in the base matrix. The arrangements as well as different weight percentages of natural fibers in the polymer composites have shown wide results in the material performance properties. This paper deals with the research so far done in the field on natural composites depicting best composites materials out of waste fibers by using different types of natural fibers. Various tests like impact tests, tensile test, Rockwell hardness test, water absorption test were carried on the composite material to evaluate the best possible natural composite materials. Even for fracture analysis Scanning

Electron Microscope (SEM), Fourier Transform Infra-Red (FTIR) spectroscopy [4] is used.

**2. LITERATURE REVIEW:**

Dispersion of natural fibers in the base matrix is called natural fiber reinforced polymer composites (NFRPC). The NFRPC have unique features different from synthetic fibers polymer composites. Due to their excellent physical and chemical characteristics they find wide application in enhancing strength of polymer composites.

J. S. Binoj et al. [1] explained about newly developed blue agave fiber composite (BAFC) material, which exhibit less weight, better mechanical and thermal properties compared with other natural fiber polyester composites. Conclusion drawn from this paper is, optimum weight percentage of dried agave fiber of high tensile strength with unsaturated polyester having distribution (polyester: agave fiber) (60:40) showed good result.

Somashekhar T. M. et al. [2] proved that the utilization of coconut shell powder and tamarind powder as reinforcement with epoxy matrix will increase load carrying capacity. This analysis shows that tensile strength of composite is increased by 50 percent with specific ratio of content in it. Good result was obtained for the following sample having distribution (Coconut shell powder (CSP): tamarind shell powder (TSP): epoxy) (50: 5: 45).

Asheesh Kumar et al. [3] stated that jute epoxy composite exhibited better tensile and compressive strength. Conclusion drawn is, bending strength is directly proportional to percentage of jute fiber in jute fiber epoxy composites.

Ramchandran M. et al. [4] stated significant result i.e. mechanical behavior of natural fiber polymeric composite (NFPC) having banana, bamboo, linen as reinforcement material in different proportion by performing impact, FTIR, hardness tests. The conclusion drawn from paper is bamboo-banana natural composite with the distribution (epoxy: bamboo: banana) (90:5:5) showed good result as compared to others composites.

Jacob O. A. et al. [5] examined natural coconut shell fiber on the basis of hardness, tensile strength, impact strength. It has been stated that the effect of fiber/epoxy ratio and amine/epoxy ratio leads to increase tensile strength of coconut shell fiber reinforced polymer composites.

Alok Singh et al. [6] stated that the properties like tensile strength, flexural strength and density of coconut shell powder (CSP) epoxy composites was greatly influenced by CSP filled volume fraction. The conclusion drawn is final composite prepared with 20 percent to 30 percent of CSP fill volume fraction are suitable for optimum performance application.

M. Jawed et al. [7] stated the effect of woven jute fabrics on tensile and flexural properties of oil palm empty fruit bunches (EFB)/woven jute fabrics reinforced with epoxy composites resulted with good tensile strength. Conclusion drawn is the change in tensile strength of the epoxy composite varies with the change in stacking sequence of reinforcement material.

Punyapriya Mishra et al. [8] examined the properties of bagasse fiber reinforced polymer composites (BFRP) by conducting different tests. The conclusion drawn from paper is, abrasive wear rate of BFRP is strongly dependent on the size and orientation of fibers in polymer composites.

S. Harish et al. [9] carried out an experimental study on fiber of coconut coir obtained from outer shell or husk of coconut as reinforcement and epoxy resin as matrix. Conclusion drawn from this study is coir / epoxy composites exhibits average value of tensile strength, impact strength, and flexural strength.

M. A. Maleque et al. [10] proved that the tensile strength of pseudo-stem banana woven fabric reinforced epoxy composite is increased up to 90 percent compared to virgin epoxy. Conclusion drawn is the impact strength is increased by approximately 40 percent, which states that higher the impact strength leads to increase the toughness property of material.

**3. METHODOLOGY:**

J. S. Binoj et al. [1] prepared a sample using unsaturated polyester with methyl ketone peroxide as a curing catalyst, cobalt napthanate as an accelerator and blue agave plant leaves fiber of size 300 mm length and 537 µm to 584µm diameter which is allowed to soak in the mixed resin of matrix in random orientation and poured in mould of 300 mm x 125 mm x 3 mm and pressed under hand roller followed by compression load of 350 KN. Finally, 5 samples of 10 percent, 20 percent, 30 percent, 40 percent and 50 percent of weight of fibers were produced.

Somashekar T. M. et al. [2] prepared a sample by blending the mixture of crushed epoxy resin (pelletized polyethylene), grinded coconut and tamarind shell powder (CSP and TSP) of size 300 µm followed by compression load of 300 tons at 150ºC. Finally, 6 samples of different weight percentages of materials were prepared for testing.

Asheesh Kumar et al. [3] prepared a sample using epoxy resin (AY103), jute fiber. The composite was made by hand layup process in a mould of 600 mm x 300 mm x

27 mm size. The composite is prepared in 3 layers (matrix (1-1.5 mm)/ jute fiber/ matrix). The composite is pressed under hand roller for removing air trapped between two materials.

Ramchandran M. et al. [4] prepared a sample using epoxy resin, hardner with bamboo, banana, and linen fiber as reinforcement material. The mixture was poured in the mould and 3 samples were prepared using hand layup process i.e. (epoxy resin: bamboo fiber) (90:10), (epoxy resin: bamboo fiber: banana fiber) (90:5:5), (epoxy resin: bamboo fiber: linen fiber) (90:5:5). The natural fibers in composites were cut into 2 mm to 4 mm.

Jacob O. A. et al. [5] prepared a sample using epoxy resin (15 ml to 35 ml), acetone (20 ml), and amine (0 ml to 1 ml) along with coconut shell fibers of 100 mm length. The composite is casted using hand layup technique. After the cast is cured for 2hours at 60ºC to 80ºC in oven, again it is cured under press at pressure of 10 bars at 110ºC for 20 minutes. Thus 20 samples were produced by varying volumes of each material.

Alok singh et al. [6] prepared sample composite using epoxy resin (El301), hardner (MH-33) and coconut shell powder of maximum size 300 µm to 850 µm. The mixture was poured in mould of size 320 mm x 120 mm x 6 mm having base of glass and sides of wood and finally sample of 20 percent, 30 percent, 40 percent of weight of coconut shell powder in matrix were prepared.

M. Jawaid et al. [7] prepared a sample composite using epoxy resin (DGEB), hardner (A062), fiber mat of oil palm empty fruit bunches (oil palm EFB) and woven jute (JW) fiber. There were two stacking sequence JW/EFB/JW, EFB/JW/EFB. The resin matrix is poured in mould of 304 mm x 203 mm over the fiber mat. The composite is pressed by hand roller followed by curing at 105ºC for 1 hour at a 275 bars pressure in hot press. Again the composite was kept in oven at 105ºC for 30 minutes and cooled in cold press for 15 minutes.

Punyapriya M. et al. [8] prepared a sample composite using epoxy resin, hardner (HY951), and bagasse fiber as reinforcement material. The composite was prepared using hand layup process with 20 percent fiber volume and resin: hardner is (10:1). Three different orientations of fibers were used namely normal, parallel and antiparallel.

S. Harish et al. [9] prepared a sample using epoxy (CY205), hardner (HY951) with 10:1 ratio respectively and mould of dimension 300 mm x 300 mm is used wherein 3 layered composite is formed (matrix/ coir fiber (chopped strands)/ matrix) using hand layup process. The sample was compressed and left for curing for 24 hours.

M. A. Malaque et al. [10] prepared sample composite using epoxy resin (3554A), hardner (3554B), and dried fibers of banana stems in woven fabric configuration as reinforcement material. The matrix is poured in mould in stacking sequence of matrix/woven fabric/ matrix and composite is formed using hand layup process. The proportion of composites is (epoxy: woven fabric) (4:1) in terms of volume.

**4. RESULTS:**

J. S. Binoj et al. [1] tested the composite material on INSRON (5500R) universal testing machine, impact testing machine, Rockwell hardness testing machine. The following results were obtained:

| Fiber percent | Tensile strength (MPa) | Tensile modulus (GPa) | Flexural stress (MPa) | Flexural modulus (GPa) | Impact strength (J/ $cm^2$) | Hardness (HRRW) |
|---|---|---|---|---|---|---|
| 0 | 35.11 | 1.30 | 43.70 | 1.81 | 0.60 | 62 |
| 10 | 26.41 | 3.14 | 39.12 | 0.88 | 3.57 | 64 |
| 20 | 31.85 | 3.76 | 42.03 | 0.93 | 4.67 | 67 |
| 30 | 39.61 | 4.56 | 51.59 | 1.10 | 5.27 | 73 |
| 40 | 44.20 | 4.95 | 56.25 | 1.12 | 6.82 | 78 |
| 50 | 33.84 | 4.15 | 44.50 | 0.98 | 5.15 | 71 |

Somashekar T. M. et al. [2] tested 6 samples of different proportions. The tensile testing is done on universal testing machine with best results obtained from sample (CS powder: TS powder: epoxy resin) (50:5:45), whereas the elongation is constant. Hardness testing was done on Rockwell hardness testing machine with best results obtained from sample (CS powder: TS powder: epoxy resin) (50:5:45), grain distribution was increased by tamarind powder. Even the maximum flexural strength was obtained from same distribution.

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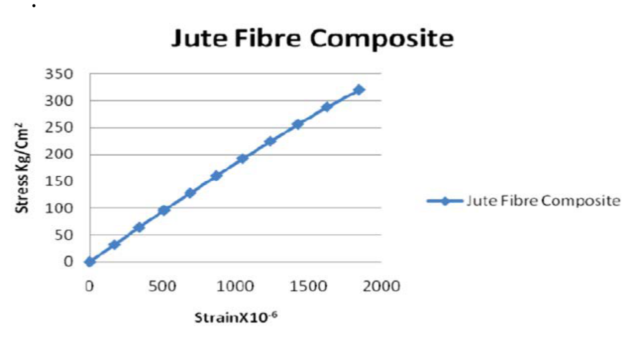


Asheesh kumar et al. [3] tested the sample composites on Hounsefield Tensometer. Graph of compression test indicates that jute fiber composites are better in compression strength in comparison to epoxy

Ramchandran M. et al. [4] performed specimen testing on impact testing machine, Rockwell hardness testing machine. The results obtained are:

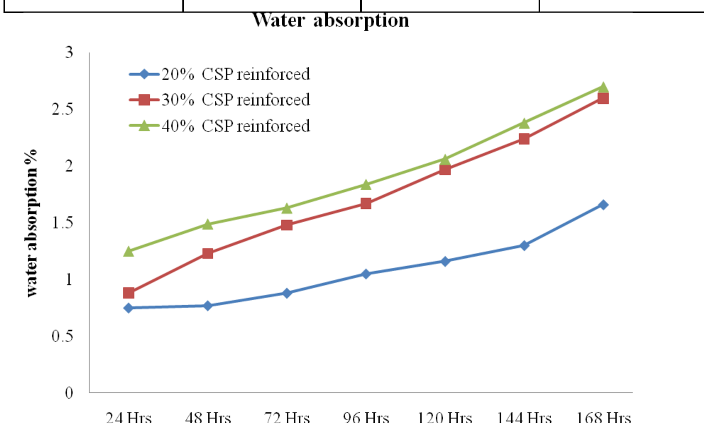
| Specimen | Izod test | Charpy test | Hardness (RHN) |
|---|---|---|---|
| Bamboo epoxy resin composite | 2 joules | 3 joules | 20 |
| Bamboo-Banana epoxy resin composite | 4 joules | 5 joules | 35 |
| Bamboo-linen epoxy resin composite | 3 joules | 4 joules | 40 |

According to the FTIR results, the functional groups of bamboo epoxy resin composite and bamboo–banana epoxy resin composite are same except one extra Alcohol/Phenol stretch and one less Alkyl CH stretch and Aromatic CH bending functional groups.

Jacob O. A. et al. [5] tested samples on Hounsfield Tensomter, Duromter type D machine and impact testing machine. The maximum hardness obtained is 70.67 DHN from the sample having fiber/epoxy ratio and Amine/epoxy ratio as 0.20 and 0.0375 respectively with 2 gm of CSP. Whereas maximum impact strength is obtained from the sample having fiber weight, epoxy weight, and amine as 4.033 gm, 15 gm, and 1 ml respectively

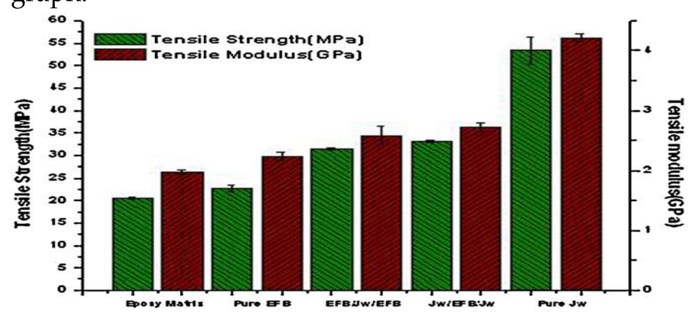
Alok Singh et al. [6] tested coconut shell powder epoxy composite on INSTRON 1195 for tensile strength; used three points bending method for flexural test and long term water immersion method is used to determine the absorption behavior of composites. The results of tests are as follows:

| Sample | Density ($gm/cm^3$) | Flexural strength (MPa) | Tensile strength (MPa) |
|---|---|---|---|
| 20 percent CSP filled | 1.0462 | 83.38 | 19.23 |
| 30 percent CSP filled | 1.0532 | 86.45 | 17.05 |
| 40 percent CSP filled | 1.0639 | 73.92 | 14.64 |




Thus, the composite with 20 percent to 30 percent CSP possess optimum performance properties.

M Jawaid et al. [7] tested samples on INSTRON 5582 Universal testing machine, used 3 points bending test for flexural analysis, SEM to analyze morphological images of hybrid composites. Tensile strength and modulus of oil palm EFB/woven jute (JW) fiber hybrid composite having ratio of oil palm EFB & woven jute fiber of 4:1 at 40 percent of fiber by weight is shown in the following graph.




Punyapriya M. et al. [8] tested the composites samples on two body abrasive wear tester. Different loads of 1N, 3N, 5N, 7N were applied along with abrasives of different grit size namely 150, 180, 320, 400. It has been observed that for all grit sizes wear rate increases with increase in load. Wear rate of composites varies with the orientation as shown in descending order, parallel> anti-parallel> normal orientation.

S. Harish et al. [9] carried out tensile test, 3 points bend test, Izod impact test on the coir composite. The following results were obtained:

| Sample composite | Average tensile strength (MPa) | Average flexural strength (MPa) | Average impact strength ($KJ/m^2$) |
|---|---|---|---|
| 1 | 17.26 | 31.08 | 11.49 |

These results were compared with glass fiber reinforced polymer (GFRP).

M. A. Malaque et al. [10] tested samples on INSTRON Universal tester, used 3 points bend method for flexural stress and impact testing machine. The ultimate tensile strength, flexural strength and impact strength of pseudo-stem banana fiber reinforced epoxy composites are 45.57 MPa (mean value), 73.58 MPa and 6.95 KJ/$m^2$ which is more than virgin epoxy material.

**5. DISCUSSIONS:**

J. S. Binoj et al. [1] initially noted that mechanical properties of the composites were found to be high with the increase in the fiber content up to 40 percent fibre weight and thereafter a sudden reduction was observed. Further it was found that while fiber content increases its density increases and gradually decreases. Large amount of matrix reinforcement led to formation of voids and weakened the strength. Finally the material of specific properties having 40 percent fiber weight content and 60 percent weight matrix content fabricated BAFC can be recommended.

Somashekar T. M. et al. [2] founded that there is no significant change in flexural property. Addition of tamarind powder showed a tremendous increase in strength of composite material. There is no significant change in flexural property when tamarind shell powder was used but addition of tamarind powder showed a tremendous increase in its load carrying capacity during the tensile test.

Asheesh Kumar et al. [3] showed that the jute epoxy composite exhibited better tensile and compressive strength compared to its virgin form. Bundle strength of fibers decreases with increase in number of fibres in a bundle. Tensile strength increases with jute fiber reinforcement. Bending strength increases with increase in percentage of jute fibre, compressive strength increases with increase in percentage of jute fibre, impact strength has no noticeable change after additionof fibre.

Ramchandran M. et al. [4] founded that according to the Impact results, bamboo−banana epoxy resin composite showed the highest value of 4 Joules and 5 Joules. According to the FTIR results, the functional groups of bamboo epoxy resin composite and bamboo−banana epoxy resin composite are same except one extra Alcohol/Phenol OH stretch and one less Alkyl CH stretch and Aromatic CH bending functional groups. According to the hardness results, bamboo−linen epoxy resin composite had the highest Rockwell hardness test value of 40 RHN while bamboo epoxy resin composite had the lowest Rockwell hardness test value of 20 RHN.

Jacob O. A. et al. [5] founded that the tensile strength of the composite material increase with increase in fibre/epoxy ratio. When coconut granulated powder were added to aid the strength, a reduction was observed when more than 2 gm of powder was added. This is as a result of the coconut powder absorbing the epoxy resin which subsequently reduced the adhesion bond between the fibres and the matrix. Initially, it formed dislocation points which impedes the flow and resulted in increase in tensile strength There is an increase in hardness number as the ratio of fibre/epoxy and amine/epoxy increases. However, when coconut powder were injected into the matrix, the hardness value reduced as a result of the powder absorbing the epoxy which resulted in weak bonding.

Alok singh et al. [6] evaluated that the density of the composite having 20 percent CSP filled is less compared to others, the rate of increase in density is maximum from 30 percent to 40 percent CSP filled composites. An increase in filler volume results the decrease in tensile strength. Thus, the rate of decrease in tensile strength from 20 percent to 30 percent and 30 percent to 40 percent CSP filled epoxy composite is approximately constant. With the rate of increase from 20 percent to 30 percent CSP filled composite there is an increase in reinforcing volume, causing increase in water absorption.

M. Jawaid et al. [7] showed that pure woven jute composite showed a higher tensile strength and modulus than pure EFB composite. This is because woven jute fibres are stronger and stiffer than oil palm EFB fibres. Hybridization of oil palm EFB fibre with woven jute fibre has resulted in an increase of tensile strength and modulus of pure EFB composite. The woven fabrics used as core and skin material in hybrid composites improved flexural strength of JW/EFB/JW and EFB/JW/EFB hybrid composites compared to chopped strand mat based jute/oil palm EFB hybrid composites. It may be due to fabric mats have a higher fibre count than chopped strand mat, would exhibit a superior flexural strength when reinforced in hybrid composites.

Punyapriya M. et al. [8] evaluated that abrasive wear rate of BFRP composite strongly depends upon load and abrasive grit size. With increase of load and grit size, wear rate increases.The orientation of fiber in composites has a significant influence on the wear rate of composite. The wear rate of Parallel Orientation samples is greater than that of the Anti Parallel and Normal samples. It follows the trend WNO < WAPO < WPO.

S. Harish et al. [9] found that coir/epoxy composites exhibits average values for the tensile strength, flexural strength and impact strength of 17.86 MPa, 31.08 MPa and 11.49 KJ/$m^2$ respectively.The glass fiber/epoxy specimen failed in flexure shows the presence of hackles near the fiber bundle. After the tensile test the fibers are detached from the resin surface due to poor interfacial bonding, with some voids formed on the resin surface due to fiber pull-out which eventually afftected its impact strength.

M. A. Malequeet et al. [10] founded that the tensile strength of the pseudo-stem banana woven fabric reinforced epoxy composite is increased by 90 percent compared to virgin epoxy. The flexural strength increased when banana woven fabric was used with epoxy material. The results of the impact strength test showed that the pseudo-stem banana fiber improved the impact strength properties of the virgin epoxy material by approximately 40 percent. Higher impact strength value leads to higher toughness properties of the material. The banana fiber composite exhibits a ductile appearance with minimum plastic deformation.

**6. CONCLUSIONS:**

Natural fiber when well dispersed in the polymer matrix with the optimum weight percentage enhance the overall strength properties of the natural fiber reinforced polymer composite over the base virgin polymer material. Thus they can be potentially used in advance strength application in manufacturing industry. This paper presented an overview on recent developments in the field of natural fiber reinforced polymer composites including sample preparation methodology, testing process, and evaluation of results. The performance of the composites depends on the size of fiber, orientation of fiber, weight percentage of fiber, compatibility with base polymer matrix, other treatments on the natural fiber to increase its performance as well as to improve fiber matrix interface. In summary, the future scope of this composite material is to concentrates on strength enhancements and determining its physical mechanism, taking into consideration of parameter affecting the performance of the composites. Precise measurements and documentation of strength properties are extremely important. Better characteristic of composite materials is also important for developing engineering design. Finally, it is to suggest that natural fiber reinforced polymer composites require a genuinely multidisciplinary approach with complementary efforts from all sides.

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**8. REFERENCES:**

[1] J. S. Binoj, J. S. Bibin. (2018). Failure analysis of discarded Agave tequilana fiber polymer composites. Vol.95,379-391, org/10.1016/j.engfailanal.2018.09.019.

[2] Somashekhar T. M., Premkumar Naik, Vighnesha Nayak, Mallikappa, Rahul S. (2018). Study of mechanical properties of coconut shell powder and tamarind shell powder reinforced with polymer composites.doi:10.1088/1757-899X/376/1/012105.

[3] Kumar A., Srivastava A. (2017). Preparation and mechanical properties of jute fiber reinforced epoxy composites. Vol.6.doi:10.4172/2169-0316.1000234.

[4] Ramachandran M., Sahas Bansal, Pramod Raichurkar. (2016). Experimental study of bamboo using banana and linen fiber reinforced polymer composites. doi:10.1088/1757-899X/376/1/012105.

[5] Jacob O. A., Ayogu Harrison, Olawale Monsur Sanusi. Evaluation of mechanical properties of coconut shell fibres as reinforcement material in epoxy matrix. Volume 3, Issue 2 February - 2014www.ijert.org.

[6] Alok singh, Savita singh, Aditya kumar. (2014). Study of mechanical properties and absorption behavior of coconut shell powder epoxy composites. Vol.2, 151-167. doi:10.11648/j.ijmsa.20130201.12

[7] M. Jawaid, H.P.S. Abdul Khalil, A. Abu Bakar. (2011). woven hybrid composites: Tensile and flexural properties of oil palm-woven jute fibers based epoxy composites. Volume 528, Issue 15, 15 June 2011, Pages 5190-5195.doi.org/10.1016/j.msea.2011.03.047.

[8] Punyapriya Mishra and S.K. Acharya. (2010). Anisotropy abrasive wear behavior of bagasse fiber reinforced polymer composite. Volume 2, No. 11, 2010, Pages 104-112.

[9] S. Harish, D. Peter Michael, A. Bensely, D. Mohan Lalb, A. Rajadurai. (2008). Mechanical property evaluation of natural fiber coir composite. Vol.60, 44-49. doi.org/10.1016/j.matchar.2008.07.001.

[10] M. A. Maleque, F. Y. Belal and S.M. Sapuan. (2007). Mechanical properties study of pseudo-stem banana fiber reinforced epoxy composite. Volume 32, No. 2, 2007.