Experimentation and Optimization of Sugar Cane Bagasse (SCB) Dust Reinforced Epoxy Based Composite

[1]Nitin Mukesh Mathur, [2]Kedar Bairwa, [3]Rajkumar, [4]Dr. Archana Singh

[1]Assistant Professor, [2]Assistant Professor, [3]Assistant Professor
[1]Department of Mechanical Engineering,
[1]Poornima Group of Institutions, Jaipur, India
[1]nitinmthr3@gmail.com, [2]bairwame@gmail.com

Abstract- In the present investigation, epoxy based Sugar cane bagasse dust reinforced green composite is prepared with four different percentage of the filler weight as (100 wt% epoxy + 0 wt% SCBF), (100 wt% epoxy + 6 wt% SCBF), (100 wt% epoxy + 12 wt% SCBF), and (100 wt% epoxy + 18 wt% SCBF). The low temperature curing epoxy resin (AW 106) chemically belongs to the 'epoxide' family and corresponding hardener (HV 953U) selected to fabricate the sample. The hand lay-up method used to fabricate the polymer composite sheet, and as per ASTM standard sample be cut and mechanical behaviour (Tensile and Flexural) studied. The fabricated samples tested at two different speeds respectively 2 mm/minute and 4 mm/minute. Also, the micro structural study of the composite is carried out to exploring the filler scattering in the matrix material. Optimization of mechanical properties is also executed using Taguchi method to find out the optimal combination of design constraints which maximizes the load and stresses values.

Index Terms— **Sugarcane bagasse fiber (SCBF), Epoxy, Polymer composite, Natural filler/fiber**.

I. INTRODUCTION

The biodegradable waste from agriculture based industries have received much consideration due to they can use as potential raw material as key components of fully or partially green composite material. Agricultural crop waste and residues like cereal straw, bagasse, corn stalk, grass and cotton, etc. These are formed in millions of tonnes worldwide. It represents abundancy of agro waste based fiber with low cost availability and freely available source of lingo-cellulosic biomass. Only a minor quantity of agro waste used for animal feed or the household fuel rather mostly are useless. But, major part of agro waste burn which creates the environmental pollution. Application of biodegradable waste reinforced composite material can be used in field of various automobile parts, kitchen accessories, interior design, decking materials, low and high strength structural design in the field of aerospace and marine applications.

1.1.Definition of composite

The Composite material prepared by mixing two or more different elements in order to make the resulting material having superior properties from its parental materials. There are two parts of composite material, matrix and filler/fiber (reinforcing phase). We can reinforced in various phase, in the form of fibers, sheets, or particles. It is surrounded in the other materials called the matrix phase. Metal, ceramic, non-metal, and polymer material can be used as reinforcing element and matrix material in development of composites.

Merits and Demerits of Composites:

- Environment friendly and non-toxic.
- Biodegradable, compostable.

- User friendly and Cheaper.
- Non-abrasive.
- Light weight /small density.
- Income Source for rural/agricultural community.
- Heat and noise insulating property.
- Renewable and endless supply of raw materials.
- Free from health hazard (no skin irritations).
- Adequate specific strength.
- High and excellent toughness, thermal properties.

There are following disadvantages observed by the researchers as follows:

- Less compatibility with hydrophobic polymer matrix.
- Degradation of fiber due to storage for a long time period.
- Moisture absorptivity.
- Tendency to form aggregates during processing.
- Relatively low thermal stability and less resistance to moisture.
- Hygroscopicity.

1.3 Fabrication of Composite:

In fabrication of the sample hand lay-up method is used for tensile and flexural analysis. All steps of fabrication process done in vacuum chamber. The funnel was connected to the mould using a pipe. Epoxy resin, which comes in two components resin and hardener, were taken in two separate cups. Appropriate quantity of filler (0%, 6%, 12%, 18%) was added in the cup, contain resin and mixed using the mixing hardware available in the machine a low speed is selected to avoid spillage. The machine was closed and vacuum applied. The hardener was the pour from the cup A of the machine into cup B using the handle provided. The two were mixed thoroughly in vacuum. Since the mixture becomes viscous hence the speed of the mixture is increased appropriately. The mixed composite was pour into the mould under vacuum through the funnel and the connecting tube. The mould contain the composite was kept in the vacuum chamber and the vacuum was released slowly using the release knob. After 24-48 hours' composite sheet fully cured and ready to fabricate samples as per ASTM standards.

Fig.1. Specimen for testing.

1.4 Experimental design on the basis of Taguchi method

In this section, experimental design on the basis of Taguchi method explained thoroughly. Design of experiment is a great investigation tool, used in modeling and investigating the inspiration of control factors on performance outcome. The selection of the control factors has major role in the design of experiment. Consequently, a lot of factors are involved, so that non-significant variables can be acknowledged at the original opportunity. The selection of a suitable orthogonal array for experiments, all degrees of freedom have to be calculated. The degrees of freedom (DOF) are defined as the number of comparisons from the process parameters that require to the determine which level is good and precisely how much better it is. In this study, mechanical behavior of composite material is investigated under various operating circumstances. In this work, considering two parameters, viz., speed and filler content which having two control factors and four levels respectively as listed in Table 1 on the basis of the Taguchi's L8 orthogonal arrays. The influences of these two parameters are studied using this L8 array and tests are accompanied as per the experimental design described in Table 2 at room temperature. The experimental observations are further transformed into signal to noise (S/N) ratios. The S/N ratios for maximum load and stress values can be articulated as "higher the better" representative, which is considered as logarithmic conversion of loss function as shown in below.

Table.1 Levels of variables (control factors) used in experiment.

	Levels				
Control factors	1	2	3	4	Units
Filler content	0	6	12	18	wt.%
Speed	2 4	2 4	2 4	2 4	mm/min

Table.2 Experimental design (L_8 orthogonal array) with output and S/N ratio.

Test run	Filler content (wt. %)	Speed (mm/min)	Load (N)	S/N ratio for load (dB)	Tensile stress (MPa)	S/N ratio for tensile stress (dB)	Flexural stress (MPa)	S/N ratio for flexural stress (dB)
1	0	2	1958.54	65.8386	18.220	25.2110	29.32	29.3433
2	0	4	2464.27	67.8338	19.850	25.9552	34.43	30.7387
3	6	2	1989.46	65.9747	17.690	24.9546	28.43	29.0755
4	6	4	2602.22	68.3069	19.810	25.9377	34.02	30.3755
5	12	2	2709.59	68.6581	19.985	26.0141	36.62	31.2744
6	12	4	2117.72	66.5174	22.085	26.8819	28.78	29.1818
7	18	2	3245.91	70.2267	20.804	26.3629	34.72	30.5578
8	18	4	2954.92	69.4109	21.320	26.5757	35.89	31.0995

1.5 Experimental details

1.5.1 Tensile test

The Tensile test was carried out on the basis of ASTM D 3039 M-14 standard, using Universal testing machine having grip capacity of 100 kN. The testing was performed at surrounding temperature of 24^0C and relative humidity of 53%. Four different percent filler weight specimen (as 0%, 6%, 12% and 18%) were tested at two different speeds of 2 mm/min. and 4mm/min. The standard specimen was mounted by its ends into the holding grips of the testing equipment's. Dimension of a specimen is 125 X 25 X 5 with gauge length 60 mm, were tested at two different speeds of 2 mm/min and 4 mm/min.

Fig.2 Experimental set up for tensile test

1.5.2 Flexural test

The 3-point Flexural test of composite are carried out using Universal testing machine as per ASTM D 790-03 at 24^0C and 53% Relative Humidity. The specimen of each filler contains were testing at two crosshead speeds of 2mm/min and 4mm/min. The sample of rectangular cross section rests on two supports and is loaded by means of a loading, nose midway between the anchors. The loading nose and anchors have cylindrical surface. The standard specimen was mounted by its ends into the holding grips of the testing instruments. The dimensions of specimen are 125X25X5 with span length of 60 mm. The loading nose and anchors have cylindrical surface. The flexural modulus is calculated from the slope of the initial portion of the load deflection curve.

1.5.3 Optimization techniques

The optimization techniques are used to maximize and minimize the outcome of various kind of problem in the engineering design endeavors. There are two distinct types of optimization approaches used today. First one, algorithms which are deterministic and having specific rules with different solution. Secondly, there are methods which are stochastic in nature contain probabilistic transition rules.

Various optimization methodologies and algorithms ranging from the elementary numerical inspect approaches to become more organized methodologies. By employing non-traditional methods for the optimization of process parameters in case of composites can be used. Usually, mathematical programming procedures like linear programming, method of feasible direction, dynamic programming and geometric programming methods of optimization do not fare well over the broad variety of the problem areas. Furthermore, traditional performances may not be robust. Considering with the drawbacks of traditional optimization procedures, attempts to optimize the design the constraints using Taguchi method. The evolutionary optimization methods, multi criteria decision making, fuzzy based method, hybrid algorithm and artificial intelligence techniques are used.

In Taguchi technique used to minimize minimum required number of the tests and it can explore more information precisely and efficiently compared with the other methodology. Besides, this will represent much better consistency and reproducibility of the results since it used in the both set of standard orthogonal array, which can be used for the many other experimental situations, and a standard method for the analysis of the outcome. Taguchi recommends the usage of the loss function to estimate the quality characteristics.

1.5.4 Taguchi method

Dr. Genichi Taguchi was a Japanese quality management consultant. He developed and promoted philosophy and methodology for the uninterrupted quality enhancement in products and processes. According to his philosophy say the statistical design of experiments (SDOE or DOE) can be helpful in industrial engineer designs and manufacturing of the products, that having both of high quality as well as low cost. This approach was mainly concentrated with eliminating the causes contains poor quality and factors contain potential impact on development of product performance to variation effectively.

Taguchi promotes the procedure of orthogonal array designs to allocate with the factors selected for the experiment. The greatest commonly used orthogonal array designs are L8 (i.e. eight experimental trials), L16, L9, L18, and L27. The power of Taguchi method integrates the statistical approaches into the engineering process [2]. The process of performing a Taguchi experiment follows a number of distinct steps:

Step1: Problem Formulation

Step 2: Identify Output and Input parameter that affect outcome of the problem.

Step 3: Identify the control factors, noise factors and signal factors (if any). The Control factors are those, which can control under regular making conditions. The noise factors are those, which are either too difficult or too expensive to control under usual making conditions. The signal factors are those which affect mean performance of process.

Step 4: The selection of factor levels, possible interactions with the degrees of freedom related with each factor and the interaction effects.

Step 5: Design an appropriate orthogonal array (OA).

Step 6: Preparation of experiment.

Step 7: Run the experiment having appropriate data collection.

Step 8: Statistical analysis with interpretation of the experimental results.

Step 9: Undertaking a confirmatory run of experiment.

The selection of an appropriate orthogonal array (OA) design is critical for the success of an experiment. Which depends on the total degrees of freedom required to study the main and interaction effects with the objective of experiment, resources, and budget (Cost) available and time constraints. The orthogonal arrays allow first to compute the main and interaction belongings via a smallest number of experimental trials. The term ‘‘Degrees of freedom’’ denotes the number of fair and independent comparisons that can be made from a set of observations. In the perspective of SDOE, the number of degrees of freedom having one less than number of levels related with factors. In other words, the number of degrees of freedom (DOF) related with a factor at p-levels is (p-1). The number of degree of freedom (DOF) related with an interaction of the product having the number of degrees of freedom linked with each main effect involved in interaction. It is essential to notice that the number of experimental trials must be larger than the entire degrees of freedom essential for studying the effects. The standards orthogonal arrays (OA) for factors with two levels are L4, L8, L16, L32 and so on. Here the symbolization ‘‘L’’ suggests that the information based on the Latin square procedure of the factors. A Latin square procedure is a square matrix arrangement of factors with separate factor effects. Here the numbers 4, 8, 12, 16, etc. represent the number of experimental trials.

In Taguchi’s design, the elementary objective is to identify the circumstances which enhance process/product performance. In arriving at optimum set of the surroundings, Taguchi supports the use of signal to noise ratio (SNR) the essential to maximize the performance of system or product by minimizing the effect of noise with maximizing the mean performance. The SNR treated as a response (output) of experiment. It is a measure of deviation when uncontrolled noise factors were present in system. Taguchi has established and defined over 60 different SNRs for the engineering applications of constraint design. In this study, as the objective is to maximize the mechanical properties. So, SNR associated to larger-the-better (LTB) quality characteristics be selected.

Researchers done a lot of research on natural fiber reinforced polymer composites but SCB dust particle has never been used in fabrication and application of epoxy based composite at low cost. There is definite scope on study of mechanical behavior under different testing conditions of SCB dust reinforced polymer composite. Cost and quality control of natural filler reinforced composite is the major stone to use as alternative material by product designer and manufacturers. Besides all these, the main motive is to fabricate a economic natural fiber based composite material for commercial usage.

1.6 Experimental results

1.6.1 Tensile test result

The tensile tests are taken out using four different percentage of the filler weight having samples at two different speeds. For each percentage of filler wt., six specimens are tested to attain the repeatability in results. The variations of load with different percentage of the filler weight shown in Fig.2. In this case, load attain maximum at 18 percentage of filler weight and speed having 4 mm/min. But, tensile stress maximum at 12 percentage of filler weight contains samples as shown in Fig. 3 at crosshead speed 4 mm/min. The tensile strain shown in Fig.3, maximum at 18 percentage of filler particle with 4 mm/min. speed. From the consequences, it can be concluded that as the percentage of filler wt. increases, load, tensile stress and strain value increases and becomes maximum at 12 percentage filler content by weight and then these properties decreases and becomes minimum at 18 percentage filler weight having tested samples. The highest and smallest values of load with speed of 2 mm/min are found at 18 percentage and 0 percentage of filler weight respectively. Their respective values are 3245.91 N and 1958.54 N. The highest and lowest values of tensile stresses with speed of 2 mm/min are 20.80MPa and 17.690 MPa at 12 percentage and 6 percentage of filler weight respectively. The maximum and minimum tensile strain values are 14.58 and 4.57 respectively at 18 percentage and 0 percentage of filler weight with speed of 2 mm/min respectively. The maximum value of the stress is found at higher percentage of filler with lower speed. This is due to the fact that the fillers get time to reorient themselves and results in higher value of the stress whereas in case of higher speed the maximum value of stress is reached at a lower percentage of filler.

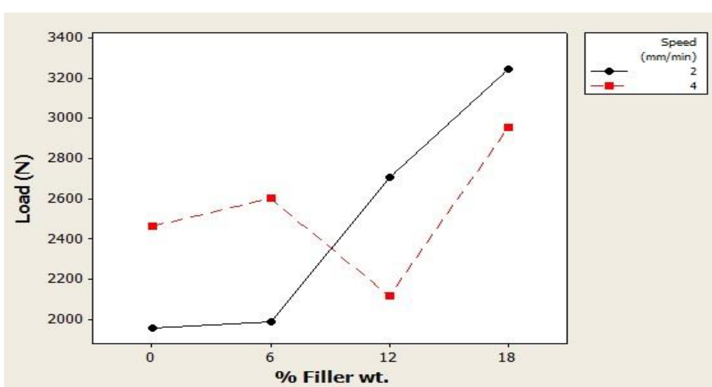


Fig.2. Load Vs Filler Percentage

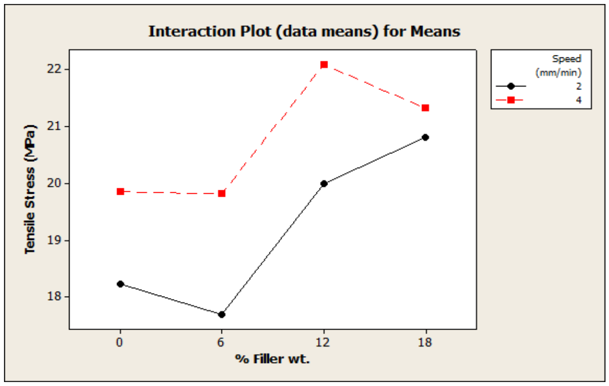


Fig.3. Tensile Stress Vs Filler Percentage

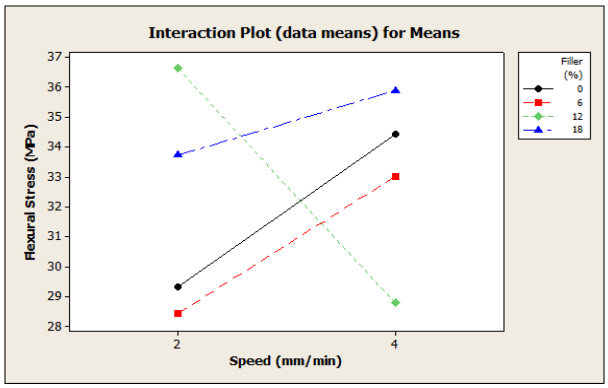


Fig.4.Tensile Stress Vs. Filler % and Speed

1.6.2 Flexural test results

The flexural test is carried out at four percentages of filler weight samples at two separate speeds. For each percentage of the filler weight, four samples are tested to attain the repeatability of results. The variation of flexural stress, and strain vs. filler content at different speed are shown in Fig. 4. From the outcomes, it is concluded that as the filler weight percentage increases, flexural stress and strain value increases and becomes maximum at 18 percentage of filler weight and minimum at 0 percentage of filler weight. The highest and lowest values of flexural stress are 36.62 MPa and 28.43 MPa respectively for 12 percentages and 6 percentage of filler weight with 2 mm/min speed. The maximum and minimum flexural strain values are 14.58 and 4.57 respectively for 18 percent and 0 percentage of filler weight with 2 mm/min speed. As discussed in the case of tensile properties regarding the maximum stresses and its relationship with speed of testing, the same is also true for the flexural properties.

At high percentage of the filler it is observed due to the agglomeration, drop in tensile and flexural behaviours of the composites occurs of the filler molecules around the matrix which prevents the proper curing of the composite and the same may be observed in the SEM (scanning electron microscope) images. The SEM images are carried out for each percentage of filler weight specimens and are shown in Fig.A-D In the Fig. A, particles seen are due to cutting of the zero percentage of filler weight sample. The filler particles look scattered in six percentage of filler weight sample as shown in Fig. B. For twelve percentage of filler weight, specimen filler particles are started forming clusters and mechanical properties are at the highest value as shown in Fig. C. For higher filler weight percent of the clusters started overcoming the resin resulting segregation and hardener resulting in imperfect curing of composite as shown in Fig.D.

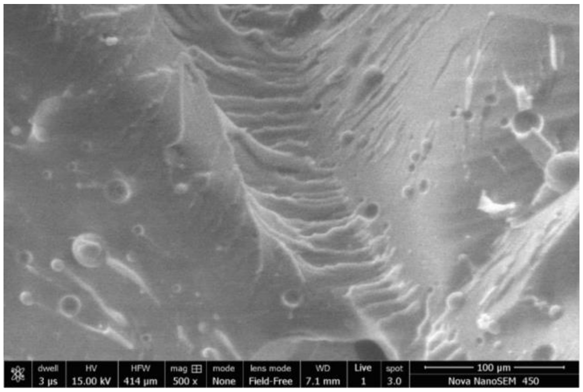
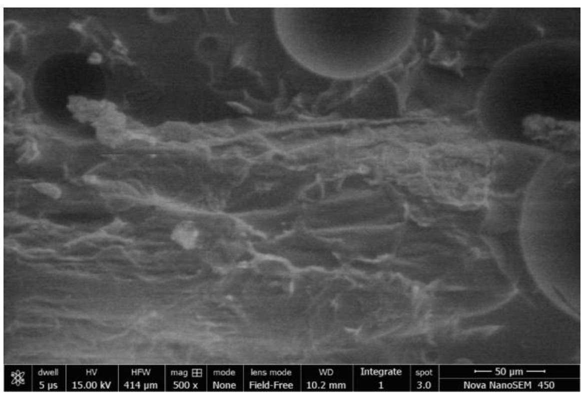


Fig.(A). At 0% Filler

Fig.(B) At 6% Filler



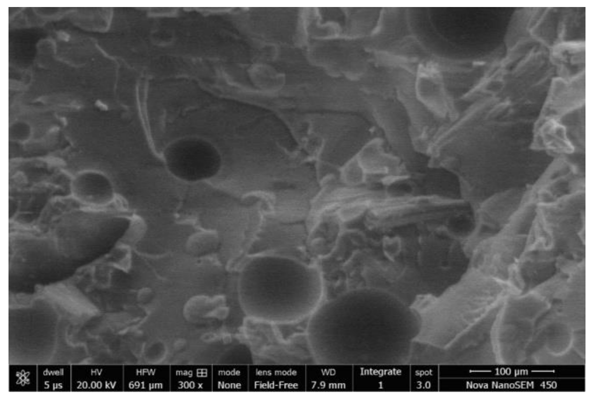
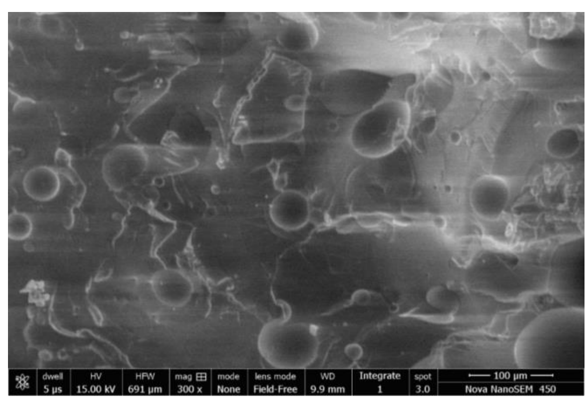


Fig.(C) At 12% Filler

Fig.(D) At 18% Filler

1.7. Conclusion-



Experimental results support the successful fabrication of sugar cane bagasse dust reinforced epoxy based composites is possible and possesses good filler characteristics as it improves the tensile and flexural properties of the polymeric resin. The maximum load, tensile stress and strain, and flexural stress and strain values are found to be maximum and minimum at the filler wt. of 18 percent and 0 percent respectively with speed of 2 mm/min. But, the tensile and flexural modulus values are observed to be maximum and minimum at 12 percent filler wt. with speed of 4 mm/min and at 0 percent filler wt. with speed of 2 mm/min respectively. The best mechanical properties are observed for 18 percent filler wt. and speed of 2 mm/min and 4 mm/min speed.

REFERENCES

[1] J Jayaramudu, S C Agwuncha, S S Ray, E R Sadiku, A. V Rajulu. Studies on the chemical resistance and mechanical properties of natural polyalthia cerasoides woven fabric/glass hybridized epoxy Composites. Research Article Adv. Mater. Lett. 2015, 6(2), 114-119.

[2] B Chanda, R Kumar, K Kumar and S Bhowmik. Optimisation of Mechanical Properties of Wood Dust-reinforced Epoxy Composite Using Grey Relational Analysis. © Springer India 2015 K.N. Das et al. (eds.), Proceedings of Fourth International Conference on Soft Computing for Problem Solving, Advances in Intelligent Systems and Computing 336, DOI 10.1007/978-81-322-2220-0_2.

[3] T E Motaung, R D Anandjiwala. Effect of alkali and acid treatment on thermal degradation kinetics of sugar cane bagasse. Industrial Crops and Products 74 (2015) 472–477.

[4] R C Mohapatra, A Mishra, B B Choudhury. Experimental Study on Thermal Conductivity of Teak Wood Dust Reinforced Epoxy Composite Using Lee’s Apparatus Method. International Journal of Mechanical Engineering and Applications. 2014; Vol. 2, No. 6, pp. 98-104. doi: 10.11648/j.ijmea.20140206.14.

[5] K R Dinesh, S P Jagadish, A Thimmanagouda. Characterization and analysis of wear study on sisal fibre reinforcement epoxy composite materials used as orthopedic implant. International Journal of Advances in Engineering & Technology, Jan. 2014.

[6] L k rout, S S sahoo. Study on erosion wear performance of jute-epoxy composites filled with industrial wastes using Taguchi methodology. Proceedings of second IRF international conference, 30th november-2014, mysore, India, ISBN: 978-93-84209-69-8.

[7] F A Raju, K B kumar. Design and Analysis of Horizontal tail of UAV using Composite materials. International Journal of Computer Trends and Technology (IJCTT) – volume 4 Issue 7–July 2014.

[8] A K Rout, S S Sahoo. Study on erosion wear performance of jute-epoxy composites filled with industrial wastes using taguchi methodology. Proceedings of Second IRF International Conference, 30-11-2014, Mysore, India, ISBN: 978-93-84209-69-8.

[9] D J O Brien, W K Chin, L R Long, E D Wetzel.Polymer matrix, polymer ribbon-reinforced transparent composite materials. Composites: Part A 56 (2014) 161–171

[10] Qinglin Wu, Kai Chi, Yiqiang Wu, Sunyoung Lee. Mechanical, thermal expansion, and flammability properties of co-extruded wood polymer composites with basalt fiber reinforced shells. Materials and Design 60 (2014) 334–342.

[11] Y Karaduman, M M A Sayeed, L Onal, A Rawal. Viscoelastic Properties of Surface Modified Jute Fiber/ Polypropylene Nonwoven Composites, Composites: Part B (2014), doi: http://dx.doi.org/10.1016/j.compositesb.2014.06.019.

[12] R Kumar, K Kumar, P Sahoo and S Bhowmik. Study of Mechanical Properties of Wood Dust Reinforced Epoxy Composite. Procedia Materials Science 6 (2014) 551 – 556.

[13] K K Kumar, P R Babu and K R N Reddy. Evaluation of Flexural and Tensile Properties of Short Kenaf Fiber Reinforced Green Composites. International Journal of Advanced Mechanical Engineering. ISSN 2250-3234 Volume 4, Number 4 (2014), pp. 371-380.

[14] G. Rathnakar, H. K. Shivanand. Fibre Orientation and Its Influence on the Flexural Strength of Glass fibre and Graphite fibre reinforced polymer composites. International Journal of Innovative Research in Science, Engineering and Technology. 2013; Vol. 2, Issue 3, ISSN: 2319-8754.

[15] Aarthi S and Velmurugun T. Investigation of Impact Performance of Glass/Epoxy Laminates. International Journal of Innovations in Engineering and Technology. 2013; Vol. 2, issue 1, ISSN: 2319-1058.

[16] V P Kommula, O R Kanchireddy, M Shukla, and T Marwala. Tensile Properties of Long Untreated and Alkali Treated Napier Grass Fiber Strands/Epoxy Composites. International Conference on Chemical, Mining and Metallurgical Engineering (CMME'2013) Nov. 27-28, 2013 Johannesburg (South Africa).

[17] G Venkatesha Prasanna and K V Subbaiah. Hardness, tensile properties, and morphology of blend hybrid biocomposites. Scholarly Journal of Engineering Research Vol. 2(1), pp. 21-29, May 2014. ISSN 2276-8955 © 2013 Scholarly-Journals.

[18] S Malaiah, K V Sharma, M Krishna. Investigation on Effect of Fiber and Orientation on the Properties of Bio-Fibre Reinforced Laminates. International Journal of Engineering Inventions e-ISSN: 2278-7461, p-ISSN: 2319-6491 Volume 2, Issue 2 (January 2013) PP: 65-70.

[19] K R Dinesh, S P Jagadish, A T gouda, N Hatapaki. Characterization and Investigation of Tensile and Compression Test on Sisal Fibre Reinforcement Epoxy Composite Materials Used as Orthopedic Implant. International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 2, Issue 12, December 2013 ISSN 2319 – 4847.