

Experimental Study of Mechanical Properties of Bhimal Fiber Reinforced Epoxy Bio-Composite

Bikraj Upreti ¹, Arun Kumar Chaudhary ²M. Tech Student, Department of Industrial and Production Engineering, G.B.P.U.A &T, Pantnagar, Uttarakhand, India¹Asst. Professor, Department of Industrial and Production Engineering, G.B.P.U.A &T, Pantnagar, Uttarakhand, India²

ABSTRACT: Bio-composites are putting forth a concentrated effort in almost every engineering field due to their cost viability and bio-degradable nature. In a huge variety of natural fibers, bhimal fiber is a very promising fiber that still needs to be explored as an engineering material, because it has very rarely been used by researchers in their research work. Bhimal fiber is a cellulosic fiber extracted from the stems of bhimal tree. It has a great tensile strength and flexibility. In present work bhimal fiber reinforced epoxy bio-composite was successfully prepared by hand lay-up casting technique in order to examine its mechanical properties for varying content of bhimal fiber (i.e. 2, 3, 4, 5 & 6 weight %). Before the preparation of composite, the surface of bhimal fiber was treated with potassium hydroxide to improve its adhesion properties. From the experiments it was observed that while increasing the fiber content up to 5 wt%, the tensile, flexural and compressive strength continuously increased then started decreasing. Similarly hardness and impact strength were also observed to be increasing up to a peak value at 4 wt% of bhimal fiber. All these results were supported by the SEM results. From the observations, it has been concluded that the bhimal fibers are lighter in weight than all existing fibers and strength to weight ratio of the bhimal fiber reinforced epoxy bio-composite is also quite higher than the other conventionally used natural fiber based composites. Hence these can be used as reinforcement to produce much lighter weight bio-composites.

KEYWORDS: Bio-composites, Bhimal Fiber, Epoxy, Tensile Strength.

I. INTRODUCTION

In this modern world, there is a demand of highly advanced materials with notable blend of properties that are not fulfilled by the inevitable polymers, alloys and ceramics. This is very crucial for the materials that are required in aerospace, underwater and transportation purposes. That is why the Composite is getting used as a broader term in order to overcome these problems. Composite is any poly-phase material that comprises more than one chemically different elements those are having a distinct boundaries separating them [1]. Composites are mainly formed of more than one irregular phases which are engrafted in an unremitting phase. The irregular phase is frequently stronger and harder than the unremitting phase and is termed as the reinforcement, whereas the unremitting phase as the matrix. The matrix can be polymeric, metallic or ceramic. The final composite is called as the Polymer Matrix Composite (PMC) if the matrix formed is a polymer. The reinforcement phase can be a particle or fiber and the fiber is known as the natural or biodegradable fibers only if the fibers are a ensuing from living species. Usually, fibers are used to carry more load than matrices; while the main purpose of matrix is to orient the fibers at their desired direction and location and also to protect them from any natural destruction. In last few years, the natural fibers have been catching the focus of researchers as a reinforcing material for many PMCs from both the ecological and economical point of view [2, 3]. The main source of obtaining the biological fibers is from plants, animals and minerals. The utilization of bio-fibers in composites has got more popularity because of their relative low cost, their capability of recycling and due to the fact that they give a tough competition in terms of strength per unit weight of composite [4].The natural

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

fibers have perked up the fuel efficiency and reduced emission in automobile applications due to its greater volume to weight ratio than the synthetic ones [5].

This paper is organized as follows. Section II describes the brief idea about the work that has been done and the methodology used. Section III presents experimental results of SEM and mechanical tests in the form of graphs, charts and images. Finally, Section IV presents conclusion.

II. RELATED WORK

The prime idea of this research work is to fabricate a composite that is the combination of a natural fiber (bhimal fiber) [6-8] and matrix (epoxy resin) having properties good enough to work as an engineering material in comparison with the composites based on synthetic fibers which are expensive, dangerous or depleting materials. Bio composites are more environment friendly, biodegradable, economical, user friendly, lower density and have higher strength to weight ratio as compared to synthetic fiber based composites. In order to do as above various mechanical and micro-structural tests of the composite were carried out, in which Scanning Electron Microscopy (SEM) [9] technique was used to show the microstructure of the resultant composite which shows the distribution of bhimal fiber in epoxy resin matrix and their interaction with each other and the mechanical tests such as tensile test, compressive test and flexural test are performed in order to estimate different mechanical strengths.

In present work a bhimal fiber reinforced bio-composite was fabricated by hand lay-up casting technique. In order to do this, chopped bhimal fibers of size 0.5 to 2mm were used as reinforcement in the epoxy resin (i.e. Araldite CY-230) [10]. Then after the removal of casting, specimen for all mechanical tests were cut from it by using various machining processes. Before using the fibers it was treated with KOH [11] and hardener (HY-951) was used as curing agent. Bhimal fiber is extracted from Bhimal tree (*Grewia Optiva*), which is found in western Himalayan ranges up to the altitude of 1600m [12].

III. EXPERIMENTAL RESULTS

In this section, outcomes of the scanning electron microscopy and mechanical tests of bhimal fiber reinforced epoxy resin are presented and discussed.

3.1 Results of Micro-Structural Test (SEM):

The morphology or surface characteristics of the resultant fabricated composite materials are considered through the Scanning electron microscopy (SEM) technique [8, 13]. The cross sectional scrutiny of the fabricated composite materials consisting of epoxy resin, various wt% of bhimal fiber and hardener are offered in the Fig. 3.1(a-n). The Scanning Electron Microscopy (SEM) images are taken to monitor the internal cracks, interfacial properties and internal structure of the fractured surfaces of fabricated composite materials.

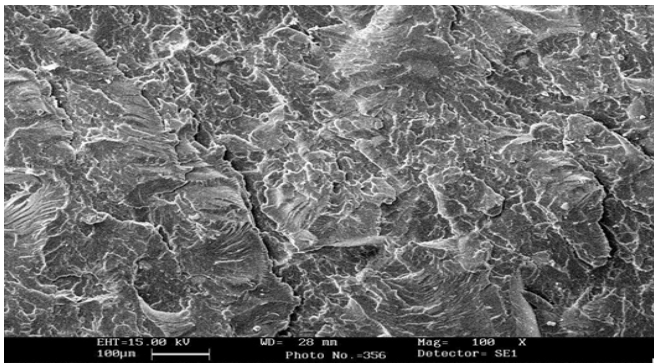


Fig. 1(a): Scanning electron micrograph for fractured surface of Epoxy resin (CY-230 + 9 wt% HY-951)

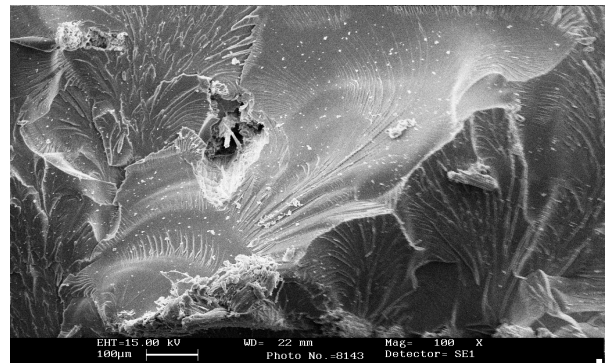


Fig. 1(b): Scanning electron micrograph showing the fractured surface for Epoxy resin and 2 wt% of bhimal fiber

Fig. 1(a) displays the fractured surface of neat epoxy resin matrix under tensile loading. Fig.1(b) showcases the fractured surface of epoxy resin amalgamated with 2 wt% of bhimal fiber, as we can see from this figure a very few bhimal fibers can be viewed on the fractured surface due to a less wt% of fiber present. In addition to this the failure reason is the fiber pull off from the fractured surface, a void formed resulting from the fiber pull off can be easily seen.

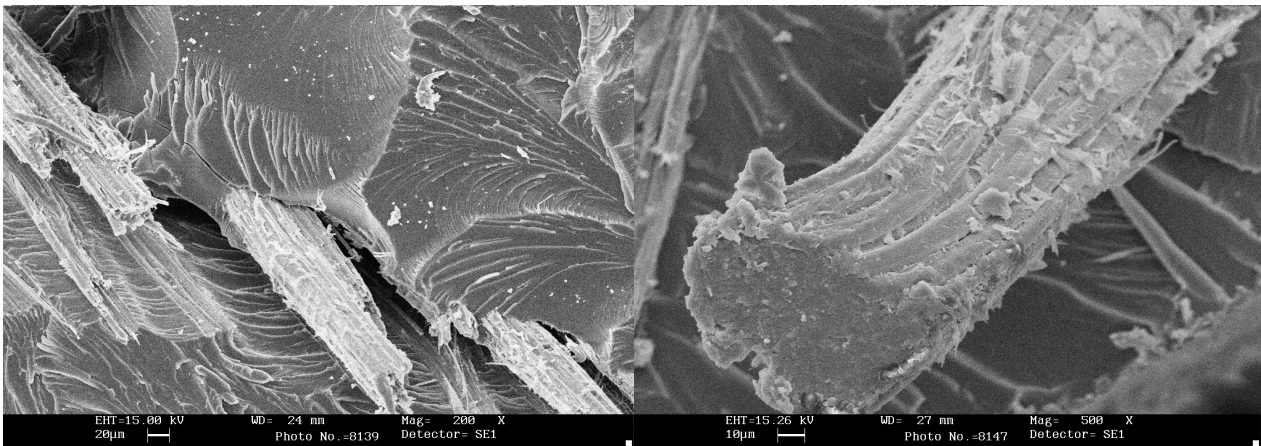


Fig. 1 (c): Scanning electron micrograph displaying crack formation through bhimal fiber (3 %) in the Epoxy resin

Fig. 1(d): Scanning electron micrograph showing the single strand of bhimal fiber reinforced in epoxy resin

Fig.1(c) shows the failure of the material. The failure mechanism is due to the crack growth which leads to splitting of bhimal fiber from the surface. This type of failure is generally seen at lower concentration of fiber having a strong bond with the matrix which establishes with matrix cracking then the fiber and followed up by de-bonding of matrix inter-phases, followed by another fiber failure and so on leading to whole composite failure. Fig. 1(d) shows the magnified view of a single strand of bhimal fiber.

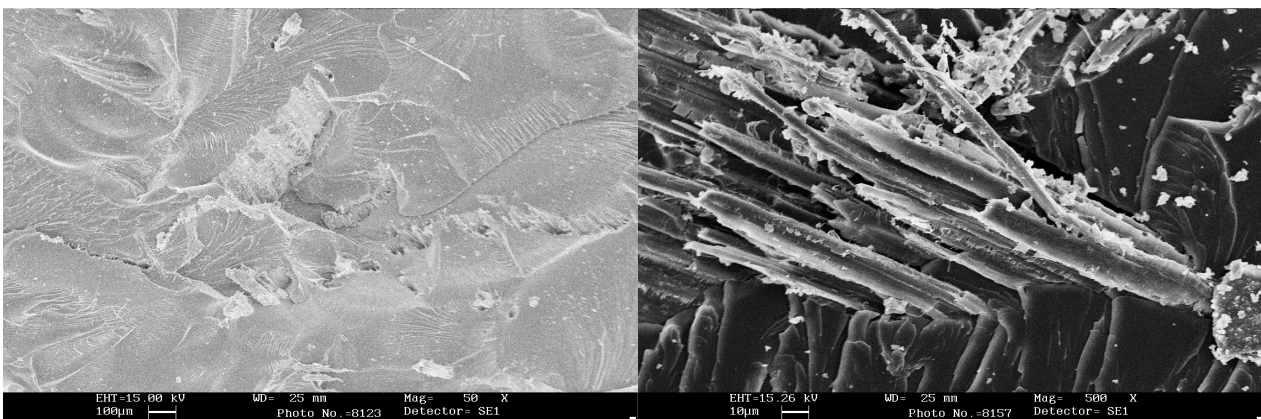


Fig. 1(e): Scanning electron micrograph showing the breakage of fibers in Epoxy resin reinforced with 5 wt% of bhimal fiber

Fig. 1(f): Scanning electron micrograph showing the distribution of fibers in form of clusters in bhimal fiber(6%) reinforced epoxy resin

Similarly in Fig. 1(e), as the fiber wt% is further increased to 5 wt%, this resulted in the highest tensile and compressive strength amongst the various compositions tried due to the uniformity of the fiber throughout the matrix and proper load transmission through the fibers. From the Figure it can be easily seen that almost all fibers are getting properly broken that means the load is getting transferred successfully. Finally in fig. 1(f) the distribution of bhimal fiber in cluster form and crack formed is shown. The composite containing 6 wt% of bhimal fiber showed the lower tensile strength because of low bonding between fiber and matrix. Density of bhimal fiber is approximately 0.453 gm/cm^3 due to this even at 6 wt% of fiber, it takes a large volume of matrix so the improper bonding between fiber and matrix occurs due to which material gets failed even at low loading condition.

3.2 Results of Mechanical Tests

3.2.1 Tensile test results

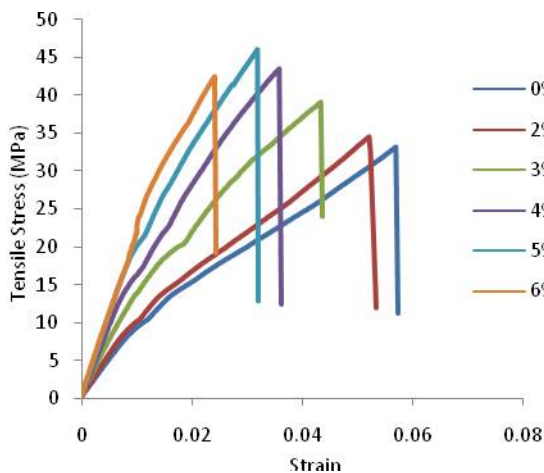


Fig. 1(g): Tensile Stress-Strain Diagram for various compositions

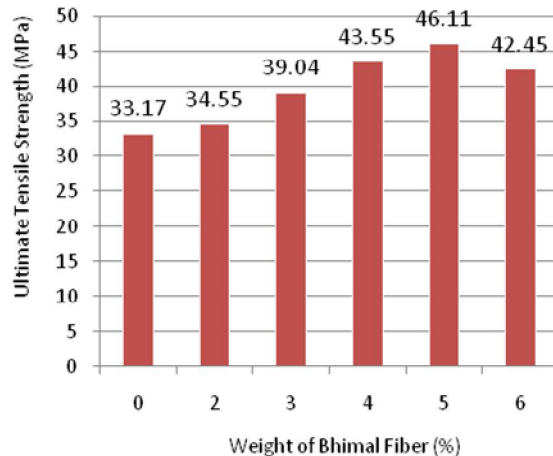


Fig. 1 (h): Effect of fiber weight % on Ultimate Tensile Strength

- From the graph, remarkable differences can be seen in the magnitude of ultimate tensile strength. It can be observed from the results that for all specimens under investigation, the ultimate tensile strength is highest for the composition (Epoxy resin + Hardener + 5 wt% bhimal fiber) which is approximately 46.11MPa. If we see Fig. 1(h), it can be clearly seen that with the increase in fiber wt% in the matrix there is an increase and then decrease in the tensile strength trend [13, 14].
- At 2-4 wt% of bhimal fiber, the load distribution was almost equal between the matrix and fiber, thus leading to a moderate increase in the tensile strength as compared to the neat epoxy resin matrix tensile strength.
- At 5 wt% of bhimal fiber, a higher magnitude of load was transferred to the fiber i.e. the contribution of fiber increased that lead to increase in the tensile strength. This was supported by the occurrence of fiber breakage as shown in SEM results (Fig. 1(e)). As already mentioned, the tensile strength value of bhimal fiber is very high.
- At 6 weight % of bhimal fiber, as the fiber wt% increases the tensile strength started deteriorating because of the lack of bonding between the fiber and matrix because fibers get accumulated in some areas and epoxy resin in the remaining areas (Fig. 1(f)).

3.2.2 Compressive test results

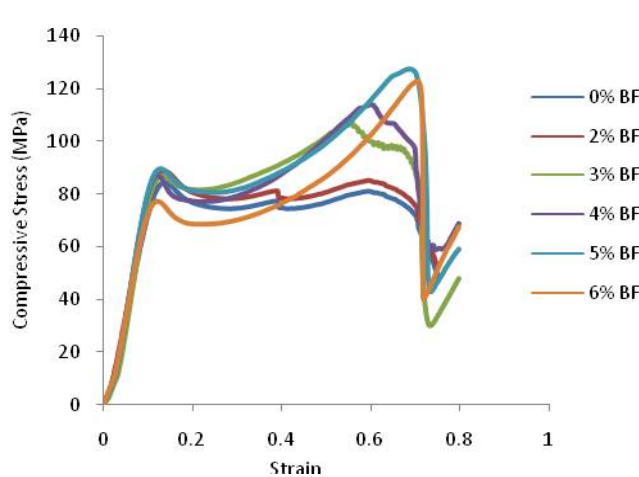


Fig. 1 (i): Compression Stress-Strain Diagram for various compositions

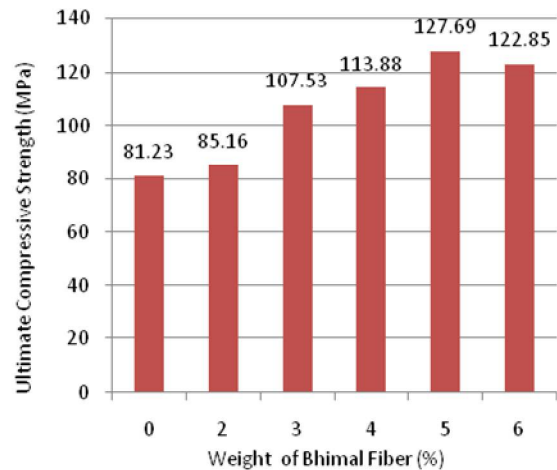


Fig. 1 (j): Effect of fiber wt% on Ultimate Compressive Strength

The compressive stress-strain curve is shown in the Fig. 1(i). It can be observed that here also the UCS is maximum for the composite containing 5 wt% of bhimal fiber that is about 1.57 times the ultimate compressive strength of the neat epoxy resin. If we see Fig. 1(j), it can be clearly viewed that with the increase in fiber wt% there is an increase and then decrease in the compressive strength trend. The basis for the above described trend is similar to that of the tensile test [13, 15].

3.2.3 Flexural test results

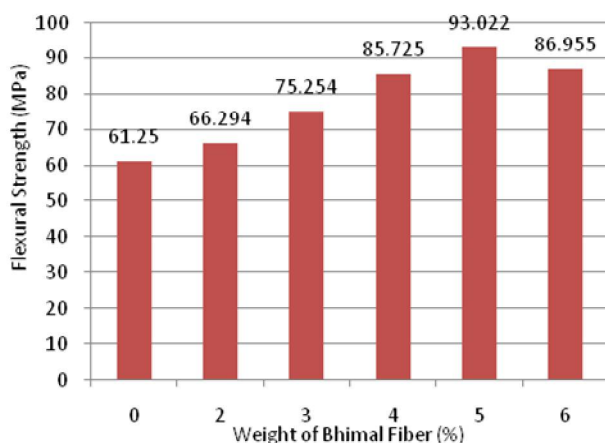


Fig. 1 (k): Effect of fiber weight% on flexural strength

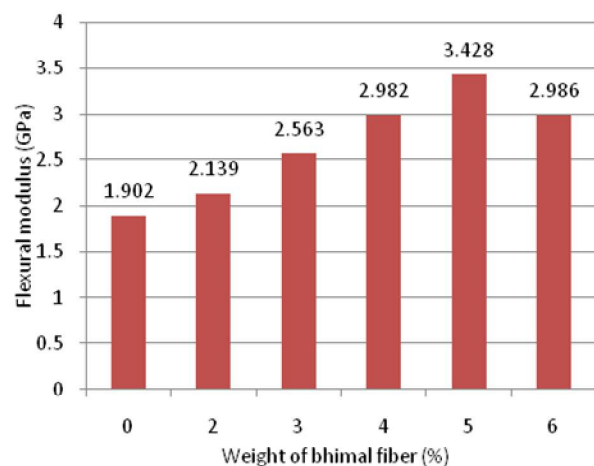


Fig. 1 (l): Effect of fiber weight% on flexural modulus

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Similarly, from Fig. 1(l) the variation between flexural modulus and wt% of bhimal fiber can be viewed. The flexural modulus is found to be maximum for the composition having bhimal fiber 5% by weight with a magnitude of 3.428 GPa. From both the graphs, the trend seen is that firstly the value increases and after attaining a maximum at 5 wt% it starts decreasing [13, 16]. The explanation for the above depicted trend is quite similar to that of the tension and tension test.

IV. CONCLUSION

The research work presented in this thesis has provided the portrayal about fabrication and study of mechanical and thermal properties of bhimal fiber filled epoxy resin composites. By incorporating the bhimal fiber with epoxy resin, outstanding outcomes, as expected were achieved in the form of perked up mechanical properties. Incorporation of the bhimal fiber in epoxy resin matrix resulted in improvement of tensile, compression and flexural strength to a higher magnitude. The biological fibers used have certain kind of waxes, impurities, hemi-cellulose, pectin and a part of lignin stuck to their surface which tries to reduce the bonding of fiber to the matrix. When the fibers were surface treated with KOH, the surface become free from the constituents listed above and become rough in nature. As a result, the bonding improves which leads to better mechanical properties. Through SEM we could actually spot how the fibers were dispersed in the matrix, how they are bonded to matrix and each other, how at higher wt% they form clusters and composite failure occurs due to fiber pull out or splitting of fiber and validate our results. Thus, it can be concluded that 5wt% bhimal fiber filled in epoxy resin gave the satisfactorily results from various other combinations. Hence, the properties have significantly improved for the composite as compared to pure epoxy based composite.

REFERENCES

- [1] Callister, W.D. (2015). Materials Science and Engineering, 2nd edition, John Wiley & Sons, pp. 540-556.
- [2] Wambua, P., Ivens, J. and Verpoest, I. 2003. Natural Fibre can replace glass in fiber reinforced plastic. *Journal of Composite Science and Technology*. 63: 259-264.
- [3] Chaudhary A.K, Gope P.C., V.K. Singh, 2014. Water absorption and thickness swelling behaviour of almond (*Prunus amygdalus L.*) shell particles and coconut (*Cocos nucifera*) fiber hybrid epoxy based biocomposite, *Science and Engineering of Composite Materials*, 22(4): 375–382.
- [4] John, M.J. and Thomas, S. 2008. Bio-fibres and bio-composites. *Carbohydrate polymers*, 71(3): 343-364.
- [5] Sahieb, D.N. and Jog, J.P. 1999. Natural fiber polymer composites: a review. *Advances in polymer technology*, 18(4): 351-363.
- [6] Gupta, K.M. and Kalauni, K. 2015. Fabrication and Characterization of Bio-composite Using Grewia Optiva Fibre (i.e. Bhimal) Reinforced Polyvinyl Alcohol (PVA). In: *Advanced Materials Research* (Vol. 1105, pp. 51-55). Trans Tech Publications.
- [7] Singha, A.S. and Rana, A.K., 2012. Effect of surface modification of Grewia Optiva fibres on their physicochemical and thermal properties. *Bulletin of Materials Science*, 35(7): 1099-1110.
- [8] Singha, A.S. and Thakur, V.K. 2009. Grewia Optiva fiber reinforced novel, low cost polymer composites. *Journal of Chemistry*, 6(1): 71-76
Sons: 540-556
- [9] Cerqueira, E.F., Baptista, C.A.R.P. and Mulinari, D.R. 2011. Mechanical behaviour of polypropylene reinforced sugarcane bagasse fibers composites. *Procedia Engineering*, 10: 2046-2051.
- [10] Irfan, M.H., 2012. *Chemistry and technology of thermosetting polymers in construction applications*. Springer Science & Business Media.
- [11] Bledzki, A.K. and Gassan, J., 1999. Composites reinforced with cellulose based fibres. *Progress in polymer science*, 24(2): 221-274
- [12] K. Chandrasekar, Indra D. Bhatt, Ranbeer S. Rawal, Shyamal K. Nandi, Pitamber P. Dhyani, 2010 “Promising Fibre-Yielding Plants of the Indian Himalayan Region”, G.B. Pant Institute of Himalayan Environment & Development.
- [13] Shin, F.G., Xian, X.J., Zheng, W.P. and Yipp, M.W. 1989. Analyses of the mechanical properties and microstructure of bamboo-epoxy composites. *Journal of Materials Science*, 24(10): 3483-3490.
- [14] Rajesh Ghosh, G. Reena, A. Rama Krishna, Bh.Lakshmiipathi Raju, 2011. “Effect of fibre volume fraction on the tensile strength of Banana fibre reinforced vinyl ester resin composites”. *International Journal of Advanced Engineering Sciences and Technologies* Vol. 4(1): 089 – 091.
- [15] Naidu, V.N.P., Reddy, G.R., Kumar, M.A., Reddy, M.M., Khanam, P.N. and Naidu, S.V., 2011. Compressive & impact properties of sisal/glass fiber reinforced hybrid composites. *International Journal of Fibre and Textile Research*, 1(1): 11-14.
- [16] Zhong, J.B., Lv, J. and Wei, C., 2007. Mechanical properties of sisal fibre reinforced urea formaldehyde resin composites. *Express Polymer Letters*, 1(10): 681-687.