Effect of Mercerization of Mechanical Behavior of Banana Fiber Reinforced Epoxy Composites

Mohd Shaver[1], Amit Kaimkuriya[2]

[1]M.Tech. Research Scholar, Mechanical Engineering Department, Millennium Institute of Technology, Bhopal, India
[2]Assistant Professor, Mechanical Engineering Department, Millennium Institute of Technology, Bhopal, India

---***---

Abstract:- In present work, banana fibers are used as reinforcement in epoxy matrix. The fibers used in present work are of two different kinds having 4 mm length. The first is untreated banana fiber and the other is banana fiber treated with NaOH aqueous solution. With the above fibers, two different categories of composites were fabricated using simple hand lay-up technique. Each category consists of five different sets of composites with fiber content maximum up to 15 wt%. General trend observed in their mechanical properties i.e. tensile strength, flexural strength, hardness and impact energy are reported in the present investigation. The main emphasis of the work is to study the effect of treatment of banana fiber surface with NaOH aqueous solution on various mechanical properties. The reason for change in behaviour of properties of composites with fiber content and surface treatment were discussed in detail in the work.

Keywords: Polymer matrix composites, epoxy, banana fiber, mercerization, mechanical properties.

1. Introduction

In the last few decades, natural fiber-reinforced polymer composites have received substantial attention in the field of research and innovation [1, 2]. Natural fibers in simple definition are fibers that are not synthetic or manmade. They can be sourced from plants or animals. Among the two natural fibers obtained, plants fibers find more potential application in polymer composites. Natural fibers obtained from plants are harvested from renewable resources and readily available at low prices. Their specific properties are comparable to synthetic fibers (e.g., glass fibers) that are traditionally used as reinforcing phases in polymer based composite materials [3, 4]. The plant, which produces cellulose fibers can be classified into bast fibers (jute, flax, ramie, hemp and kenaf), seed fibers (cotton, coir and kapok), leaf fiber (sisal, pineapple and banana), grass and reed fibers (rice, corn and wheat) and core fibers (hemp, kenaf and jute) as well as all other kinds (wood and roots) [5].

Fiber reinforced polymer composites are in great use because of the good properties and superior advantages of natural fiber over synthetic fibers in terms of its relatively low weigth, low cost, less damage to processing equipments, good relative mechanical properties, improved surface finish, renewable resources, being abundant, biodegrability and minimal health hazards [6]. On the other hand, natural fibers are not free from problems and they have notable deficits in properties. The natural fiber structure consists of cellulose, hemicellulose, lignin, pectin etc and permits moisture absorption from the surroundings which cause weak bindings between fiber and polymer. Accordingly, natural fiber modification using specific treatments are certainly necessary. In a review of chemical treatments of natural fibers, Kabir et al. [7] concurred that treatment is an important factor that has to be considered when processing natural fibers. They observed loose hydroxyl groups due to different chemical treatments, thereby reducing the hydrophilic behavior of the fibers and causing enhancement in mechanical strength as well as dimensional stability of natural fiber reinforced polymer composites.

Banana fiber, one of the most widely used natural fibers, has an annual output about 1.5 million tons all over the world. Among the available cellulosic fibers, banana fiber possesses moderately high specific strength and stiffness and is a good candidate as reinforcing material [8]. Banana fiber reinforced thermoplastics composites have gained tremendous interest because of their easy processing, low cost and recyclability. This is the main reason banana fiber in its long form were used as reinforcement in polymers and were investigated by many researchers in past. In this series Liu et al. [9] used banana fiber in high density polyethylene in their study and evaluated the morphological, water absorption and thermal stability of the fabricated samples. Later Paul et al. [10] used banana fiber in the form of short length and incorporated it in polypropylene fiber. Prior to that, they modified the surface of banana fiber with various chemical treatment to provide good adhesion between fiber and matrix body. They used solvatochromic technique for investigating the polarity parameters of the chemically modified banana fiber. After that they observed that the polarity of the banana fiber was decreased after the chemical treatment. The adhesion between the matrix and fiber were increased drastically as observed by micrograph by them. The most effective treatment was alkali treatment as reported in their study. Raghvendra et al. [11] also used banana fiber in its short form but not with any plastic. They incorporated the fiber in rubber and established natural rubber based composites. They studied the mechanical properties of the fabricated composites. Venkateshwaran et al. [12] found that fiber length and its content were the most influential factor which determines the mechanical properties of the composites. In their study, they optimize the length of the fiber and produce a set of composites with varying content of fibers. The optimized results give best mechanical properties which include tensile strength and modulus, flexural strength and modulus and impact strength. Apart from that, they also study the water absorption behavior of the fabricated composite and found that length of the fiber is not a factor on which water absorption depend, rather it increases with increase in fiber content. Ramesh et al. [13] were also fabricated banana fiber reinforced polymer composites with thermoset polymer epoxy and experimentally determined its mechanical properties. Jorden et al. [14] improves the interfacial bonding between banana fiber and LDPE matrix with the help of chemical treatment. They used two different techniques for fiber treatment i.e. peroxide treatment and permanganate treatment. Muktha, and Gowda [15] focused their work on water absorption and fire resistance behavior of banana fiber reinforced polyester composites. They prepared specimen of two different thicknesses i.e. of 3 mm and 5 mm with same fiber volume fraction. In their analysis they found that water absorption and fire resistance capacity of 3 mm thick specimen is less than that of the 5 mm thick specimen. Against this background, an attempt has been made in this research work to develop short banana fiber (SBF) based epoxy composites using simple hand lay-up technique and to study their mechanical properties i.e. tensile strength, flexural strength, hardness and impact with varying fiber content and also to study the effect of surface modification of fiber on various mechanical properties.

2. Methods

The epoxy resin Lapox-12 is used in the present work which belongs to the epoxide family. Bisphenol-A-Diglycidyl-Ether (commonly abbreviated to DGEBA or BADGE) is the common name of the presently used epoxy. It provides a solvent free room temperature curing system when it is combined with the hardener tri-ethylene-tetramine (TETA) which is an aliphatic primary amine with commercial designation HY 951. Banana fiber, a natural fiber is used in present investigation as reinforcement. Banana fiber has good mechanical strength and an appreciable specific property. Apart from good specific properties, smaller elongation, fire resistance quality, great potentialities and biodegradability are the major advantages of this fiber.

Fabrication of composites is accomplished by fabricating two different sets of composites. In Set I composite, epoxy is reinforced with untreated short banana fiber in different weight fraction ranging from 3 to 15 wt %. For Set II composites, prior to the incorporation of fiber in matrix, it is treated with alkali solution i.e. NaOH. This process is also known as mercerization of fiber and is well established method for producing high quality fibers. In present work composite is fabricated using simple hand lay-up technique which involves following steps:

1. The epoxy resin (LY556) and the corresponding hardener (HY 951) are mixed in a ratio 10:1 by weight as recommended.
2. Short banana fiber will then added to the epoxy-hardener combination.
3. Before pouring the epoxy/filler mixture in the mould, a silicon spray is done over the mold so that it will easy to remove the composite after curing. The uniformly mixed dough is then slowly poured into the respective mould.
4. The cast is than cured for 24 hours before it was removed from the mould.
5. The specimens of different sizes according to the ASTM standards for different tests were then cut from the fabricated rectangular sheet. The list of fabricated composite is presented in table 1.

Testing of fabricated composites was carried out in view of standard procedure and guidelines as per ASTM standards. The tensile strength of the composite specimen is measured using universal testing machine (UTM) INSTRON H10KS. ASTM D638 tensile testing is used to measure the force required to break a polymer composite specimen. The flexural test measures the force required to bend a beam under three point loading conditions. The three point bend test was carried out in Universal Testing Machine in accordance with ASTM D790 to measure the flexural strength of the composites. Leitz micro-hardness tester is used to determine the micro-hardness of the fabricated composite. The tests are in accordance with ASTM E384. In order to determine the impact energy, Izod impact test is performed following ASTM D256 standard which is used for plastic materials.

3. Results and discussion

Micro-Hardness

Surface hardness of the composites is one of the most important factors that directly concerned with the detachment of fibers when it undergoes different service condition. The results obtained during the experimentation of are shown in figure 1. From the figure it is clear that, with the increase in the content of banana fiber in epoxy matrix, hardness of the composites increases and reaches its maximum value of 0.172 GPa for 15 wt. % of fiber loading when untreated fiber is used This is an increment of around 98 % as compared to neat epoxy. The increment in the value of hardness increased when untreated short banana fiber is replaced by NaOH treated short banana fiber. In that case the maximum value of hardens is measured to be 0.192 GPa for similar fiber loading. This increment is of around 120 %. By the addition of short banana fiber, the material gains its resistance to the indentation. Further, it can be concluded that due to the increase of filler content, the composite becomes stiffer and harder.

Tensile strength

The tensile strength are measured by universal testing machine. The results obtained after the experimentation are plotted and shown in figure 2. From the figure it can be seen that the ultimate tensile strength of the fabricated composite increase with increase in fiber content. Also from the figure is can be seen that the tensile strength of epoxy reinforced with treated fibers are having higher value of tensile strength as compared to the tensile strength of epoxy composites reinforced with untreated fibers for same filler content. The maximum tensile strength among the various fabricated samples was of sample with 15 wt. % of short banana fiber in treated form. Its values were reported to be of 63.4 MPa which is an increment of around 15 %. Against that, the maximum tensile strength value is noted to be 61.8 MPa which is an increment of around 12 %. So it can be clearly observed that treatment of banana fiber with specified concentration of NaOH results in improvement in the value of tensile strength.

Flexural strength

Composite materials used in structures are prone to fail in bending and therefore development of new composites with improved flexural characteristics is essential. In the present work, the variation of flexural strength of epoxy based composites reinforced with short banana fiber with respect to the content of banana fiber is shown in figure 3. It is observed from the figure that there is a gradual increase in the value of flexural strength with increase in short banana fiber content in epoxy resin. The maximum value of flexural strength for epoxy composite with untreated banana fiber is reported to be 138.6 MPa for 15 wt % of fiber. This is an increment of 6.6 % over neat epoxy resin. The improvement increases further when the untreated short banana fiber is replaced by chemically treated short banana fiber. The maximum value of flexural strength in this case is reported for fiber content 15 wt % and is 142.2 MPa. This is an appreciable increment of 9.3 % over neat epoxy resin. Pretreatment of fibers in natural fiber-reinforced composites often showed improvement in flexural properties owing to the increased fiber-matrix adhesion.

Impact Energy

The effect of filler content on the impact energy of the fabricated composites is shown in figure 4. It is seen from this figure that impact strength is gradually increasing with addition of short banana fiber in epoxy composites. It can further be seen that this increment is irrespective of the type of fiber used i.e. untreated or treated fiber. But, rate of increase of impact strength is appreciably depends upon the type of fiber used. From the figure it is clear that when epoxy is used with untreated fiber, the maximum impact strength is obtained of maximum fiber content and the value of impact strength increases from 17 kJ/m^2 to 23.8 kJ/m^2 for epoxy reinforced with 15 wt % fiber. The increment of 40 % is reported in this case. Again, from the same figure it is observed that untreated short fiber is replaced by NaOH treated banana fiber, the impact strength reached a much higher value i.e. 26.4 kJ/m^2 for 15 wt % of fiber content. This is an appreciable increment of around 55 % over neat epoxy. So it can be seen that an enhancement of 15 % is registered when modification of fiber is performed. This indicates that the toughening effect of banana fiber incorporation in epoxy composites is significant and this improves further with fiber treatment. The gradually increasing trend in impact strength is due to the increase of fiber contents and also due to compression pressure which eliminates voids contents. When banana fiber reinforced epoxy composites receive an impact force, the fibers will induce crazes in the matrix around the surface because of stress concentration, and will increase surface area to absorb the impact fracture energy.

4. Conclusions

This experimental investigation on short banana fiber reinforced epoxy composites has led to the following specific conclusions:

1) Successful fabrication of epoxy matrix composites reinforced with short banana fiber is possible by simple hand-lay-up technique.
2) Successful modification of surface of banana fiber is possible with NaOH aqueous solution as can be observed by the improved properties obtained.
3) The hardness of the composites increases with the increase in the content of banana fiber in epoxy matrix. The maximum value obtained is 0.172 GPa for 15 wt. % of fiber loading when untreated fiber is used The increment increased when treated short banana fiber is used. In that case the maximum value of hardens is measured to be 0.192 GPa for similar fiber loading.
4) The ultimate tensile strength of the fabricated composite increase with increase in fiber content. The maximum tensile strength among the various fabricated samples was of sample with 15 wt. % of short banana fiber in treated form. For maximum treated fiber content its values were reported to be of 63.4 MPa. Against that, the maximum tensile strength with untreated fiber is noted to be 61.8 MPa which is an increment of around 12 %.
5) The flexural strength of the fabricated composite increase with increase in fiber content. The maximum value of flexural strength for epoxy composite with untreated banana fiber is reported to be 138.6 MPa. This is an increment of 6.6 % over neat epoxy resin. The maximum value of flexural strength in this case is reported for fiber content 15 wt % and is 142.2 MPa.
6) The impact strength is gradually increasing with addition of short banana fiber in epoxy matrix. When epoxy is used with untreated fiber, the maximum impact strength is obtained with maximum fiber content i.e. 15 wt % and the value of impact strength is 23.8kJ/m^2. Against that, with treated fiber the impact strength reached a much higher value i.e.26.4 kJ/m^2 for 15 wt % of fiber content.

List of Tables

Table 1: List of epoxy based composites filled with short banana fiber

S.No.	Category	Set	Composition
1		Set 1	Neat Epoxy
2	SET I	Set 2	Epoxy + 3 % by weight untreated short banana fiber
3		Set 3	Epoxy + 6 % by weight untreated short banana fiber
4		Set 4	Epoxy + 9 % by weight untreated short banana fiber
5		Set 5	Epoxy + 12 % by weight untreated short banana fiber
6		Set 6	Epoxy + 15 % by weight untreated short banana fiber
7	SET II	Set 7	Epoxy + 3 % by weight treated short banana fiber
8		Set 8	Epoxy + 6 % by weight treated short banana fiber
9		Set 9	Epoxy + 9 % by weight treated short banana fiber
10		Set 10	Epoxy + 12 % by weight treated short banana fiber
11		Set 11	Epoxy + 15 % by weight treated short banana fiber

List of figures

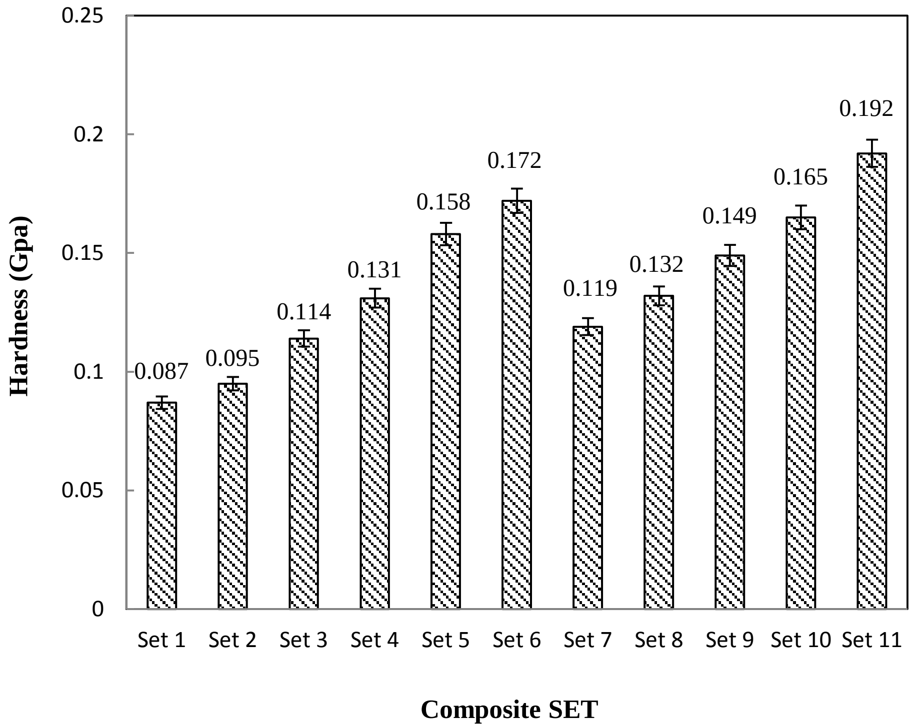

Figure 1: Hardness of epoxy/short banana fiber composite

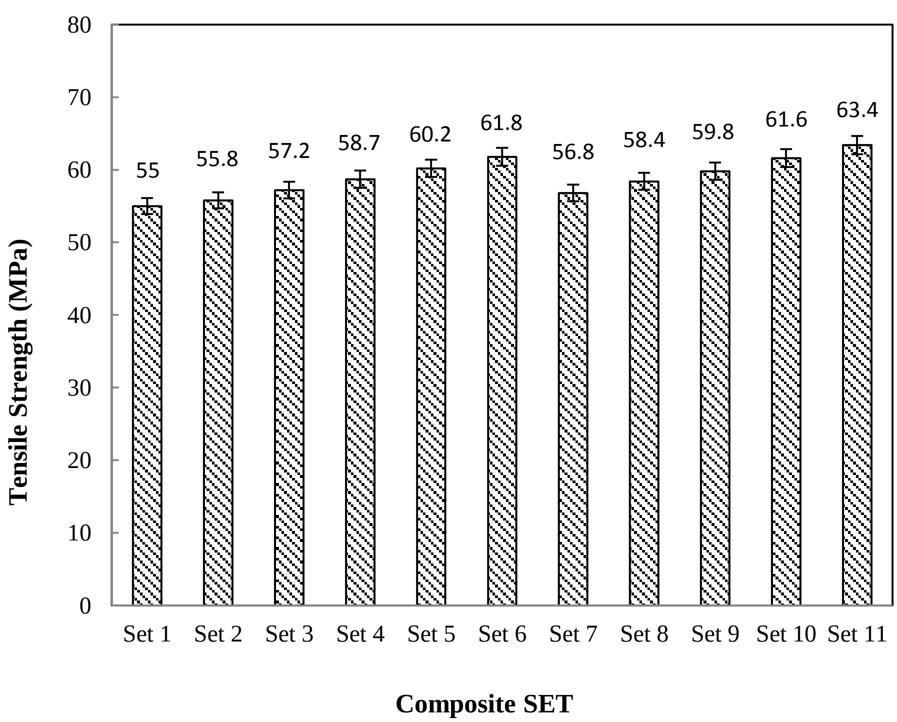

Figure 2: Tensile strength of epoxy/short banana fiber composites

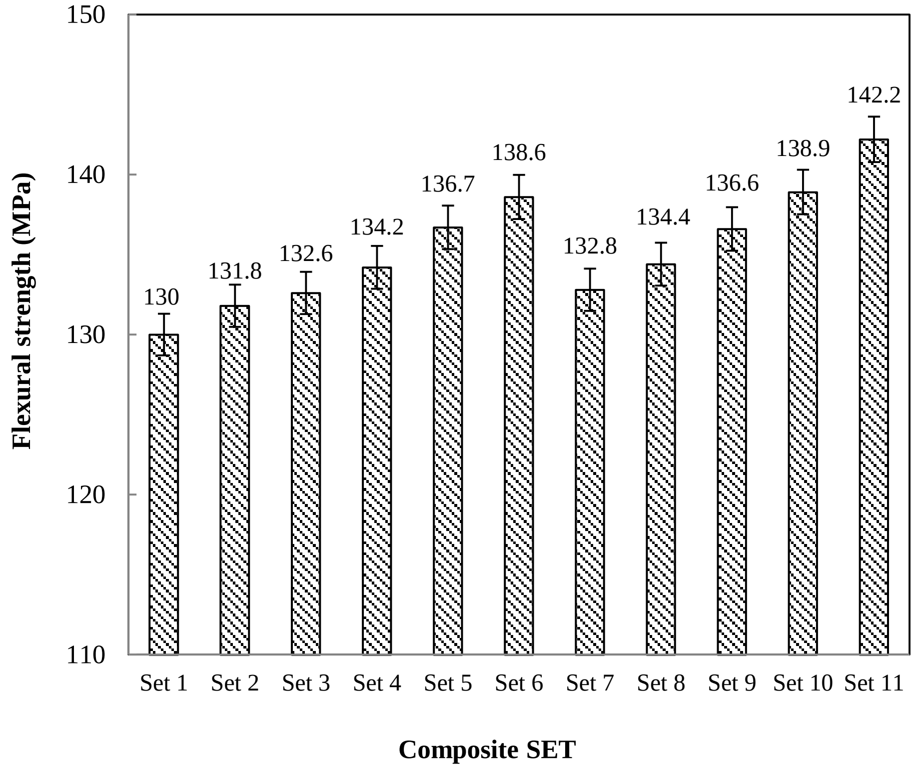

Figure 3: Flexural strength of epoxy/SGM composites

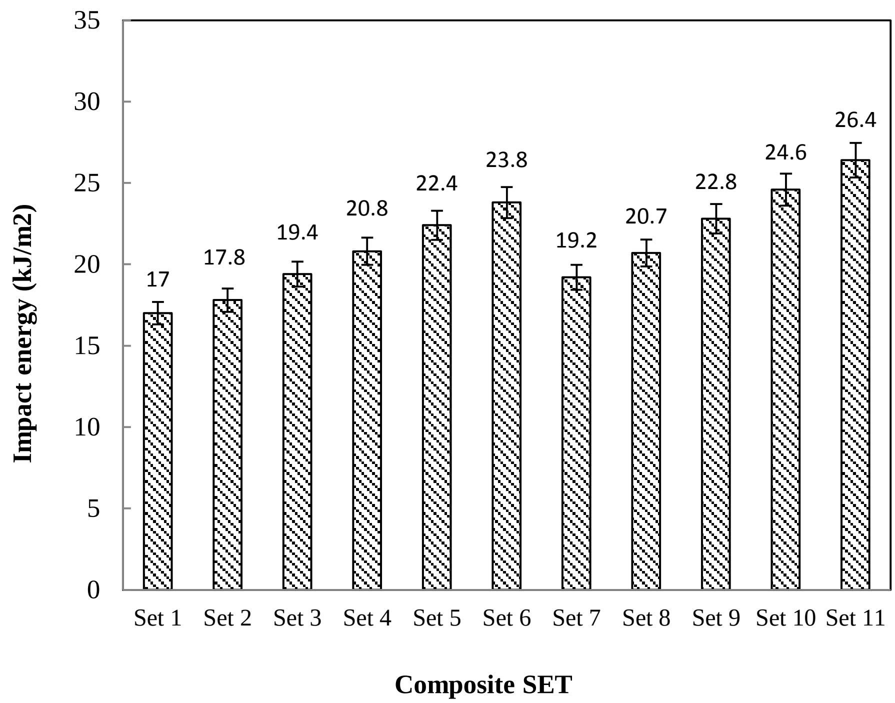

Figure 4: Impact energy of epoxy/SGM composites

References

1. Saheb, D. N., & Jog, J. P. (1999). Natural fiber polymer composites: a review. *Advances in Polymer Technology: Journal of the Polymer Processing Institute*, *18*(4), 351-363.
2. Mohammed, L., Ansari, M. N., Pua, G., Jawaid, M., & Islam, M. S. (2015). A review on natural fiber reinforced polymer composite and its applications. *International Journal of Polymer Science*, *2015*.
3. Bledzki, A. K., & Gassan, J. (1999). Composites reinforced with cellulose based fibres. *Progress in polymer science*, *24*(2), 221-274.
4. Paul, W., Jan, I., & Ignaas, V. (2003). Natural fibers: can they replace glass in fiber reinforced plastics. *Composites Science and Technology*, *63*, 1259-1264.
5. Faruk, O., Bledzki, A. K., Fink, H. P., & Sain, M. (2012). Biocomposites reinforced with natural fibers: 2000–2010. *Progress in polymer science*, *37*(11), 1552-1596.
6. Shalwan, A., & Yousif, B. F. (2013). In state of art: mechanical and tribological behaviour of polymeric composites based on natural fibres. *Materials & Design*, *48*, 14-24.
7. Kabir, M. M., Wang, H., Lau, K. T., & Cardona, F. (2012). Chemical treatments on plant-based natural fibre reinforced polymer composites: An overview. *Composites Part B: Engineering*, *43*(7), 2883-2892.
8. Zhao, X., Li, R. K., & Bai, S. L. (2014). Mechanical properties of sisal fiber reinforced high density polyethylene composites: Effect of fiber content, interfacial compatibilization, and manufacturing process. *Composites Part A: Applied Science and Manufacturing*, *65*, 169-174.
9. Liu, H., Wu, Q., & Zhang, Q. (2009). Preparation and properties of banana fiber-reinforced composites based on high density polyethylene (HDPE)/Nylon-6 blends. *Bioresource Technology*, *100*(23), 6088-6097.
10. Paul, S. A., Joseph, K., Mathew, G. G., Pothen, L. A., & Thomas, S. (2010). Influence of polarity parameters on the mechanical properties of composites from polypropylene fiber and short banana fiber. Composites Part A: Applied Science and Manufacturing, 41(10), 1380-1387.
11. Venkateshwaran, N., ElayaPerumal, A., & Jagatheeshwaran, M. S. (2011). Effect of fiber length and fiber content on mechanical properties of banana fiber/epoxy composite. Journal of Reinforced Plastics and Composites, 30(19), 1621-1627.
12. Raghavendra, S., Lingaraju, P., Shetty, B., & Mukunda, P. G. (2013). Mechanical properties of short banana fiber reinforced natural rubber composites. International Journal of Innovative Research in Science, Engineering and Technology, 2(5), 1652-1655.
13. Ramesh, M., Atreya, T. S. A., Aswin, U. S., Eashwar, H., & Deepa, C. (2014). Processing and mechanical property evaluation of banana fiber reinforced polymer composites. Procedia Engineering, 97, 563-572.
14. Jordan, W., & Chester, P. (2017). Improving the Properties of banana fiber reinforced polymeric composites by treating the fibers. Procedia Engineering, 200, 283-289.
15. Muktha, K., & Gowda, B. K. (2017). Investigation of Water Absorption and Fire Resistance of Untreated Banana Fibre Reinforced Polyester Composites. Materials Today: Proceedings, 4(8), 8307-8312.