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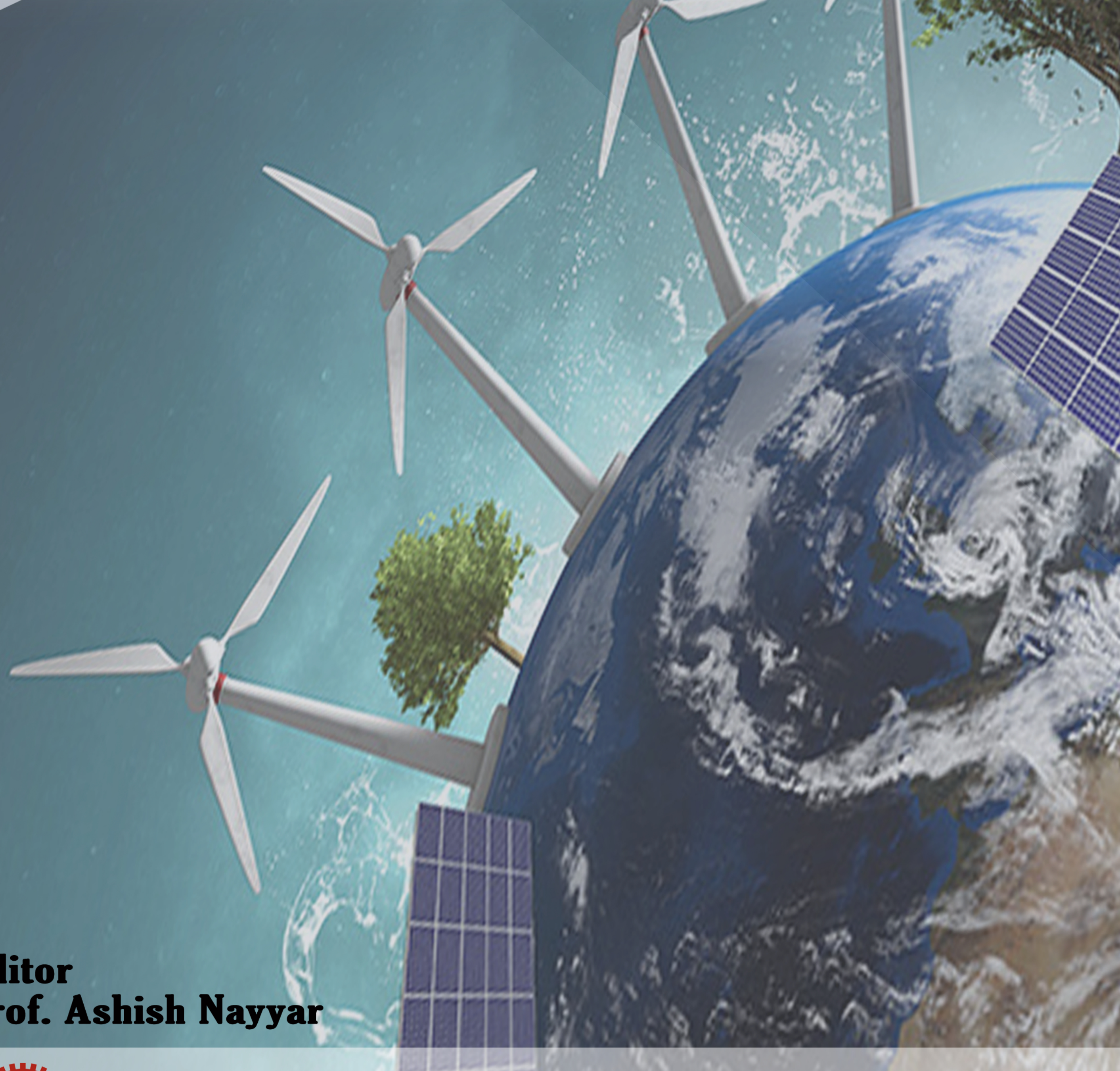

Editor

Prof. Ashish Nayyar

SKIT

असतो मा सद्गमय

Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur

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FABRICATION AND TESTING OF BANANA FIBRE REINFORCEMENT POLYMER COMPOSITES

Yogesh Kumar Sharma[1], Vishnu Jangid[2], Sanjay Bairwa[3], Arun Beniwal[4]

[1,2,3,4] Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur

Corresponding Author email: yogesh.sharma@skit.ac.in

Abstract

The fibre-reinforced polymer composite is widely used in engineering applications and there is an increasing need to understand the mechanical and tribological behaviour of such composites. Due to increase in environmental awareness, the world attracts towards the utilization of natural materials. The natural/renewable fibresare widely used for the fabrication of fibre-reinforced polymer composites.The natural fibre reinforced composites have low weight & free from health hazard. The banana fibre falls in natural fibre category.The banana fibre is a lingo-cellulosic fibre. It has high strength, light weight, smaller elongation, fire resistance quality, strong moisture absorption quality, great potentialities and biodegradability. The banana fibre based composites are extensively used in automobile industries for the production of under floor safety panels in luxurious cars like Mercedes. The key objective of this study is to investigate the effect of fibre length, fibre loading and % wt of filler content Aluminium Oxide (Al_2O_3) on mechanical properties tensile strength and hardness) of banana fibre reinforced polymer composites. After the testing it has been observed the properties and characteristics improved.

Keywords: Banana fibre, length of fibre, fibre loading, Al_2O_3, mechanical properties

INTRODUCTION

There is a wide range of materials that are available for the manufacturing of different parts or products. These materials are broadly classifiedas: (a) Metals (b) Polymers (c) Ceramics (d) Composites. In recent days various light weight materials with excellent mechanical and tribological properties are available for various engineering applications. One of the examples in this category is the composite material [1]. Composites have many applications in the field of engineering and technology i.e. civil construction, marine, automotive, aerospace, turbine blades, telecom equipment's, turbine blades, because of their excellent corrosion resistance and strength to weight ratio. etc. [2]. A composite consists a mixture of two or more than two constituents with an interface that separate them. The separate constituent is known as reinforcement while continuous phase is known as matrix. If the reinforcement is fibre then it is named as Fibre Reinforced Polymer (FRP) composites [3].

Due to the high strength, stiffness, light weight, low coefficient of friction, high thermal conductivity, excellent fracture resistance and low electrical resistivity, high wear resistance, vibration damping ability, good corrosion resistance and creep resistance fibre reinforced polymer composites are widely used in the field of aircraft, space, satellites, automobiles, ships, civil infrastructure etc. [4].The natural fibre reinforced composite also called bio composite or eco-composite is an emerging area in modern engineering. The natural fibre can be used as substitutes of synthetic fibre particular glass fibre due to growing global environmental and social concern.The banana fibre falls in natural fibre category. The banana fibre is a lingo-cellulosic fibre. It has high strength, light weight, smaller elongation, fire resistance quality, strong moisture absorption quality, great potentialities and biodegradability [8].

LITERATURE REVIEW

Due to increase in environmental awareness, the world attracts towards the utilization of natural materials, renewability, recyclability and environmental safety. In the current era, synthetic fibre (glass, carbon and aramid) are widely utilized for the fabrication of polymer-based composites [14]. These composites have good mechanical properties like high strength and stiffness properties but at the same time these composites have serious disadvantages like non-biodegradable, high initial processing costs, non-recyclable, health hazards issues etc. Due to this, now a day, researchers give attention towards the natural/renewable fibre for the fabrication of fibre-reinforced polymer composites for structural, building, and other applications [4]. Many types of natural fibre have been studied by the researchers for the fabrication of polymer composites such as sisal, pineapple, jute and banana.

The banana fibre is a lingo-cellulosic fibre. The poly-propylene reinforced banana fibre based composites is extensively used in automobile industries for the production of under floor safety panels in luxurious cars like Mercedes.

Therefore, number of researchers investigates the effect of types of fibre, length of fibre, types of filler material, etc. on mechanical properties, and tribological properties of banana fibre reinforcement polymer composites. In this section a detailed discussion has been presented regarding this.

Joseph et al. [8] made compared phenol formaldehyde (reinforced composites) with glass fibre and banana fibre on the basis of mechanical properties. Banana and glass fibre in different length and in different weight percentage have been taken for the fabrication of composites. The optimization of fibre loading and length of fibre for maximum tensile, flexural and impact strength has also been carried out. It has been revealed that as the fibre loading and length of fibre increases, the mechanical properties of both fibre also increases.

Chen et al. [6] fabricated sandwich composites using natural fibre to study the wet properties, thermal properties and mechanical properties. The DMA result shows the uniform composite feature and higher softening temperature 140o C & melting temperature 160o C, that shows for manufacturing high performance automotive components it is very important the right selection of bonding fibre.

Idicula et al. [18] examined the static and dynamic mechanical properties of banana/ polyster hybrid fibre reinforced composites. It has been revealed that mechanical properties of fabricated composites increase with increase in percentage weight of fibre in composites. The composites having volume ratio of banana and sisal 3:1 has the maximum tensile strength. Different layering patterns were tried at volume fraction of 40 %, keeping the volume ratio of fibre 1:1.

Wonderly et al. [19] compared the tensile strength and impact strength of carbon fibre vinyl ester andbiaxial glass fibre/vinyl ester composites. It has been found that the mechanical properties of vinyl ester / carbon fibre/ composite are superior as compared to biaxial glass fibre/vinyl ester composites. It has also been recommended that carbon fibre based composite has been found better as compared to glass fibre based composite for building a ship.

Suresha et al. [25] fabricated E-glass woven fabric reinforced vinylester composites to study the three-body abrasive wear behavior of 2-D & 3-D and mechanical properties. The mechanical tests for tensile strength, tensile modulus and elongation have been conducted. The mechanical property of 3-D G-V composites has been found much better than 2-D composites. Also, the abrasive wear for both composite is increased with increase in abrading distance/load.

FABRICATION AND TESTING OF FIBRE REINFORCEMENT POLYMER COMPOSITES

In this investigation, for the fabrication of fibre reinforced polymer composites, non-woven Banana fibre have been used as reinforcement, epoxy resin as matrix material while Al2O3 as filler material. The banana fibre have taken in three lengths viz. 5 mm, 10 mm and 15 mm to the range of 10 % to 30 % in three steps of the total weight of composite. Similarly, the filler material i.e. Al2O3 has been taken to the range of 0-20 % in four steps of the total weight of composite.

Banana fibre:

For fabrication of fibre reinforced polymer composite, non-woven banana fibre is used as reinforced material. Scientifically banana fibre is known as musaacuminata. The hemi-celluloses, cellulose, pectin, lignin, and some extractives are the main organic constituents of banana fibre. The banana fibre has low density as compare to glass fibre. It has high strength, light weight, smaller elongation, fire resistance quality, strong moisture absorption quality, great potentialities and biodegradability.

Fig 1(a): Pictorial view of uncut nonwoven banana fibre

Fig 1(b): Pictorial view of chopped nonwoven banana fibre

In the present study,Bisphenol-A-Diglycidyl-Ether also called Diglycidyl ether supplied by Hindoostan Composite Solutions Pvt. Ltd., Mumbai is used as a matrix material. It is commonly used thermosetting polymeric epoxy resin. The thermosetting polymeric epoxy resin exhibits superior properties like excellent mechanical, chemical and corrosion resistance properties and low shrinkage during cure. Therefore, thermosetting polymeric epoxy resins are widely used for the fabrication of different composites.

The Hinpoxy C Hardener is supplied by Hindustan Composite Solutions Pvt. Ltd., Mumbai, has been used with Bisphenol-A-Diglycidyl-Ether in the required proportion by weight i.e. 30:100 ratios. The Hinpoxy C Hardener is a modified amine hardener. Table 3.1 shows the properties of matrix material used in the present work.

Matrix material:

In the present study, Bisphenol-A-Diglycidyl-Ether also called Diglycidyl ether supplied by Hindoostan Composite Solutions Pvt. Ltd., Mumbai is used as a matrix material. It is commonly used thermosetting polymeric epoxy resin. The Hinpoxy C Hardener is supplied by Hindustan Composite Solutions Pvt. Ltd., Mumbai, has been used with Bisphenol-A-Diglycidyl-Ether in the required proportion by weight i.e. 30:100 ratio. The Hinpoxy C Hardener is a modified amine hardener. Table 1 shows the properties of matrix material used in the present work.

Table 1 Ingredients of matrix material

Ingredients	Chemical name	Density at 250C	Supplier
Epoxy Resin	Bisphenol-A-Diglycidyl-Ether	116-120 (g/cm3)	Hindustan Composite Solutions Pvt. Ltd., Mumbai
Hardener	Amine	0.94-0.95 (g/ml)	Hindustan Composite Solutions Pvt. Ltd., Mumbai

Filler material: Aluminium oxide or Alumina is the most cost effective and widely used ceramic material and widely used for the fabrication of composites as filler material.

Specimen preparation method: In this work, banana reinforced polymer composites in different proportions of fibre, matrix and filler have been fabricated using Hand lay-up method. The Hand lay-up method is the simplest method for the fabrication of composites and requires minimum infrastructural. This method requires only (i) Wooden mould (ii) Silicon Spray (iii) Brush (iv) bucket (v) Mould release sheet (vi) hand gloves and (vii) Weights.

Table 2 Fabricated Composites

Composite Designation	Fibre (wt %)	Matrix (wt %)	Filler (wt %)
Banana Epoxy (5 mm length) (B1)	10	90	0
Banana Epoxy (10 mm length) (B2)	10	90	0
Banana Epoxy (15 mm length) (B3)	10	90	0
Banana Epoxy (B4) (10 mm length)	20	80	0
Banana Epoxy (B5) (10 mm length)	30	70	0
10% Al2O3 filled Banana Epoxy (10 mm length) (B6)	20	70	10
15% Al2O3 filled Banana Epoxy (10 mm length) (B7)	20	65	15
20% Al2O3 filled Banana Epoxy (10 mm length) (B8)	20	60	20

Testing of composites: To identify the best combination of length of fibre, % reinforcement, % filler and % epoxy for the fabrication of banana reinforced polymer composites, mechanical tests such as hardness, tensile strength, flexural, impact strength have been conducted.

Hardness Test: The resistance to penetration or scratch is called hardness. The Rockwell hardness of all fabricated composites have been carried out on Rockwell hardness tester machine.The hardness tests have been conducted according to ASTM: E-18. In this static indentation test, a diamond indenter having diameter 120-degree diamond cone has been forced into the specimen. The area of indentation and applied load gives the hardness of the specimen. The minor load and major load for measurement of hardness has been taken as 10kgf and 150 kgf respectively.

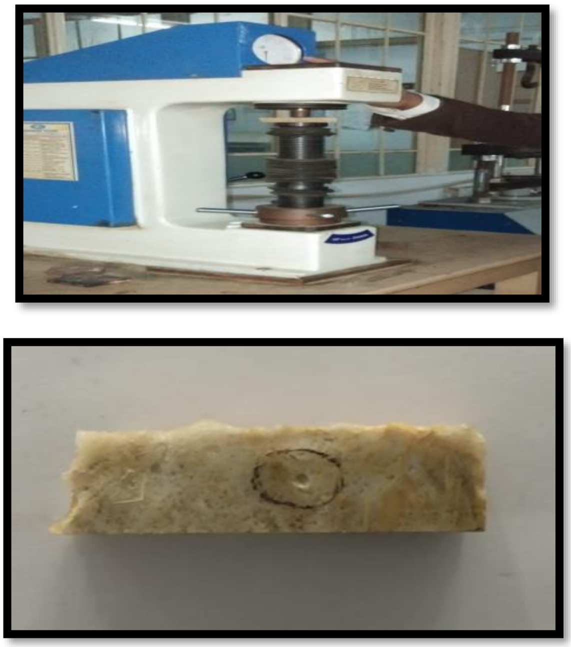

Fig 2(a): Hardness tester **(b)**: Specimen after the measurement of hardness

The hardness for each specimen has been repeated at two different locations. Finally, mean of all two hardness has been considered for that sample. The photographic view of hardness tester is shown in figure 2 (a) while figure 2 (b) shows the specimen after the measurement of hardness.

Tensile strength: The tensile strength of all fabricated banana reinforced polymer composites have been evaluated using universal testing machine. Flat specimens have been fabricated for the tensiletest having dimensions 120 mm x 10 mm and 80 mm x 10 mm, respectively.

Fig 3(a): Universal testing machine for tensile **(b)**: Test specimen for tensile test

Effect of fibre length on mechanical properties of unfilledbanana reinforcement polymer composites:Initially, as shown in table 2, two unfilled banana reinforced polymer composites (B1 and B2) with different fibre length and in the same ratio of fibre loading and matrix have been fabricated. After that mechanical testings have been carried out on these specimens to identify the best fibre length for the fabrication of composite. The tensile testing and hardness have been carried out to investigate the effect of fibre length on mechanical properties of fabricated banana reinforced polymer composites.

Tensile strength

The graph shows the values of tensile strength of B1, B2 and B3. The graphical representation of the mean value of tensile strengths for B1 B2 and B3 is shown in figure 3.

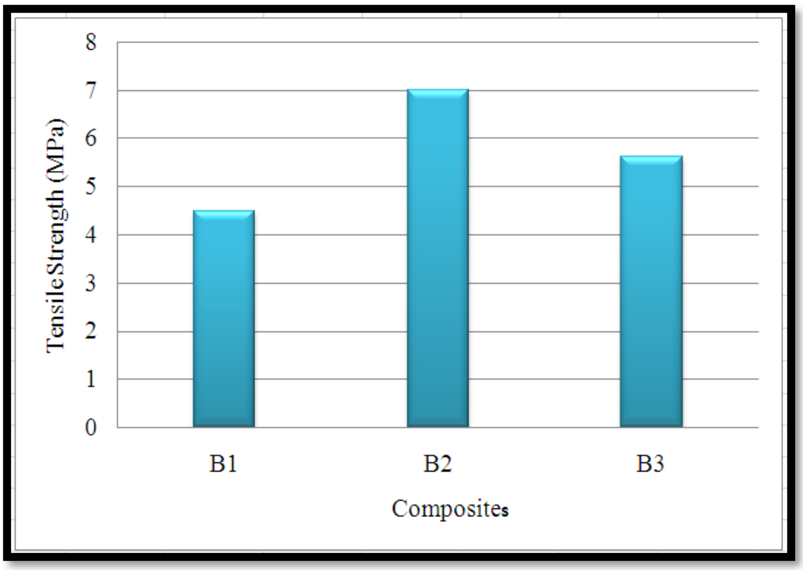

Fig. 3 Impact of fibre length on tensile strength

It has been revealed from the figure that tensile strength initially increases with increase in fibre length from 5 mm to 10 mm, after that it decreases with further increase in fibre length. As the fibre length increases, the contact area of fibre with resin also increases, which results in strong bonding between the fibre and resin, hence increase in tensile strength of composite [42]. Also, short fibre shows more debonding in composites as compared to long fibre in composites, which further increases the tensile strength of long fibre based composites [43]. Further increase in fibre length in composite, increases the fibre curling, bundling, and entanglement. Due to this, proper distribution of resin between the fibre may not occur. This reduces the transfer of stress from one point to other point in fibre composites, which results in decrease in tensile strength of the fibre composites [44].

Among the B1, B2 and B3, the maximum tensile strength of banana reinforced polymer composite has been achieved with 10 mm banana fibre length (B2).

Hardness

The hardness of the composites depends on the bonding of fibre with resign. The figure 4 shows the graphical representation of the hardness of composites (B1, B2 and B3).

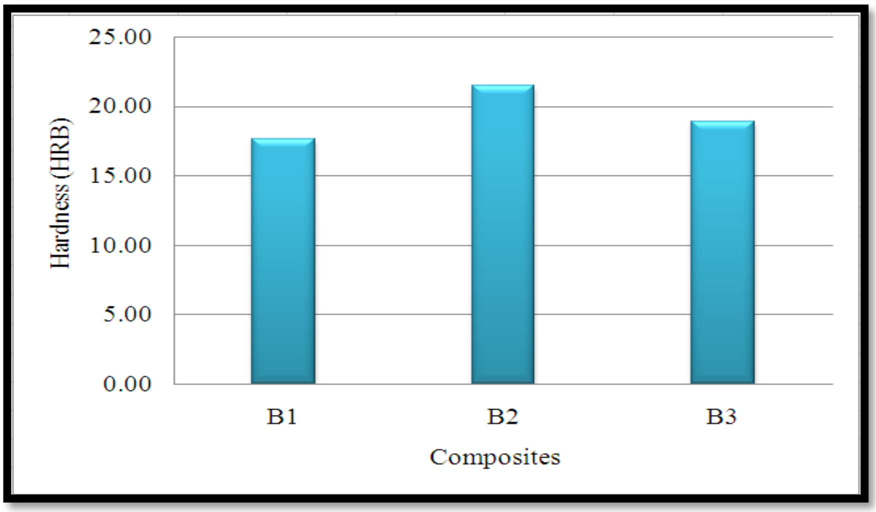

Fig. 4 Impact of fibre length on hardness

From the figure it has been revealed that hardness of composites increases with increase in fibre length from 5 mm to 10 mm. It is because of the strong bonding between the fibre and resin. Further increase in fibre length, increases the fibre curling, bundling, and entanglement in composite. This reduces the proper bonding between the fibre and resin, results in decrease in hardness of the composite [44]. The maximum hardness has been achieved with 10 mm fibre length based composites (B2) among B1, B2 and B3 composites.

From the analysis of mechanical properties, i.e. tensile strength and hardness of unfilled banana reinforced polymer composites having different fibre length, i.e. B1, B2 and B3, it has been revealed that banana reinforced polymer composite having 10 mm fibre length (B2) has been exhibited excellent mechanical properties among B1, B2 and B3. Therefore 10 mm length of banana fibre has been selected for the fabrication of unfilled banana fibre reinforced polymer composites with different fibre loading (B4 and B5) and $Al2O3$ filled banana reinforced composites (B6, B7 and B8).

Effect of fibre loading on mechanical properties of unfilled banana reinforcement polymer composites

In the present work, three unfilled banana reinforced polymer composites (B2, B4 and B5) have been fabricated in the different weight % of fibre loading and resign. After that mechanical testings have been conducted on these composites to identify the best weight % of fibre loading.

Tensile strength of unfilled composite

The bonding between the fibre and matrix depends on the fibre interface area and increases with increase in fibre loading. The graphical representation of the mean value of tensile strengths for B2 B4 and B5 is shown in figure 5.

From the figure it is visible that tensile strength initially increases with increase in fibre loading from 10% to 20%. Further increase in fibre loading decreases the tensile strength of the composite. The maximum tensile strength is achieved with 20% fibre loading (B4).

The tensile strength of B2 composite is low because of the less fibre interface area. Also, in the fibre reinforced composites, the failure takes place due to brittle nature of the composite. The brittleness of composite increases with decrease in fibre loading. The brittle nature of the composite offers less resistance for the development of cracks The composite with less fibre loading exhibit more brittleness [27]. Further increase in % weight of fibre in the composite (B4) increases the fibre interface area which increases the tensile strength of the composite. Also, ductility of composites increases with increase in fibre loading. Beyond the certain limit, further increase in fibre loading in composite (B5) decreases tensile strength due to incomplete adhesion at the entire surface because of fibre- fibre interaction and improper wetting of fibre [12].

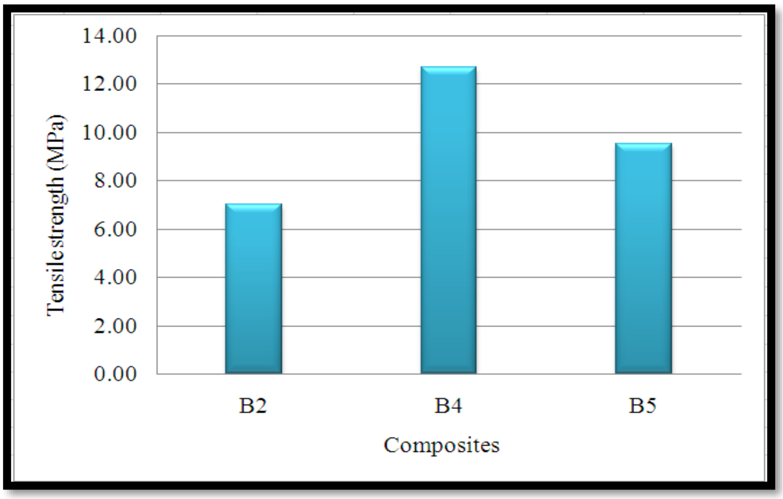

Fig. 5 Impact of fibre loading on tensile strength

Hardness of unfilled composite

The resistance to wear of any material directly depends on the hardness of that material. The figure 6 shows the graphical representation of the mean value of hardness of B2, B4 and B5 composites. From the figure it is cleared that hardness of composites initially increases with increase in fibre loading from 10% to 20%. This is because of the better bonding of matrix with the reinforcement materials. Strong bonding between the fibre and matrix increases the stress transfer from one point to another and prevent the crack formation [14]. That increases the indentation resistance of the matrix. Further increase in fibre loading decreases the hardness of composite (B5). It is due to improper bonding between the fibre in the matrix and improper wetting of fibre [12].

Effect of % weight of Al_2O_3 on mechanical properties of filled banana reinforcement polymer composites

As mention above, among the B1, B2, B3, B4 and B5, the B4 (having 10 mm fibre length and 20 % banana fibre) has been exhibited excellent mechanical properties. Therefore this combination is selected for the fabrication of Al2O3 filled banana reinforced polymer composites (B6, B7 and B8) in different weight percentage of Al2O3. After that mechanical testings have been conducted on these composites for the selection of best composite among the all fabricated composites for further analysis.

Tensile strength

The graphical representation of tensile strength of B4, B6, B7 and B8 composites has been shown in figure 7. It has been revealed from the table and figure that tensile strength increases with increase in percentage weight of Al_2O_3 filler particles from 0 wt% to 10 wt% . It is due to presence of Al2O3 particles in the composites. The Al_2O_3 particles increase the interfacial surface area for bonding and decrease the porosity, resulting in strong bonding between the fibre, matrix and filler [36].

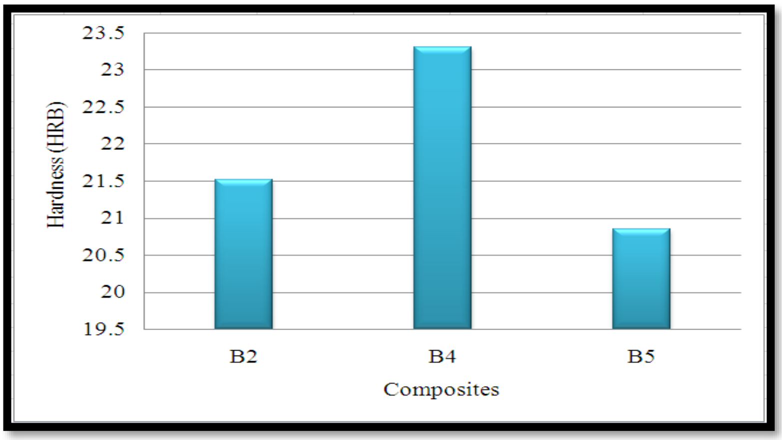

Fig. 6 Impact of fibre loading on Hardness

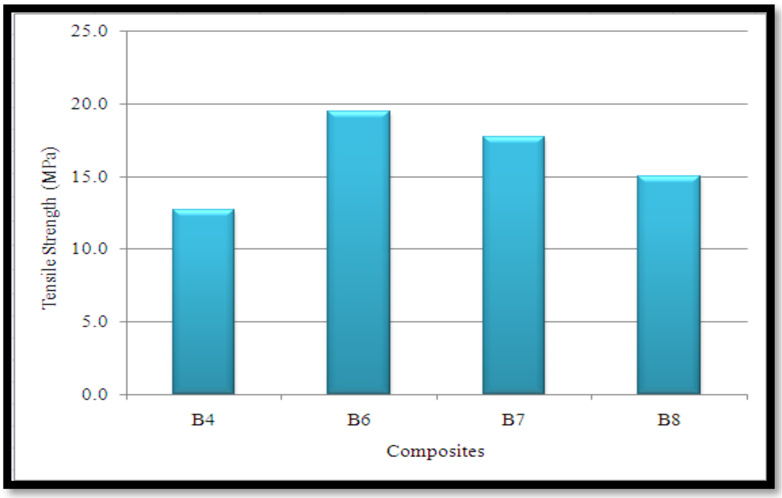

Fig. 7 Impact of filler loading on tensile strength

That improves the tensile strength of the composite. Also, during the tensile loading, transfer of stress from matrix to particles takes place, the particles act as mechanical interlocking between fibre and matrix, which offer resistance for the crack formation and propagation resulting increase in the tensile strength [38]. Further increase in percentage weight of Al_2O_3 particles (beyond 10%) in composite decreases the tensile strength. The sharp edges of filler particles acts as stress raiser. These sharp edges create discontinuity in transfer of stress across the interface of filler and matrix, resulting in stress concentration and early initiation of the failure process [38]. Also, large interfacial surface area increases and the percentage of matrix decreases with increase in percentage weight of filler in composite. Due to lack of matrix, inadequate bonding takes place between the filler, matrix and fibre in the composite which reduces loads transfer capacity of the composite [36], hence decreases the tensile strength of the composite.

Hardness

The figure 8 shows the hardness of unfilled banana fibre reinforced polymer composite (B4) and Al_2O_3 (B6, B7 and B8) filled composites.

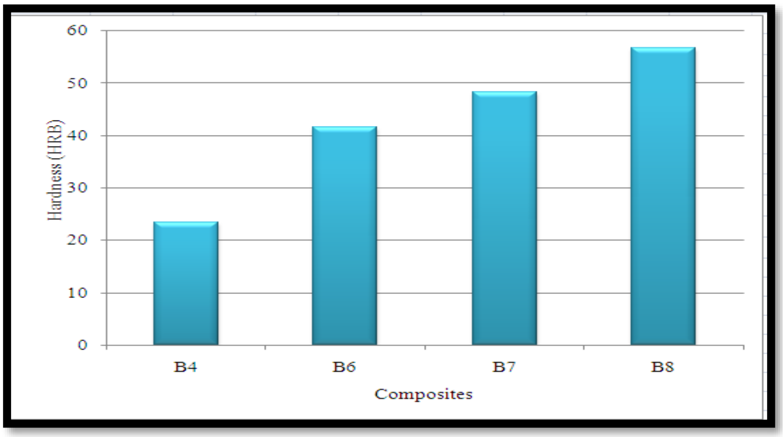

Figure 8: Hardness of unfilled banana fibre

Conclusion and Future Scope

The main objective of this work is to investigate the effect of fibre length, fibre loading and % wt of filler content on mechanical tensile strength and hardness behaviour.

The investigation of the effect of fibre length, fibre loading and % wt of filler content on mechanical and erosion behavior of banana fibre reinforced polymer composites has led to the following conclusions:

The variation in length of banana fibre, % wt of fibre loading and % wt of filler material affects the mechanical properties tensile strength and hardness of unfilled banana reinforcement polymer composites.

The mechanical properties increase with increase in fibre length from 5 mm to 10 mm. Further increase in length of fibre beyond 10 mm leads to decrease in mechanical properties. The best mechanical properties of banana fibre reinforced polymer composites has been achieved with 10 mm fibre length.

The mechanical properties of the banana fibre reinforced polymer composites increases with increase in fibre loading from 10 wt % to 20 wt %. Further increase in banana fibre loading beyond 20 wt% leads to decrease in mechanical properties. The best mechanical properties of banana fibre reinforced polymer composites has been achieved with 20 wt % fibre loading.

The tensile strength of the banana fibre reinforced polymer composites increases with increase in filler (Al2O3) loading from 0 wt % to 10 wt %. Further increase in filler loading beyond 10 % wt leads to decrease in tensile strength.

The hardness of the banana fibre reinforced polymer composites continuous increases with increase in percentage weight of Al2O3 content from 0% to 20%. Maximum hardness is achieved with 20 percentage weight of Al2O3 content.

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ICONRER-2021

Renewable energy and sustainable development are the key technologies to offer solutions to the ever-increasing environmental pollutions and depleting conventional fuel reserves. With an aim to discuss the state of art technologies pertaining to the renewable energy domain, RTU (ATU) TEQIP III Sponsored 3rd International Conference on New and Renewable Energy Resources for Sustainable Future (ICONRER-2021) was organized by the Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Management and Gramothan, Jaipur in collaboration with Rajasthan Technical University and Department of Mechanical Engineering, Assiut University, Assiut (Egypt) from February 11 to 13, 2021. ICONRER is a series of the conference started in 2017 and it was 3rd event of that series.

असतो मा सद्गमय

Swami Keshvanand Institute of Technology, Management & Gramothan

Ramnagaria, Jagatpura, Jaipur-302017, Rajasthan

Tel. : +91-0141- 3500300, 5160400, 2759609, 2752165 & 2752167 | Fax: +91-0141-2759555

Website: www.skit.ac.in | E-mail: info@skit.ac.in

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