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RESEARCH ARTICLE

INFLUENCE OF AGRO-WASTE FILLER ON MECHANICAL AND TRIBOLOGICAL PROPERTIES OF BAST FIBER BASED EPOXY COMPOSITES

[1]Harendra Singh Sikarwar, [1]Sanjay Goyal, [2]Sandeep Kumar and [2,*]Brijesh Gangil

[1]Mechanical Engineering Department, Maharana Pratap College of Technology, Gwailior, Madhya Pradesh, India
[2]Mechanical Engineering Department, School of Engineering and Technology, HNB Garhwal University, Srinagar-246174, Uttarakhand, India

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ABSTRACT

An attempt has been made to study the influence of agro-waste filler on the mechanical and wear properties of bast fiber reinforced polymer composites. Two groups of the specimens, based on a combination of grewiaoptiva as fibrous material and epoxy as matrix material, and the grewiaoptiva containing specimens where hybridization is done with the addition of mustard cake filler as agro-waste were prepared. All specimens were fabricated by hand layup technique. The filler component fixed at 2 wt. % while the weight fraction of fibrous material was varied in the range of 3-9 wt. %, so as to fabrication of composites specimen with six different compositions. Based on the comparison, grewiaoptiva (9 wt. %) epoxy composites incorporation of mustard cake filler shows maximum value of tensile strength (24 Mpa.), flexural strength (18.31 Mpa.), hardness (39.01 Hv) and impact energy (3.6 J) among all the composites. Moreover dry sliding wear behavior was observed by using the pin on disc according to the ASTM G99 standard. Result suggested that grewiaoptiva composites incorporation of mustard cake filler exhibited superior wear resistance properties as compared to mono grewiaoptiva composites.

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INTRODUCTION

Now a days, the body parts and interiors of automobiles are extensively made by fiber reinforced polymer composites. These composites can be prepared by using man-made fibers such as glass, carbon and aramid. The plastic materials such as epoxy, vinyl ester, and polyester etc. are extensively used as matrix in fiber reinforced composites. The reasons for using these composites in industries are their high strength to low weight. Thus, researchers are in search to find out better alternate solution to replace the man-made synthetic fibers. Natural fiber are found to be better substitute for this trouble, because they are abundantly available in nature. Also they are economical good, less cost, and has properties like low density and non-toxic (Sapuan, and Maleque, 2005). Natural fibers are classified as mineral, animal, and plant fibers, among these fibers plant based reinforcing materials are extensively used in the field of polymer composites. Plant fibers also sub-divided in bast fiber, leaf fiber, seeds and fruit fiber etc. Hemp, jute, kenaf, and flax are extensively used bast fibers and are becoming raising importance in composite production due to its better strength and stiffness in comparison of other natural fibers (Petrucci *et al.,* 2013; Venkateshwaran *et al.,* 2012; Ramnath *et al.,* 2014; Sreekala *et al.,* 2002). Grewiaoptiva is recently exposed bast fiber which are extracted from the outer cell of grewiaoptiva plant and abundantly available in the hilly area of India like Himachal Pradesh, Uttarakhand, and Jammu & Kashmir etc. In the economical point of view, this fibrous material can play key role by making low cost articles such as ropes, mats, bags, boots etc. Despite of the above benefits natural fibers have some limitation also, such as low strength, and hydrophilic nature as compared to man-made fibers. These properties of natural fiber based composites can be maintained by using hybridization techniques by various researchers (Kumar *et al.,* 2017*;* Gangil and Kumar, 2017; Kaleemulla and Siddeswarappa, 2010; Ramesh *et al.,* 2016; Kumar *et al.,* 2017). The hybridization of natural fiber based composites with agro waste filler has been made popular research activity in the composite manufacturing industries since the mechanical and wear properties of the resultant material significantly change by the addition of fillers. The results were coming out by the agro-waste filler used as a reinforcing agent in polymer composites, mainly weight and the molding characteristics (Ofem and Umer, 2012). Agro-waste such as rice husk, mustard cake, coir, pine bark, and palm oil, fuel ash, etc. are used as filler and accomplishment in order to encourage new classes of green fiber hybrid polymer composites with better mechanical properties as well as to

***Corresponding author:* Brijesh Gangil**
Mechanical Engineering Department, School of Engineering and Technology, HNB Garhwal University, Srinagar-246174, Uttarakhand, India

attain new product with low cost. Mustard cake is the residue left over from commercial mustard oil or meal production. In lieu of established prepared mustard identity standards, according to the Food and Drug Administration (FDA), mustard cake's only definition is ground mustard seed or meal where some of the inherent oil has been removed. In the present investigation, the inclination or declination of mechanical (tensile strength, flexural strength, hardness, and impact energy) and wear (dry sliding wear) properties of grewiaoptiva epoxy composites with and without additions of mustard cake filler (fixed 2 wt. %) were evaluated. These composites are fabricated with 3 wt%, 6 wt%, and 9 wt% of grewiaoptiva fiber by simple hand lay-up technique. The result indicated that the incorporation of mustard cake filler make the composites hybrid and it enhanced the properties of material.

MATERIALS AND METHODS

Materials

For this research, grewiaoptiva mat and mustard cake filler (with density 1.27 g/cm^3) were collected from village of Uttarakhand, India. Epoxy resin with density 1.1 g/cm^3 was procured from Amtech Private limited, New Delhi, India. The surface morphology of natural fiber used in this study is shown by the SEM (Scanning Electron Microscopy) in figure 1. The SEM images depicted the surface roughness which leads to providing better strength and good bonding features with plastic resin (Balasundar *et al.,* 2017). Also the pictorial view of grewiaoptiva mat and mustard cake filler as shown in figure 2(a), (b).

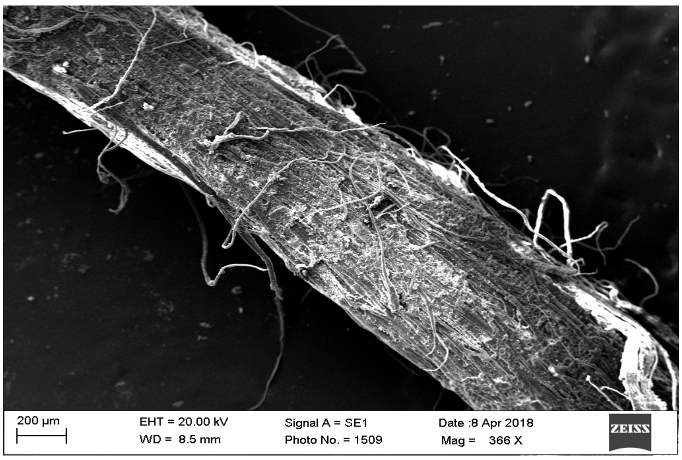


Figure 1. Surface morphology of grewiaoptiva fiber

Figure 2 (a), (b). Present the pictorial view of grewiaoptiva fiber and mustard cake

Fabrication of composites

- Each composite laminates well compound mixture of Epoxy, grewiaoptiva bi-directional mat are used in this research is NaOH treated because of minimized the hydrophilic nature of natural fiber.
- An open mold made up of wooden of dimensions 310X310 mm is prepared
- Hybrid composites with 3wt %, 6wt%, and 9wt% of grewiaoptiva fiber and fixed 2 wt% of mustard cake filler are fabricated.
- Based on weight proportion calculation appropriate amount of resin and fiber are weighed in the precision electronic balance machine.
- The reinforcement fibers are used in mat form, grewiaoptiva mat first placed inside the mold which are already laminated with mixture of epoxy resin and mustard cake filler.
- Apply mixture of resin and hardener over first layer of fiber.
- Again suitable amount of resin and hardener mixture is applied over previously grewiaoptiva mat
- Remaining epoxy mixture is placed over last fiber layer, roller is used to eliminate the pores and voids in fabricated composites.
- A 10 kg weight is applied over the mold and left for settlement
- After 24 hours the cured specimens are extracted from the mold and kept in room temperature for proper curing.
- The composition and designation of the composites prepared for this study are listed in Table1. Also fabricated sample and mechanical test specimen as shown in figure 3 (a), (b).

Table 1. Fabricated composites and its compositions

S. No.	Composites	Compositions
1	GE-3 wt.%	Epoxy resin + Grewiaoptiva fiber (3 wt. %)
2	GE-6 wt.%	Epoxy resin + Grewiaoptiva (6 wt. %)
3	GE-9 wt.%	Epoxy resin + Grewiaoptiva (9 wt. %)
4	GEM-3 wt%	Epoxy resin + Grewiaoptiva (3 wt. %) + Mustard cake (2 wt. %)
5	GEM-6 wt%	Epoxy resin + Grewiaoptiva (6 wt. %) + Mustard cake (2 wt. %)
6	GEM-9 wt%	Epoxy resin + Grewiaoptiva (9 wt. %) + Mustard cake (2 wt. %)

Figure 3. (a), (b)fabricated sample and tensile test specimens.

Methods

Mechanical characterization: The universal testing machine HEICO (HL590) with 10mm/min cross-head speed was used to conduct tensile test. The ASTM: D303 standard was used for preparing tensile and flexural test specimens were like rectangular strip. The hardness of composite materials was measured from computerized vicker hardness tester under ASTM E92 standard. A diamond indenter with an apical angle of 136° was intended over the surface of the sample under a load of 1 kg for 15 second. The suitability of a composite for such applications should therefore be determined not only by usual design parameters, but by its impact or energy absorbing properties. The ASTM: E23 is used to find out the impact strength of given sample. The specimens were prepared with dimension of 55×10×10 mm and 3.33 mm depth of notch with acute angle.

Sliding wear test: The wear performance of fabricated composites was performed on pin on disc test rig which is supplied by Ducom Instrument Pvt. Ltd. ASTM G99 standard was used under dry sliding condition. The specimen is held stationary and the disc rotated while a normal is applied through a lever mechanism. The specimen is held stationary and the disc rotated while a normal is applied through a lever mechanism. A series of test are conducted with constant sliding velocity 1.25m/s and time 60 min under different normal loadings 10N, 20N, 30N and 40N. The material losses from the composite surface are measured by using precision electronic balance and then find the specific wear rate by using given equation.

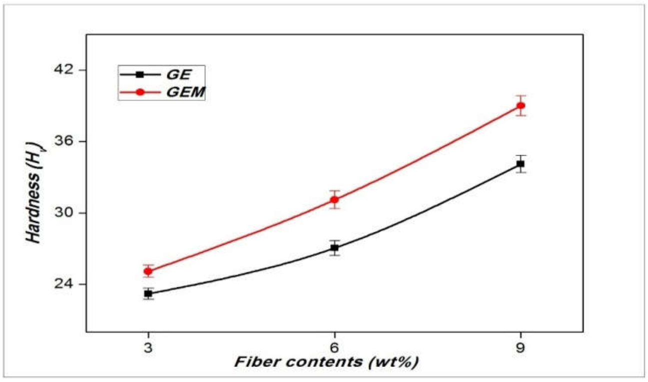
$$W_s = \frac{\Delta M}{\rho l f_n}$$

The specific wear rate denoted by W_s (mm^3/N-m), the mass loss due to wear during test is indicated by ΔM (g), density represent by ρ, l is the sliding distance in (m), and f_n is the load applied on the specimen in (N).

RESULTS AND DISCUSSIONS

Mechanical characterization

Hardness and Impact energy: From figure4**,** it is clear that hardness of composites increases considerably as the weight fraction of grewiaoptiva fiber is increased. Variations in the average value of hardness were found in to the range of (23.21-34.11) H_v for GE composites (3-9 wt %). Average value of hardness for 6 wt. % and 9 wt. % GE composites were obtained as 23.21 and 34.11 H_v respectively. The composites hardness is also found to enhance by approximately 8%, 14%, and 16% with GE hybrid with mustard cake filler with the hardness increases from 25.1 to 39.01 H_v with the GEM contents in the matrix varying form 3 wt% to 9 wt%. For both GE as well as GEM composites, the maximum hardness values is 39.01 H_v is observed at the reinforcement of 9 wt%. The ability of materials to absorb energy under shocking or loading condition is known as impact energy. The impact energy of composites is depending on the factors like chemical bonding between fibre and matrix and toughness of fibre reinforcement. The notched charpy impact energy with different compositions is presented in Figure 5. In this case the impact energy linearly increases with fibre loadings from 3 wt% to 9 wt% and hybridization also affected such property. Experiment shows that GEM with 9 wt% exhibited maximum value of impact energy.



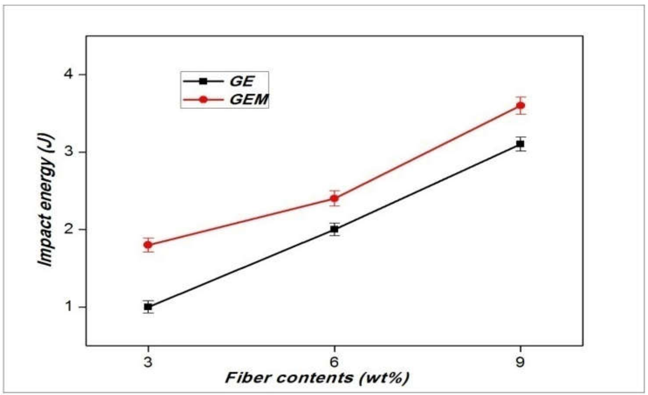


Figure 5. Variation of impact energy with fiber contents

Tensile strength and Flexural strength

From figure 6, it is understandable the tensile strength of the GE and GEM composites increases significantly as the wt% of fiber is increased. The inclination in strength of GE composites may be attributing to chemical reaction between fiber and matrix interface may be too strong to transfer the tensile stress and GEM composites may be attributing to chemical reaction between fiber/filler and matrix interface may be too strong to transfer the tensile stress. In this investigation, the variations of flexural strength of both GE and GEM composites with 3 to 9 wt% are shown in figure 7.A gradual enhancement in flexural strength was noticed in both GE and GEM composites with different wt %. GEM composites exhibited approximately 22%, 20%, and 21% enhancement in flexural strength as compared to GE composites with different fiber loadings (3-9 wt%). Hence GEM composites with 9 wt% contents have higher bearing strength among all the composites. Similar trend was observed by Stalin and Athijayamani (Stalin and Athijayamani, 2016), they revealed that the increase the amount of fiber contents (combination of reeds and fruit) resulted in increases the tensile and flexural strength.

Dry sliding wear analysis

The variation of specific wear rate with fiber contents (wt. %) is depicted in figure 8. The applied loads are 10N, 20N, 30N, and 40N and the sliding distance is kept constant at 4500m. It is clearly seen from the figure the specific wear rate decrease with increase of fiber contents from 3 wt. % to 9 wt. % in both composites (GE and GEM). At 9 wt. % of grewiaoptivafiber and 2 wt. % mustard cake filler contents composites with 40 N applied load gives proficient wear resistance as compared to other fabricated composites.

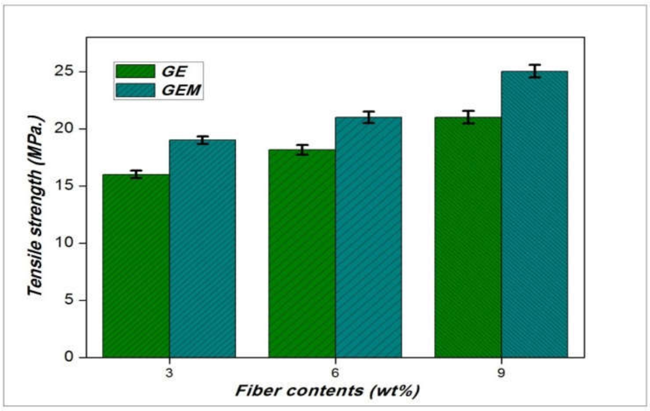


Figure 6. Variation of tensile strength with fiber contents

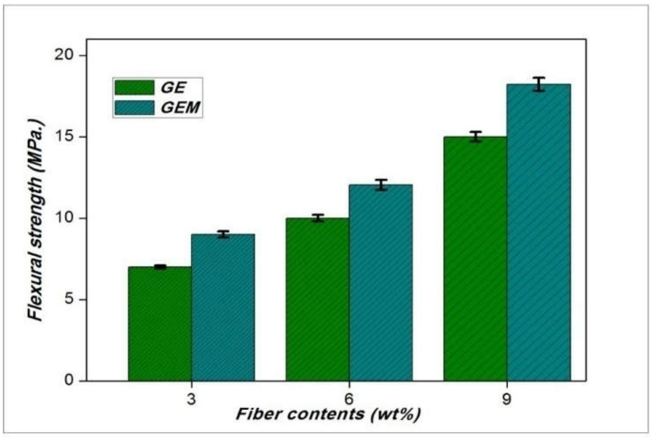


Figure 7. Variation flexural strength with fiber contents

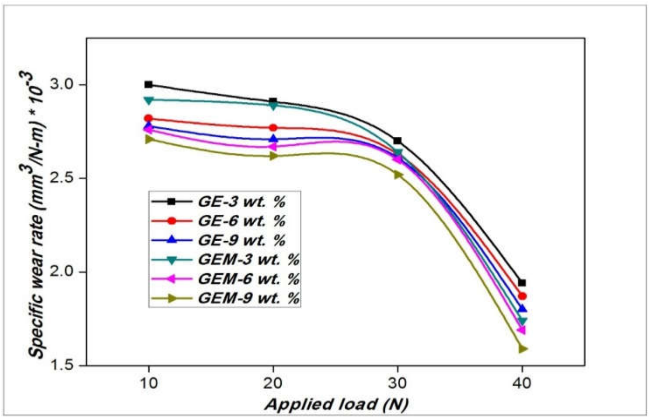


Figure 8. Variation specific wear rate with applied load

This inclination of wear resistance property may be due to better adhesion between fiber and matrix interface and also the flaccid nature of mustard cake filler, which act as barrier against tribological environment (Kumar *et al.,* 2017).

Conclusion

The two groups of environment friendly composites containing grewiaoptiva fiber and combination of grewiaoptiva and mustard cake filler were fabricated. This study revealed that fiber contents (wt. %) and incorporation of agro-waste filler gives the positive effect on mechanical and wear behavior of composites. GE composites with 9 wt. % perform superior in hardness of 34.11 H_v while in case of GEM composites, 9wt. % fiber contents shows highest hardness of 39.01 H_v. The impact energy linearly increases with fibre contents from 3 wt. % to 9 wt. % and hybridization also affected such property. Result shows that GEM with 9 wt. % exhibited maximum value of impact energy. Tensile and flexural strength of both GE and GEM composites increases with the increase of fiber contents. GEM composites exhibited superior in mechanical performance as compared to GE composites, this may be due to the addition of filler improve the composites adhesion and bonding between fiber-matrix interface. Moreover at 9 wt% of GEM composites at 40N load having lowest specific wear rate of 1.59 $\times 10^{-3}$ mm^3/N-m. This study also revealed that these composites may be used where the medium strength and low tribological properties are required such as particle board and polymeric flooring.

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