Study on Impact strength of Untreated and Alkali treated Napier grass fiber strands reinforced Epoxy composites

Venkata Parasuram Kommula, Obi Reddy Kanchireddy, Mukul Shukla, Tshilidzi Marwala

Abstract— Napier grass fiber strands were extracted using the combined mechanical and water retting process. The extracted fiber strands were treated with various proportions (5, 10 and 15% w/v) of NaOH solution to improve their surface morphology and bonding with the resin. This study investigates the impact properties of composites made by reinforcing alkali treated, long and short Napier grass fiber strands in to epoxy resin with different orientations (0º, 90º and random). The composites were prepared with 0, 5, 10, and 15% of alkali treatment and with a fiber loading (weight %) of 10, 20, and 30%. The effect of alkali treatment, orientation and fiber loading on the impact strength of the composites was analyzed using scanning electron microscope micrographs. Quantitative results from this study will be useful for more accurate design of Napier grass fiber strand reinforced composite materials for possible automotive applications.

Keywords— Napier grass, Impact strength, Alkali treatment, SEM

I. INTRODUCTION

TREMENDOUS progress has been made in recent years in the development of natural fibers from renewable agricultural based materials. To find substitution for non-biodegradable-manmade fibers, researchers continued developing many biodegradable natural fibers. Liu et al. [1] and Rao et al. [2] found the properties of thermoplastic and thermosetting composites reinforced with natural fibers that can replace non-biodegradable glass and carbon fibers. Some characteristics of these natural fiber reinforced composites are comparable to conventional materials, which makes them increasingly being used in engineering applications. Advantages like lightweight, low material cost, renewability and environment friendliness are playing a vital role to market these materials. The limitations of these composites however are strength and durability. These properties can be enhanced by improving the interfacial bonding between the fiber and the matrix [3].

Natural fiber reinforced composites have poor wettability, incompatibility with some polymeric matrices and high moisture absorption when these fibers are used as reinforcing composites. The fiber–matrix adhesion is poor due to the incompatibility between the hydrophilic nature of the fibers and the hydrophobic nature of the polymer matrix. Chemical treatment of natural fibers surface helps to improve the bonding between the matrix and the fiber surface. Researchers have used alkali treatment to modify the fiber surface to lower the surface tension and enhance the interfacial adhesion between a natural fiber and a polymeric matrix [4]. Many researchers have reported improvements in mechanical properties of natural fibers when alkalized for different periods and at different concentrations [5-14].

Napier grass also called ‘elephant grass’ belongs to the Poaceae family of *Pennisetum purpurumschum* species and requires very little supplement of nutrients for growth. It can be harvested with a dry biomass yield per hectare per annum of 40 tons [15]. Napier grass is a tall grass that grows in dense clumps up to 3 meters in height. It is yellowish in colour and the stems are about 30 mm wide. Napier grass has been used for biomass production [16]. Earlier researchers have reported the tensile properties of Napier grass fiber [17]. The natural fibers are lignocellulosic consisting α-cellulose as the main component along with hemicellulose and lignin as other components [18-20].

The most serious concern with natural fibers is their hydrophilic nature, which causes the fiber to swell and ultimately rotting them through fungi attack. The natural fibers are also widely used in thermoplastic polymers such as polyethylene, polypropylene and polyvinyl chloride in the preparation of green composites [21].

Photographs of Napier grass clump, stem and extracted fiber strands are shown in Fig. 1.

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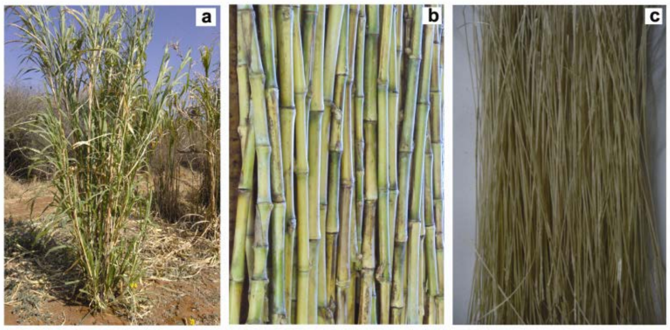

Fig. 1.Photographs of (a) Napier grass clump; (b) Napier grass stem; and (c) Extracted fiber strands

It is reported that alkali treatment has two effects on the fiber: (i) it increases surface roughness resulting in better mechanical interlocking; and (ii) it increases the amount of cellulose exposed on the fiber surface, thus increasing the number of possible reaction sites [22]. Obi reddy *et al.* [23, 24] reported the thermal degradation and tensile properties of alkali treated (up to 5%) Indian grown Napier grass fibers. Murali Mohan Rao *et al.* [25] also reported the tensile properties of Indian grown Napier grass fibers extracted through chemical and mechanical retting processes. The higher modulus and abundant availability of Napier grass fibers have been the prime reasons for the choice of these fibers for the present study [24].

II. MATERIALS AND METHODS

A. Materials

Extracted Napier grass fiber strands, sodium hydroxide, acetic acid (Merck Chemicals), Epoxy (Araldite-LY 556) and hardener (HY951) was used.

B. Extraction of fibers

One year old Napier grass stems were collected from Botswana. Fiber strands were extracted from the internodes of the grass stem by the mechanical combined with water retting process was adopted for extraction of fiber strands from grass internodes. Initially, the stems were cleaned and crushed using a rolling machine to remove maximum amount of pulp and juice. Later they were beaten by a mallet to separate the strands which were washed thoroughly in mineral water and dried in the sun for several days to ensure maximum moisture removal.

C. Alkali treatment

The processed Napier grass fiber strands were treated with 5, 10, and 15% (w/v) sodium hydroxide solution for 2 h at room temperature, maintaining a liquor ratio of 20:1 to remove the surface impurities from the fiber strands. Finally, 0.1% (w/v) acetic acid solution was used to neutralize the fibers, followed by water cleaning. These fibers were dried at 100° C for 24 h in a hot air oven.

D. Composite preparation

A glass mould having dimensions of 160x160x3 mm was used to produce the composite laminates through hand layup process. Initially, the glass mould was covered completely with a Teflon® sheet. The epoxy (degasified) resin, and hardener were mixed in a proportion of 100 and 15 parts by weight, respectively. Finally, the matrix mixture and long Napier grass fiber strands were loaded in to the glass mould in an orderly manner with two different orientations i.e. 0º and 90º. Also short (20 mm) Napier grass fiber strands and matrix mixture were loaded with random orientation. The composite laminates were prepared with different fiber loading i.e. 10, 20 and 30% by weight, and allowed to cure at room temperature for 24 hours. The cured laminates were removed from the glass mould, and post cured in a hot air oven at 100^{o} C for 3h. Test specimens were prepared from these laminates as per the ASTM standard.

E. Impact Testing

ASTM-D 256-05 standard was used to conduct the impact tests. To achieve a statistically significant result for each condition, ten specimens were tested to evaluate the mechanical properties. M/s PSI Instruments make impact testing machine was used to conduct Izod impact.

F. Composite surface morphology

Samples from each untreated and alkali treated specimens were cryogenically cooled and instantly subjected to brittle fracture. The fractured surfaces of these samples were coated with carbon and the micrographs of the fractured composites are recorded using X-Max (Oxford instruments) Scanning electron microscope operating with secondary electron imaging at 10kV.

III. RESULTS AND DISCUSSION

The effects of the alkali treatment, fiber orientation and the fiber loading on the impact strength of Napier grass fiber strands-epoxy composites were studied in this work. In order to test the performance of Napier grass fiber strands reinforced epoxy composites for sudden loading, Izod impact test was used to assess their impact strength.

Fig. 2 shows the impact strength of 0, 5, 10, and 15% alkali treated, 90º oriented Napier grass composites with fiber loading of 10, 20, and 30 %. Alkali treatment had a significant influence on increasing the impact strength of the composites due to improvement in chemical bonding between the matrix and fiber strands. 10% fiber loading of 5%, 10, and 15% alkali treated fiber composites showed an improvement in the impact strength of 57.28, 82.21 and 68.93% respectively, when compared with untreated composites.

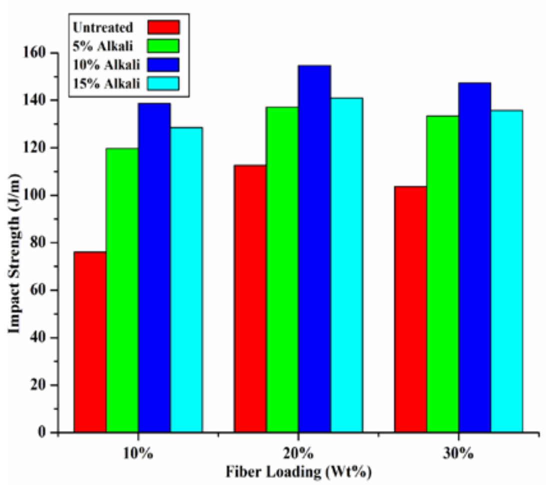

Fig 2. Impact Strength of Napier grass-epoxy composites with 90º orientation

In case of 20%, fiber loading the composites showed an improvement of 21.74%, 37.26% and 25.11%, when compared with untreated composites. At 30%, the composites gained an improvement of 28.67, 42.20 and 30.99%, when compared with untreated fiber reinforced composites. Table 1 shows the impact strength values of Napier grass fiber-epoxy composites with 90º orientation.

Table I. Impact strength of 90º oriented Napier grass -epoxy composites (J/m)

Fiber Loading (Wt %)	Untreated	Alkali treatment (%)		
		5	10	15
10	76.09	119.68	138.65	128.54
20	112.64	137.13	154.62	140.93
30	103.66	133.11	147.38	135.76

The impact strength of composites with same alkali treatment and orientation also depends on the fiber loading. The impact strength of untreated fiber composites loaded with 20 and 30% was 48.03 and 36.20% higher when compared with 10% fiber loading. The impact strength of 5% alkali treated fiber composites with fiber loading of 20 and 30% was 14.58 and 11.43% higher when compared with 10% fiber loading. The impact strength of 10% alkali treated fiber composites with fiber loading of 20 and 30% was 11.51 and 6.29% higher when compared with 10% fiber loading. The impact strength of 15% alkali treated fiber composites with fiber loading of 20 and 30% was 9.63 and 5.61% higher when compared with 10% fiber loading.

Fig. 3 shows the impact strength of 0, 5, 10, and 15% alkali treated, 0º orientated Napier grass composites with fiber loading of 10, 20, and 30 %.

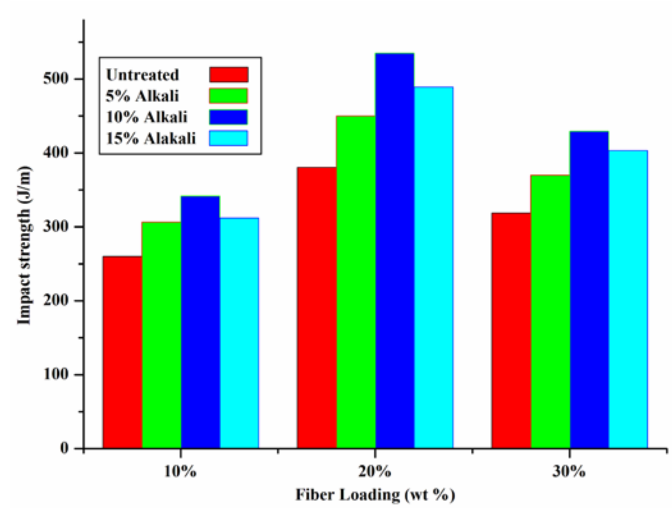

Fig 3.Impact strength of Napier grass-epoxy composites with 0º fiber orientation

Table II. Impact strength of 0º oriented Napier grass composites (J/m)

Fiber Loading (Wt %)	Untreated	Alkali treatment (%)		
		5	10	15
10	260.19	306.65	322	311.88
20	481.55	517.08	534.99	489.16
30	318.93	370.15	429.37	403.18

The impact strength of 0º oriented Napier grass composites are shown in Table 2. 10% fiber loading of 5, 10, and 15% alkali treated fiber composites showed an improvement in the impact strength of 17.86, 23.75 and 19.86% respectively, when compared with untreated fiber composites. In case of 20% fiber loading the composites showed an improvement of 16.06%, 34.62% and 26.41% respectively, when compared with untreated fiber composites. At 30%, the composites gained an improvement of 7.37%, 11.09% and 1.58% respectively, when compared with untreated fiber composites.

The impact strength of composites with same alkali treatment and orientation also depends on the fiber loading. The impact strength of untreated fiber composites loaded with 20 and 30% was 85.08 and 22.58% higher when compared with 10% fiber loading. The impact strength of 5% alkali treated fiber composites with fiber loading of 20 and 30% was 68.62 and 20.70% higher when compared with 10% fiber loading. The impact strength of 10% alkali treated fiber composites with fiber loading of 20 and 30% was 66.15 and 33.34% higher when compared with 10% fiber loading. The impact strength of 15% alkali treated fiber composites with fiber loading of 20 and 30% was 56.84 and 29.27% higher when compared with 10% fiber loading.

Fig. 4 shows the impact strength of 0, 5, 10, and 15% alkali treated, random oriented short (20 mm) Napier grass composites with fiber loading of 10, 20, and 30 %.

The impact strength of composites with same alkali treatment and orientation also depends on the fiber loading. The impact strength of untreated fiber composites loaded with 20 and 30% was 85.07and 22.57% higher when compared with 10% fiber loading. The impact strength of 5% alkali treated fiber composites with fiber loading of 20 and 30% was 68.61 and 20.70 % higher when compared with 10% fiber loading. The impact strength of 10% alkali treated fiber composites with fiber loading of 20 and 30% was 66.14 and 33.34% higher when compared with 10% fiber loading. The impact strength of 15% alkali treated fiber composites with fiber loading of 20 and 30% was 56.84 and 29.2% higher when compared with 10% fiber loading.

Table III. Impact strength of random oriented short Napier grass composites (J/m)

Fiber Loading (Wt %)	Untreated	Alkali treatment (%)		
		5	10	15
10	89.05	125.45	156.81	132.11
20	165.81	234.36	320.01	284.72
30	115.27	195.32	271.28	251.51

The impact strength of random oriented Napier grass short fiber strand composites are shown in Table 3. 10% fiber loading of 5, 10, and 15% alkali treated fiber composites showed an improvement in the impact strength of 40.87, 76.09 and 48.35% respectively, when compared with untreated fiber composites. In case of 20% fiber loading the composites showed an improvement of 41.34%, 92.98% and 71.7% respectively, when compared with untreated fiber composites. At 30%, the composites gained an improvement of 69.44%, 135.34% and 118.19% respectively, when compared with untreated fiber composites.

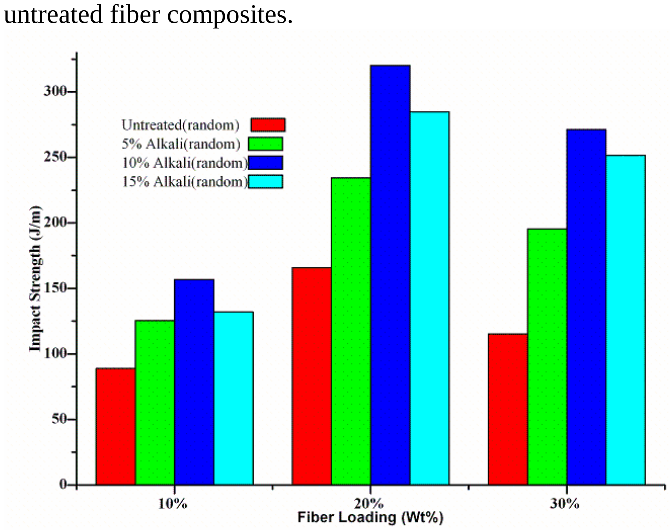

Fig 4. Impact strength of short Napier grass-epoxy composites with random fiber orientation

The impact strength of composites with same alkali treatment and orientation also depends on the fiber loading. The impact strength of untreated fiber composites loaded with 20 and 30% was 86.19and 29.44% higher when compared with 10% fiber loading. The impact strength of 5% alkali treated fiber composites with fiber loading of 20 and 30% was 86.81 and 55.89 % higher when compared with 10% fiber loading. The impact strength of 10% alkali treated fiber composites with fiber loading of 20 and 30% was 104.07 and 72.99% higher when compared with 10% fiber loading. The impact strength of 15% alkali treated fiber composites with fiber loading of 20 and 30% was 115.51 and 90.37% higher when compared with 10% fiber loading.

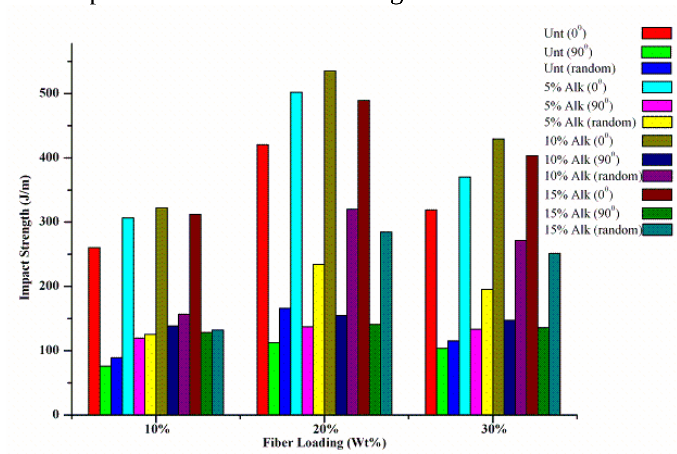

Fig 5. Comparison of impact strength of Napier grass composites with 0º, 90º and random orientation.

The impact strength of 0, 5, 10, and 15% alkali treated, 0º and 90º oriented Napier grass fiber composites with fiber loading of 10, 20, and 30 % was shown in Fig 5. The maximum impact strength of 10% alkali treated, 0º oriented fiber composite with 20% fiber loading was found to be 534.99 J/m. The maximum impact strength of 10% alkali treatment, 90º oriented and 20% fiber loaded fiber composites was found to be 154.62 J/m. The maximum impact strength of 10% alkali treatment, random oriented short fibers and 20% fiber loaded fiber composites was found to be 320.01 J/m. The maximum impact strength of Napier grass fiber composites with 0º orientation are 2.46 and 0.67 times greater than 90º and random orientation fiber composites and times.

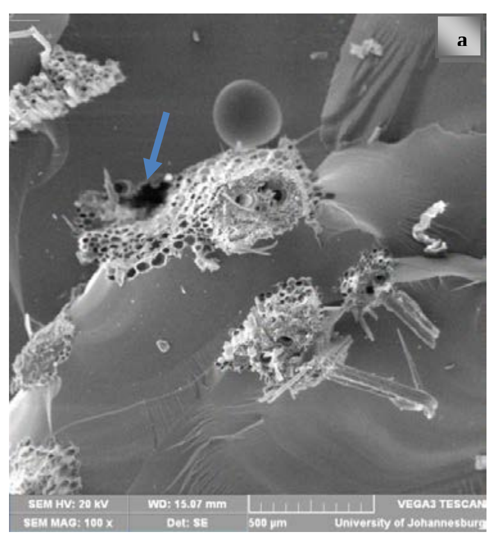

Fig. 6 SEM micrograph of untreated Napier grass fiber reinforced epoxy composite

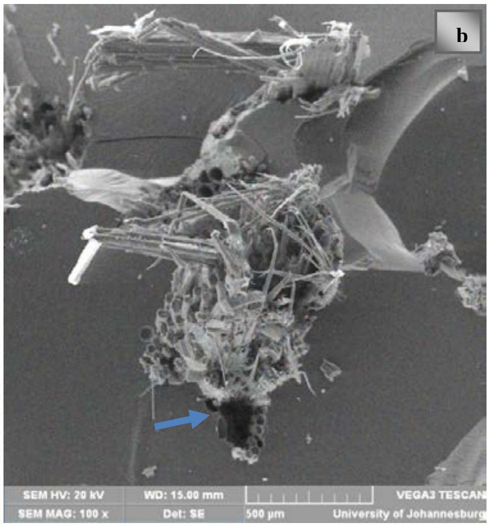

Fig. 7 SEM micrograph of 5% alkali treated Napier grass fiber reinforced epoxy composite

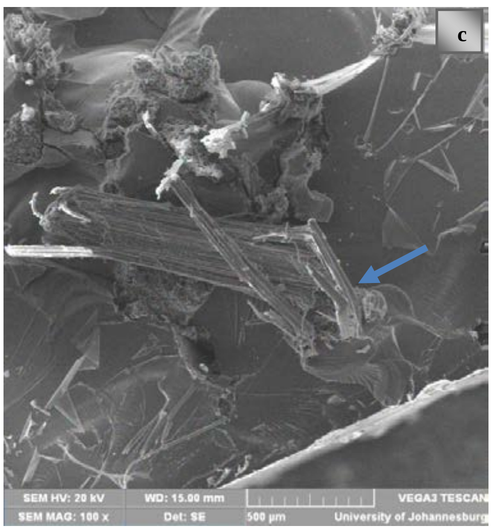

Fig. 8 SEM micrograph of 10% alkali treated Napier grass fiber-reinforced epoxy composite

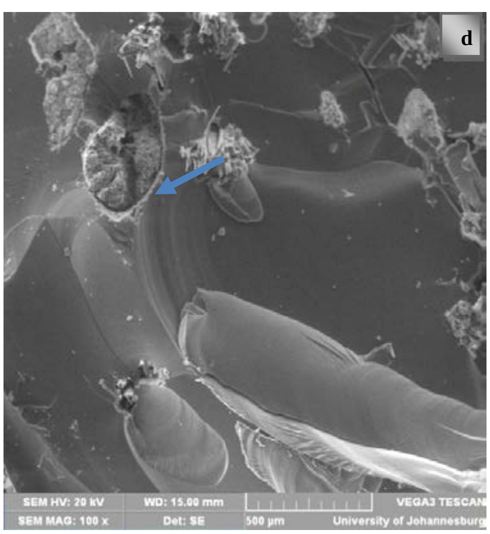

Fig. 9 SEM micrograph of 15% alkali treated Napier grass fiber-reinforced epoxy composite

Fig. 6 - 9 shows the micrographs of untreated and alkali treated Napier grass-epoxy composites. In case of both 0º and 90º fiber orientation, the impact strength was steadily increased up to 10% alkali treatment and with further higher concentration the impact strength was reduced.

SEM micrographs reveal improved bonding of the fiber strands with resin in case of 10% alkali treatment, which resulted in the higher impact strength. In addition, the impact strength of the composites also increased with fiber loading up to 20%. Further, higher fiber loading caused a drop of impact strength, which is due to the reason that most of the mould is filled by the fiber leaving not enough space for the resin for proper bonding.

From Fig. 6 it is evident that, some untreated Napier grass fiber strands appear to be free from the matrix materials without adhering to it, thus indicating poor fiber matrix adhesion causing brittle failure and leaving debris on the fiber surface. The 5% alkali treated Napier grass fiber strands-reinforced composite shown Fig. 7 depicts that the composite is free from most of the cavities and better bonding of matrix to the fiber surface. Fig. 8 illustrates the fracture surface of 10% alkali treated fiber composites have very good mechanical interlocking between fiber and matrix. In Fig. 9 composite reinforced with 15% alkali treated shows few fibers on the fracture surface due to the fiber cover up by the matrix material.

IV. Conclusion

In the present work, impact properties and surface morphology of native and alkali treated Napier grass fiber-epoxy composites were studied. Alkali treatment had a significant effect on the fiber structure and as a result, on the impact strength. The micrographs show an improvement in interfacial bonding between the matrix and the reinforcement by surface modification of fibers. Fiber orientation had a huge influence on the impact energy of the composites. From this study, it is evident that 10% alkali treated fibers at 20% fiber loading gives the best result for both long fibers with 0º, 90º and random orientation. The highest impact strength of 10% alkali treated long Napier grass fiber-epoxy composites with 0º, 90º and random orientations were found to be 534.99, 154.62, and 320.01J/m respectively. The fiber orientation also had great influence on the impact strength of the composite; this favors its application where in the composite industry.

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