Calitropis Gigantean fiber as potential reinforcement for polymer composites-A review

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Abstract

Calitropis Gigantea is an emerging staple fibre for polymer composites. The environmental friendly nature of this natural fibre has caught attention of the researchers worldwide. Recent trends and studies have reported the physical, chemical and mechanical properties of the CG reinforced polymer composites which indicate that the composites can be as proficient as other available options of composites materials. The development of CG composites can fulfil the dire need of green technology which is the demand of current situation. Few studies prove that the treated strands results in high strength of the composites in comparison to the untreated fibers. The treated fibers were found to be suitable for textile industry but the limitation of difficulty in dyeing due to high cellulose content still needs attention. Research shows that the higher amount of fibre loading in composites increases its flexural, tensile and compressive strength but the tribology of these composites is yet to be discovered more in future. The economic nature of CG fibre composites along with attractive specific properties makes it eye catchy in current scenario.

Keywords: Calitropis Gigantea, strand, reinforced polymer composites, flexural, treated fibre

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1. Introduction

Natural Fibre reinforced Composites (NFRC) have recently largely replaced the conventional materials. The quest for developing advanced materials having the qualities like light weight, energy efficiency, economically feasible along with a better substitution for the material based on natural resources, is the motto of material scientists and technologists. One of the most concerning issues amongst them is the problem arising from corrosion, friction, and wear of materials. This leads to the fiscal loss to the industries due to material loss and consequent energy loss. This aspect of material and energy loss needs to be tackled and solved appropriately. Because tribology is synonymous with the reliability, energy saving and long life of components, machines, industry and hence the economy of the nation.

The key reasons why these composites are chosen for these applications are their high strength-to - weight ratio, high tensile strength at high temperatures, high creeping resistance and high toughness. On a macro scale, composites are materials made up of two or more chemically distinct components with a distinct interface separating them and a bulk behaviour that differs significantly from each of the components. They may be categorized into three types, based on the form of matrix materials used, such as metal matrix composites, polymer matrix composites, and ceramic matrix composites. Every type of composite material serves a number of uses. Polymer is the most widely used material in matrix composites. There are two fold advantages to this explanation. First, their strength and rigidity are weaker than that of ceramics and metal, and these limitations are overcome by strengthening other polymer materials. Secondly, polymer matrix composite processing doesn't need high pressure and high temperature. For these reasons composites of the polymer matrix are rapidly emerging and soon becoming popular for structural applications. There are two main polymer groups that are used as matrix materials, including thermoplastics and thermosets. Thermoplastics (polypropylene, nylons, acrylics etc.), by heat application, can be softened and re-formed repeatedly. On the other hand, thermosets (phenolic, epoxies, etc.) are products that undergo a process of curing during part manufacturing, after which they are rigid and cannot be re-formed. Epoxy is the most widely used matrix due to its benefits such as good adhesion to other materials, good mechanical properties, good electrical insulating properties, good chemical and environmental resistance, and so on.

The new research strategy in the field of materials has the sole goal of achieving energy conservation, economic viability, and a better substitute for natural resources around the world. Most of the industrialized nations are facing serious problem of machine parts and components and high-energy consumption due to wear and friction. Thus, friction and wear is one of the most important obstacles in the path of technological progress.

Natural fibre reinforced polymeric composites (NFRC) have attracted increasing attention because of their cost effectiveness, availability, renewable resources, low density and biodegradability in association with high specific strength. These advantages are of interest to the automotive industry, which requires materials of light weight, high performance/weight ratio, recycling possibility, and minimum environmental impact. Natural fibres have been used as a good reinforcement material for some polymeric materials, and the mechanical properties have been documented in the literature. Sisal, banana, kenaf, hemp, and flax fibre reinforced polymer composites have been the topic of extensive amounts of research in past decade. Calitropis Gigantea (CG) is another natural fibre which is emerging as a trend due to its novelty and indifferent properties. Though the CG fibre has good potential as reinforcement, there is very less work available on CG reinforced polymer composites.

2. Overview of Calitropis Gigantea fibre

Calotropis gigantean (madar), also known as milkweed or swallow wort, is a common wasteland weed of the Asclepiadaceae family. The tree, which is indigenous to India, grows wild throughout the country on a variety of soils and climates, as well as on barren lands. Since, CG fibre has a low density and a high specific strength, it is an excellent reinforcement material [13].CG fibers have recently attracted the attention of researchers, scientists, engineers worldwide. In this area, there are only a few studies that have been published. Qin Chen et al. [9] reported the structural and chemical composition of these three kinds of natural fibers viz. Calotropis Gigantea, kapok and cotton. Their mechanical characteristics and water retention capacities were also assessed and compared. It was found that both C. gigantean fibre and kapok fibre exhibit a high degree of hollowness (80– 90%), and no natural twist exists. Qin Wang et al. [10] studied the need for fibre modification and the principles about how the reagents act on the fibers. The feasibility of using two types of mudar (Calotropis Gigantea) fibres, bark fibres and seed fibres, as an alternative raw material for fibre-reinforced composites was investigated by Ashori and Bahreini [1]. They discovered that both types of fibres have the potential to replace or supplement other fibrous raw materials as reinforcing agents. Kandeepan et al. [3] investigated the mechanical properties of stem derived madar fibre. They found that the composite with fibre to resin ratio 40/60 exhibited better mechanical properties. Dwivedi et al investigated that the addition of Nano fillers like multiwalled carbon nano tubes improved the tensile strength of the CG phenolic composites along with enhancement of PV limit [12]

2.1 Notable works:

Morphological, mechanical and chemical analysis: A morphological analysis by Ashori et al. outlines the possibility of employing two different type of mudar fibre in preparation of fibre reinforced composites. Bark fibres and seed fibers being used for preparation of composite samples. The chemical study reveals the main components in these fibers are holocellulose, cellulose and alkali soluble substance. The percentage of these three components in bark fibre is quoted to be 76%, 57% and 17% respectively while in seed fibers it is 69%, 49% and 15% respectively. Also the lignin content was found to be 18% in bark fibre and 23% in seed fibre. A significant difference has been found in dimensions of bark and seed fibers. The bark fibers are lightweight due to their geometry of possessing thin wall relative to their diameter and these fibres are long in dimensions. The bark fibers are very similar to soft wood while seed fibers are analogous to hard wood, in terms of fibre dimensions and chemical compositions. The tensile strength of bark fibers is found to be 381Mpa, strain bearing capacity-2.1% and young modulus-

9.7GPa.The study indicates that the morphology of two types of discussed fibers poses strong potential for replacing many conventional raw materials as reinforcing agent [1].

Tensile and wear characterization: Dilli Babu et al. aimed to investigate the tensile and wear activity of Calitropis Gigantea fruit fibre reinforced polymer composites. The composites were tailored from Calotropis Gigantea fibres collected through manual processes. The composites are fabricated up to a maximum volume fraction of fibre of 0.35. According to wear test study, the tensile strength improved as the fibre content increased. Qin Wang et al. discussed the physical, chemical, and tensile properties of CG fibres in another research. According to the findings, the CG fibres have good duration, strength, uniformity, fineness, and moisture absorption. The study emphasises the difficulty of spinning 100 percent CG yarn. The outcomes of a 75/25 mudar/cotton blend spun successfully in a cotton spinning machine have been analysed. Smooth CG fibres that have been treated with 5% NaOH produce convolutions that make spinning possible. The yarns have ample potential in the application of natural fibre-reinforced composites and industrial applications viz. textiles [10]. Venkatrajan et. al. analysed the CG-glass-phenol formaldehyde and CG-areca-phenol formaldehyde composites prepared by simple hand lay-up method. The results indicated addition of Areca fibres enhances the impact strength of the composites by 6.8% in comparison to other hybrid composites. The samples showed superior tensile properties which had CG fibre content of 17.5 wt. % and the areca fibre content of 17.5 wt. % shows the higher tensile properties than the other hybrid composites [11].Raghu et al. analysed that Calitropis procera-glass fibre composite in percentages of 5 and 15 respectively, showed less wear loss in composites as indicated by results of sliding wear test and abrasive wear test. The increase in speed, load and abrasive size also resulted in increase of wear loss [6].

Table 1.Tensile and Impact strength variation with respect to fibre to resin ratio[3]

Fibre to resin ratio	Impact strength	Flexural strength	Tensile strength	Compressive strength
50/50	0.76	38.3	21.3	39
40/60	2.722	56.2	38.4	45
30/70	1.576	44.7	34.82	32.5
20/80	1.001	34.6	25.72	26.8

Mechanical, thermal and tribological analysis: Mechanical properties of CG fibres have been identified in the majority of articles. Srinivas et al. published research on the mechanical and machining properties of composites made from mudar fruit fibre. The use of Chemical treatments ends in improving interfacial matrix-fibre bonding, which in turn enhances the mechanical properties of the composites [4].Vinod et al. developed jute fibers epoxy composites filled with CG filler by hand lay-up process and analysed thermomechanical properties. The tensile, flexural, compression, hardness, and impact properties for CG filled composites indicated superior results in comparison to the ones which were non filled or partially filled. The thermogravimetric analysis revealed that the CG-filled samples were more thermally stable (TGA).TGA indicated that higher the filler content in composites, higher was the thermal stability. Scanning electron microscopy was used to examine the matrix bonding, cracks, voids, filler distribution, scale, fibre pull out, and fracture nature of the composites. Calitropis Gigantea filler filled jute fibre epoxy composites indicated considerable raise in thermal and mechanical properties in comparison to the non -filled and partially filled composites [2]. An Investigation by Ganeshan et al proves that the addition of red mud as a filler considerably enhances the mechanical properties of the CG composites. Red mud is side product of obtained during the extraction of aluminium from bauxite ore. The filler enhances the adhesive forces between CG fibre and polymer matrix and thereby improving the mechanical properties of composites. The study shows that the tests for tensile, impact and flexural properties have been conducted as per ASTM standards. Compression moulding has been used as the preparation methodology [7].Quin Chen et al. compared the properties of Calotropis Gigantea (CG fibers), kapok and cotton fibers with each other. All three fibers are cellulosic in nature and are well suitable for textile industry. In the reported research, the structure and chemical composition of the above mentioned fibers have been studied and the dyeing properties of fabrics produced from each of them has been compared. The purpose of this study is to provide a theoretical basis for the application of C. Gigantic fibre used in textiles. The anatomy of the surface and the cross section of C Giant fibers were analysed by scanning electron microscopy compared to kapok and cotton fibers. Fourier Transform-infrared spectroscopy and X-ray diffraction analysed their fibrous structures. The mechanical properties and water absorption capabilities have also calculated and compared. Both C. Gigantea fibre and kapok fibre show a high degree of hollowness (80–90%), without natural twist; CG fibers produces a certain amount of lignin and hemicellulose. CG fibers shows 42.54% crystallinity and their crystallinity orientation index have been quoted to be 85.40%. CG fibers possess lowest tenacity but the highest water content of all three fibre types. The dyeing test results indicate that it is CG fibre fabric has the lowest absorption of dye [9]. Chordiya et al has reported the improved mechanical properties of CG reinforced composites after Silane treatment of CG fibers. Silane treatment reduces the density of CG fibre as indicated by graphical results and hence improves the strength of fibre [8].The tribological analysis by Dwivedi et al. shows that CG fibre is excellent as a reinforcement material and the findings show that bonding of the fibre with phenolic resin is excellent. At different loads, the pure phenolic value has the highest coefficient of friction. Treatment with Nano filler plays an important role in reducing composite wear. The inclusion of CG fibre in the phenolic matrix increased the PV limit, i.e. the ability to resist operation against applied load. In phenolic samples, the CG fibres promote lower friction against the EN-31 steel counter face. [12]

Comparative analysis:

- Tensile strength: The tensile strength of CG composites increases with increase in fibre content. At a 35/100 volume fraction of CG fibre, the maximum tensile strength was found to be 52.26. The tensile modulus increases with fibre content and is found to be 1.25Gpa, while the coefficient of friction is inversely proportional to fibre content [5]. The tensile strength of CG hybrid composites is greatest when the resin percentage is 60% and the fibre percentage is 40% [3]. In contrast to untreated samples, Silane treatment of Calitropis procera fibre increases composite strength by 19.05 percent, while tensile modulus increases by 10.28 percent[8].The incorporation of areca fibres to CG fibres in phenol formaldehyde, the overall tensile strength is 58.9 Mpa, and the tensile modulus is 1298.3[11].
- Wear: The wear analysis of CG composites by Dilli et al. reflects that weight loss of composite samples was 0.281 times more than pure polyester[5].The addition of glass fibre shows less wear loss in Calitropis procera and epoxy composites[6].The Nano filler(carbon nano tubes) treatment of CG-phenolic composites helps in reducing the wear rate[12].
- Flexural strength: The flexural strength of treated fibre composites is found to be 42.08% higher than the untreated fibers composites. The flexural modulus has also increased by 5.85% [8]. Flexural strength is greatest at a ratio of 60 to 40 for resin and fibre, respectively [3]. The inclusion of areca fibre to CG fibres in phenol formaldehyde results in a 35 percent increase in flexural property [11].
- Impact strength and energy: In contrast to untreated fibre composites, Silane treated fibres have a 24.70 percent rise in impact energy[8].For impact strength, a ratio of 60% resin to 40% yields reasonable results[3]. The incorporation of areca fibres to CG composites increases impact strength of the composites [11].

3. Conclusion

The fabrication of CG composites is expected to meet the urgent need for green technology, which is currently in demand. The tribological analysis reflects that Calitropis Gigantea is excellent as reinforcement. It shows good bonding with phenolic and epoxy resins. Few studies shows that incorporation of red mud filler and other fibres like glass and areca can improve the mechanical as well as tribological properties of the CG composites. The addition of carbon Nano tubes in phenolic CG composites enhanced the operating capacity to withstand load (PV limit), reduced wear rate and decreased coefficient of friction. These light weighted fibres have their distinct properties, which when processed with polymeric resins gives combination of properties and hence can be discovered more in future.

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