Investigations of tensile properties of modified epoxy-based composites reinforced with kenaf/hemp fibers for orthopaedic implants

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Abstract. The aim of this work intense on study of Femur Bone and compilation of the strength and further parameters of bone and compare the investigational results of the 12%, 18% & 24% NFRPC material with the Femur bone. This study signifying the lowest-weight, lowest-Density and highest-strength Bio composite, biocompatible material utilizes or advises to the Orthopedic Implants particularly for Femur bone. From the investigational results of Tensile strength of all 12%, 18% & 24% NFRPC material will match with femur Bone strength and recommended these polymers for Femur bone replacement.

1. Introduction
CM (Composite material) is made when more than two material (reinforce, fillers, and binder) unify (merge) together of different physical and chemical properties, upon collaboration it will yield a material with unique properties [1]. Within the composite, materials which were unified will not blend or federate to each other. By adopting this can improve the characteristics of base material and are applicable in many instances for instance to become lighter, stronger, and resistant to electricity [2]. The cause for improved unique strength, resistant to electricity, durability in composite is due to reinforcing phase. The reinforcement generally refers to fiber or particulate. Particulate composite consists of very small particles of one material in-built in to another material [3]. The particulate can be very close to that of size of <0.25 Microns particles, fibers are chopped like platelets, hollow spheres etc. they act as a reinforcement to the matrix material, by this enhancing the strength of the material. It will result in providing great creep resistance, extraordinary tensile strength at elevated temperatures, improved toughness, and increase in strength to weight ratio (lesser density and higher tensile strength). It is used in metals such as AL alloy, polymers, and ceramics.

1.1. Necessary of Composites
Composite can also afford design resilience (flexibility) because many of them can be moulded into difficult (complex) shapes. Composites can be used in various streams with low maintenance and its environmentally friendly nature is one of the reasons for choosing it. A cramped (small) elite (crack) in a piece of metal can spread promptly (rapidly) with serious consequences (ie. in aircraft). But the fibers in composite deed (act) block the widening of any cramped elite and to share the stress around. Proper composition will result in providing resistance to corrosion and heat. This makes them to use in the components which are subjected for extreme environment such as space craft, chemical-handling equipment and boats etc. Steels and other major materials cannot be completely replaced by
composite. But in many cases, they are just what we needed, and no doubt new uses will be found as the technology evolves [4].

2. Literature survey

Ribot et.al they came to know that the kenaf base fiber has got more strength (tensile) than the natural fibers like jute, sisal etc. The kenaf fiber has got tensile strength of range 400-550Mpa. So, the kenaf fiber will fall into the group of good reinforcement material, hence in polymer composite material it can be used as reinforcement material and it has got all the required properties [1]. D. Chandramohan et.al this research suggests us to adopt the renewable resources and make use of their advantage which is offered by them in the stream of orthopaedics for implant of bone. The bone plate of polymer composite with natural fiber reinforcement has got faster fracture healing property within it. It provides proper environment for the growth of bone which will help in increasing bone density [2].

Giuseppe Cristaldi et.al during their research on composite material they concentrated on the natural fibers and their uses, and they chose it has reinforcement material in composite. Most of the researchers will employee this as reinforcement because of their environmental and cost-effective property. Even it has got his own limitation and which need to be overcome for proper utilization of this [3]. Hajnalka Hargitai et.al on his work and as well as by considering the mechanical test it is concluded that 40-50% of hemp fiber is optimum and dry composite samples has got fewer bending properties than the wet sample [4].

Girisha et.al while carrying their research work, the investigation is carried out on the composite which are fabricated with sisal, coconut spath as reinforcing material for testing the tensile properties. The alkali treatment is carried out on the natural fibers which are extracted by manual as well as retting process. Composite with a reinforcement of natural fiber of individual type shows less tensile strength when compared to reinforcement of hybridization type [5]. H G Hanumantharaju from his research work he concluded that the alumina can be used as substitute (alternative) material for bone in the field of orthopaedic based on the following consequence’s (reason) i.e., the density and as well as the mechanical property of the Ti-6Al-4V is less and better than SS316L respectively. If we considered the test like wear test alumina exhibit less weight loss than the SS316L. In case of weight SS316L is more weight when compare to the alumina. It also exhibits low material density [6]. Mohammed Haneef et.al they have concluded that if the percentage of reinforcement increases in the hybrid polymer composite, then there will be increase in the strength like hardness, tensile and bending. The density of hybrid polymer composite also increases. If the TiO2 and Al2O3 used along with the polymer matrix composite will have plenty of utilization in the human body [7].

Ramesh K et.al for the improvement of mechanical property they have used the Al2O3, SiO2 and TiO2for modifying the matrix (i.e. epoxy matrix). Hand lay-up method is used for the manufacturing of composite material. The other micro modifiers will exhibit less ILSS, flexural strength and modulus when compared with the SiO2 modified epoxy composite [8]. S. Rajesh et.al with the various proportion of SiC and Al2O3 with GFRP by using the silicon carbide and aluminium oxide they have manufactured the composite with epoxy and polyester resin. To identify the properties of composites which are fabricated the various tests are conducted like shear bi axial, tensile, impact etc. finally they arrived to a conclusion that the polyester resin composite will show less strength when compare to the epoxy resin composite [9]. Anant K et.al they stated that the aluminium oxide plays vital role in increasing the erosion resistance when compared to the pure epoxy. If the percentage of this content increase in the epoxy composite will directly proportional to the erosion resistance (i.e. it will also increase the erosion resistance). At the temperature of 35degree Celsius we can get high erosion resistance by the use of 3% and 6% of glass fiber and micro Al2O3 respectively. We can get high erosion resistance when compared to the unfilled epoxy composite by the use of TiO2. Impact velocity and erodent temp are the reason for the erosion wear [10]. D. Chandramohan.K et.al they came to know that, when natural fibre - reinforced epoxy composites with the help of three different tool materials and geometries are allowed to flexural test, below conclusions could be drawn: Comparatively, the composites performed better. Brittle like failure was observed when Banana and Sisal Fibers were put under flexural loading condition. One could observe Elliptical Cracks as well as their fast propagation [11].
Naveen Kumar. et.al they concentrated to study the biological application of the titanium oxide-based materials in the field of biological world. At the end of their research work they concluded that the above-mentioned material can be used as biomaterial because of their properties like high stability and biocompatibility [12]. N. Pavan Kumar.et.al they carried a research work to study the GFRP mechanical properties with the white cement as filler material by varying its weigh percentage (i.e., 0,5,10wt%) by hand layup fabrication method. The specimens were prepared according to the standards (i.e., ASTM) and later they are subjected to the various tests (i.e., flexural, tensile test). Upon conducting the above-mentioned test, they arrived to the conclusion that the filler material (white cement) also influences the mechanical properties of composite such as flexure and tensile strength [13]. Ranganath S R et.al they have tried to study the behaviour (mechanical) of CFRP which is filled with percentage of 2%, 4%, 6% of aluminium oxide. During this study the aluminium oxide filled CFRP is compared with CFRP without filler and finally arrives to a conclusion that as the filler content increases the hardness of the surface increases [14].

3. Methodology
The methodology is followed by complete survey of published literature related to present work, Characterization is carried out using Epoxy resin as a matrix material & hardener with (12, 18, 24%) Natural fibers as the reinforcement the specimens are prepared along with Al2O3 as filler material, the tensile samples are done as per ASTM-D3039/D-3039 M-00, and finally concluding the results.

4. Natural Fiber Preparation
During the fabrication of these composites (i.e., natural fiber composites) continuous fiber is used. The steps used are as follows:

| Steps | Process |
|-------|---------|
| Comprehensive literature survey to make complete survey of published literature & compiling relevant data. | |
| Characterization is carried out using Epoxy resin as a matrix material & hardener with (12, 18, 24%) Natural fibers as the reinforcement the specimens are prepared along with Al2O3 as filler material | |
| Tensile specimens are prepared as per ASTM D3039/D-3039 M-00 i.e. 250x25x2.5 mm (LxWxT) | |
| Compare the results with Femur Bone and conclude the result. | |
| Compilation of analysis and drawing conclusion. | |

Figure 1. Methodology Flow Chart.

Table 1. Steps Involved in Natural Fiber Preparation.
With the help of distilled water cleaning of the natural fiber is done.

Drying process is carried out in the sun light for the above cleaned natural fiber.

The above dried natural fibers are subjected to chemical cleaning.

we can obtain the fibers with smooth nature by dipping above fiber in dilute NaoH

By subjecting them to sun light we need to dry it once again

By manual process the natural fiber is chopped into various required size

The above natural fibers are made to use in fabricate the natural fibers reinforced composite material.

4.1. Kenaf

Kenaf belongs to a family called Malvaceae. The main purpose of growing it is for fiber for the production of rope, papers and anything which needs fiber. For thousands of years this plant is planted and has been grown in some part of the world like India, Bangladesh, Pakistan, Afghanistan and Africa.

Figure 2. Kenaf.

The main use of this fiber is during the recycling of papers, we can recycle the papers only one or two times after that fiber become too short so they cannot be recycled further. But by mixing recycling papers with fibers coming from kenaf will increases the number of recycling frequency. The Ford and BMW using the kenaf to build their automobile body, the first implementation of kenaf within a ford vehicle was in 2013. Kenaf is even used in the petroleum industry as a product called drill wall that keeps the fluid around the drilling bit, it prevents the loss of these fluids that would otherwise be deposited back into earth’s soil. The Egyptians four thousand years ago were using the fibers out of this plant to make the sails for their ships [15].

4.2. Hemp

Hemp is rapidly renewable and hemp stocks grow in six months compared oak trees which can take decades. Hemp was widely grown in the USA until the 1900s, 80% of the world’s textiles and fabrics were made of hemp and 70 to 90% of all the paper made in the world was also made of hemp. However, it was made illegal under the marijuana tax act of 1937 and the controlled substances act of 1970. So, the US had to import 500 million dollars’ worth of hemp every year for their products and finally hemp farming is finally legal again under the agricultural act of 2014 and the form bill of 2018. The most popular hemp product in construction industry is Hemp Crete. It can be used as both construction and insulation.
Hemp Crete wall has capability to regulate the temperature and humidity inside the structure and it also resists fire mold and vermin and eliminates the needs for the vapour barrier and gypsum drywall. Another big advantage of hemp Crete is that its environmentally friendly. It’s a pretty flexible material to work with and it takes the shape of the form work into which it is poured so that you can create curved walls. Hemp has a low level of THC less than 0.3% but have high level of CBD usually 12 to 18%. Hemp has no psychoactive effect but it can help with seizures, inflammation, pain, migraines etc [16].

4.3. Aluminum oxide

The chemical formula of aluminium oxide is Al₂O₃. Alumina is most commonly used name. it has other name like aloxite, or alundum, which depends upon the application in which it is used. Aluminium oxide is associated with strongest bonding between the atoms it is associated with high strength (i.e. mechanical, compressive) [8]. The most important property which plays prominent role in this is its Hardness about 15 to 19 GPa. It exhibits moderate thermal conductivity. It mostly used as abrasive. It won’t get dissolve in H₂O (i.e., water) and has high melting point. The boiling point is immensely high. the drawback of this is the dust which comes out from it. It may cause irritation to the exposed area of human body. It may result in tissue damage [17].

5. Experimental Testing

5.1. Tensile Test
Specimen is cut into flat shape of (250x25x2.5) mm, is according to ASTM standards D-3039/D-3039M-00 [18] and is shown in figure 5.

Figure 5. ASTM Specification of Compression Test Specimen.

5.2. Specimen Set-up in UTM

Figure 6. Compression Testing Setup.
6. Results and Discussion

6.1. Tensile Test Results from Hand Layup Method
The results obtained from tensile tests from Hand Layup Method [19] are shown in Figures 7 to 9.

**Figure 7.** Tensile tests results of Kenaf reinforced composites from Hand layup method.
Form the above figure 7 it is observed that as the reinforcement of kenaf fiber get increased from 12%, 18% and 24% the applied force is shared by the fibers and it implies in increase in the Tensile strength of the composites.

**Figure 8.** Tensile tests results of Hemp reinforced composites from Hand layup method.
Form the above figure 8 it is observed that as the reinforcement of hemp fiber get increased from 12%, 18% and 24% the applied force is shared by the fibers and it implies in increase in the Tensile strength of the composites.

**Figure 9.** Tensile tests results of Hemp and Kenaf reinforced composites from Hand layup method.

Form the above figure 9 it is observed that as the reinforcement of hybrid fiber (kenaf & hemp) get increased from 12%, 18% and 24% the applied force is shared by the fibers and it implies in increase in the Tensile strength of the composites.

**6.2. Tensile Test Results from Vacuum Bag Method**

The results obtained from tensile tests from Vacuum Bag Method [20] are shown in Figures 10 to 12.

**Figure 8.** Tensile tests results of Kenaf reinforced composites from Vacuum Bag method
Form the above figure 10 it is observed that as the reinforcement of kenaf fiber get increased from 12%, 18% and 24% the applied force is shared by the fibers and it implies in increase in the Tensile strength of the composites.

![Figure 11. Tensile tests results of Hemp reinforced composites from Vacuum Bag method.](image)

Form the above figure 11 it is observed that as the reinforcement of hemp fiber get increased from 12%, 18% and 24% the applied force is shared by the fibers and it implies in increase in the Tensile strength of the composites.

![Figure 12. Tensile tests results of Hemp and Kenaf reinforced composites from Vacuum Bag method.](image)

Form the above figure 12 it is observed that as the reinforcement of hybrid fiber (kenaf & hemp) get increased from 12%, 18% and 24% the applied force is shared by the fibers and it implies in increase in the Tensile strength of the composites.
7. Conclusion
The following are the observations listed by above results:

- The density of polymer composite materials is approximately 1304 Kg/m\(^3\) and it is similar to the density of bone (1000 to 2000 Kg/m\(^3\)) is shown in the figure 13.

![Figure 12. Density of the Composites.](density.png)

- The Tensile Properties of the polymer composite with 12% hemp long fibre reinforced from Vacuum bag method is observed to be more than the 12% hemp long fibre reinforced from Hand layup method.
- The Tensile Properties of the polymer composite with 18% Kenaf long fibre reinforced from Vacuum bag method is observed to be more than the 18% Kenaf long fibre reinforced from Hand layup method.
- The Tensile Properties of the polymer composite with 24% hemp and Kenaf long fibre reinforced from Vacuum bag method are observed to be more than the 24% hemp and Kenaf long fibre reinforced from Hand layup method.
- The Tensile Properties of the polymer composite are in the acceptable rage when compare to bone properties and it can suggest for replacement.

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