Mechanical behaviour of hybrid composite filled with flax fiber

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ABSTRACT

Fibre reinforced polymer composites has been used in a variety of application because of their many advantages such as relatively low cost of production, easy to fabricate and superior strength compare to neat polymer resins. Reinforcement in polymer is either synthetic or natural. Synthetic fibre such as glass, carbon etc. has high specific strength but their fields of application are limited due to higher cost of production. Recently there is an increase interest in natural fibre based composites due to their many advantages. In this connection an investigation has been carried out to make better utilization of sisal fibre for making value added products. The objective of the present research work is to study the physical, mechanical and water absorption behaviour of flax fibre reinforced epoxy based hybrid composites. The effect of fibre loading and length on mechanical properties like tensile strength, flexural strength, hardness of composites is studied. Also, the surface morphology of fractured surfaces after tensile testing is examined using scanning electron microscopy (SEM).

Keywords: Polymer, Flax fiber, Synthetic fiber.

1. INTRODUCTION

The development of composite materials and their related design and manufacturing technologies is one of the most important advances in the history of materials. Composites are the material used in various fields having exclusive mechanical and physical properties and are developed for particular application. Composite materials having a range of advantages over other conventional materials such as tensile strength, impact strength, flexural strengths, stiffness and fatigue characteristics. Because of their numerous advantages they are widely used in the aerospace industry, commercial mechanical engineering applications, like machine components, automobiles, combustion engines, mechanical components like drive shafts, tanks, brakes, pressure vessels and flywheels, thermal control and electronic packaging, railway coaches and aircraft structures etc.

When two or more materials with different properties are combined together, they form a composite material. Composite material comprise of strong load carrying material (known as reinforcement) imbedded with weaker materials (known as matrix). The primary functions of the matrix are to transfer stresses between the reinforcing fibres/particles and to protect them from mechanical and/or environmental damage whereas the presence of fibres/particles in a composite improves its mechanical properties like tensile strength, flexural strength, impact strength, stiffness etc. Composites can be classified according to different criteria. Depending on the type of matrix materials, composite materials can be classified into three categories such as metal matrix composites, ceramic matrix composites and polymer matrix composites. Each type of composite material is suitable for specific applications. When the matrix material is taken as a metal like aluminium, copper, it is called as metal matrix composite. These are having high ductility and strength, good fracture toughness, inter-laminar shear strength and transverse tensile strength and also having superior electrical and thermal conductivity. These materials are high dimensional stable due to low thermal expansion coefficient of matrix and withstand to high temperature. Due to high elastic modulus of reinforcements they have very high stiffness. When the matrix material is taken as ceramic it is called as ceramic matrix composite.

Ceramic material include a wide verity of inorganic materials likes bricks, pottery, titles also include oxide, nitrides and carbides of silicon, aluminium, zirconium etc. They are normally non-metallic and processed very often at high temperature. The main objective in producing ceramic matrix composites is to enhance the toughness, high strength and hardness, high temperature properties, wear resistance etc.

Polymer matrix composites consist of a polymer resin as the matrix material which filled with a variety of reinforcements. This kind of composite is used in the greatest diversity of composite applications due to its advantages such as low density, good thermal and
Electrical insulator, ease of fabrication, and low cost. The properties of polymer matrix composites are mainly determined by three constitutive elements such as the types of reinforcements (particles and fibres), the type of polymer, and the interface between them. Polymers are divided into two categories such as thermoplastics and thermosets. Thermoplastic are in general, ductile and tougher than thermoset materials. They are reversible and can be reshaped by application of heat and pressure. Thermoplastic molecules do not cross-link and therefore they are flexible and reformable. Generally, thermoplastics show poor creep resistance, especially at elevated temperatures, as compared to thermosets. Their lower stiffness and strength values require the use of fillers and reinforcements for structural applications. The most common materials used in thermoplastic composites are nylon, polyetheretherketone, Acetal, polypolyethylene, teflon, polyethylene etc. Thermoset are materials that undergo a curing process through part fabrication and once cured cannot be re-melted or reformed. Thermoset materials are brittle in nature and offer greater dimensional stability, better rigidity, and higher chemical, electrical, and solvent resistance. The most common resin materials used in thermoset composites are epoxy, polyester, phenolics, vinyl ester, and polyimides.

Based on the types of reinforcement, polymer composites can be classified as particulate reinforced polymer composite and fibre reinforced polymer composites.

**Particle reinforced composites** also called particulate composites consisting of reinforcing material that is in the form particle. The shape of reinforcing particle may either spherical, a platelet, cubic, tetragonal, or of other regular or irregular geometry. The arrangement of the particles in the composites may be either random or preferred orientation. Generally, particles are used in composites to modify the thermal and electrical conductivities, improve performance at elevated temperatures, reduce friction, increase wear and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage.

**Fibre reinforced polymer composites** also called fibrous composites consisting of fibres as the reinforcement. Now-a-days, these composites have found applications in various areas such as automotive, marine, aerospace etc. due to their high specific stiffness and strength. Generally, fibres are the most important class of reinforcements in composite materials, as they satisfy the desired conditions and transfer strength to the matrix constituent, influencing and enhancing their desired properties. A fibre is characterized by its length being much greater as compared to its cross-sectional dimensions. The properties of matrix, fibre and its interface have greatly influencing the properties of composite materials.

Fibres in polymer composites can either synthetic/man-made fibres or natural fibres.

Some commonly used synthetic fibres for composites are glass, aramid and carbon etc. There are many types of glass fibre depending upon the type of application like E-glass fibre (electrical application), C-glass (corrosive environment), S-glass (structural application, high temperature). Glass fibres are available in various forms such as continuous, chopped and woven fabrics etc. If the fibres are derived from natural resources like plants or some other living species, they are called natural-fibres.

Among all reinforcing fibres, natural fibres have gained great significance as reinforcements in polymer matrix composites. Depending upon the source of origin, natural fibres are classified as plant, animal and mineral fibres. Recently, due to the growing global energy crisis and ecological risks, natural fibres reinforced polymer composites have attracted more research interests. The main advantages of natural fibres are their availability, biodegradable, renewable, environmental friendly, low cost, low density, high specific properties, good thermal properties and enhanced the energy recovery, low energy consumption, non-abrasive nature and low cost. A great deal of work has been carried out to measure the potential of natural fibre as reinforcement in polymer such as jute, coir, bamboo, sisal, banana and wood fibres have been reported. Plant fibres are justifies their use as reinforcement for polymer composites due to their renewability with good mechanical properties. It is also observed that natural fibres are non-uniform with irregular cross sections, which make their structures quite unique and much different from man-made fibres such as glass fibres, carbon fibres etc. The properties of some of these fibres are presented in the following table. These fibres are low-cost fibres with low density and high specific properties which are comparable to synthetic fibres.

Among various natural plant fibres, jute fibre has a great potential to be used as reinforcement in polymer composites. Over hundreds of years jute has been used in the applications of ropes, beds, bags etc. Jute is abundantly available in countries like India, Bangladesh, China, Nepal and Thailand. It possesses high toughness and aspect ratio in comparison to other natural fibres. Jute is a lingo-cellulosic fibre and its composites have high impact strength with moderate tensile and flexural properties compared to other fibres like coir, sisal, pineapple, banana etc. The inborn properties of jute fibre such as low density, low elongation at break and its specific stiffness and strength comparable to those of glass fibre draws the attention of the world.
Physical Properties of Natural Fibres

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Tensile strength (MPa)</th>
<th>Young’s modulus (GPa)</th>
<th>Elongation at break (%)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abaca</td>
<td>400</td>
<td>12</td>
<td>3-10</td>
<td>1.50</td>
</tr>
<tr>
<td>Alfa</td>
<td>350</td>
<td>22</td>
<td>5.80</td>
<td>0.89</td>
</tr>
<tr>
<td>Bagasse</td>
<td>290</td>
<td>17</td>
<td>-----</td>
<td>1.25</td>
</tr>
<tr>
<td>Bamboo</td>
<td>140-230</td>
<td>11-17</td>
<td>-----</td>
<td>0.60-1.10</td>
</tr>
<tr>
<td>Banana</td>
<td>500</td>
<td>12</td>
<td>5.90</td>
<td>1.35</td>
</tr>
<tr>
<td>Coir</td>
<td>175</td>
<td>4.6</td>
<td>30</td>
<td>1.20</td>
</tr>
<tr>
<td>Cotton</td>
<td>287-597</td>
<td>5.50-12.60</td>
<td>7-8</td>
<td>1.50-1.60</td>
</tr>
<tr>
<td>Curaua</td>
<td>500-1150</td>
<td>11.80</td>
<td>3.70-4.30</td>
<td>1.40</td>
</tr>
<tr>
<td>Date palm</td>
<td>97-196</td>
<td>2.50-5.40</td>
<td>2.40</td>
<td>1.10-2.00</td>
</tr>
<tr>
<td>Flax</td>
<td>345-1035</td>
<td>27.60</td>
<td>2.70-3.20</td>
<td>1.50</td>
</tr>
<tr>
<td>Hemp</td>
<td>690</td>
<td>70</td>
<td>1.60</td>
<td>1.48</td>
</tr>
<tr>
<td>Henequen</td>
<td>500-70</td>
<td>13.20-3.10</td>
<td>4.80-1.10</td>
<td>1.20</td>
</tr>
<tr>
<td>Jute</td>
<td>500-600</td>
<td>-----</td>
<td>5-6</td>
<td>1.20-1.30</td>
</tr>
<tr>
<td>Kenaf</td>
<td>393-773</td>
<td>26.50</td>
<td>1.50-1.80</td>
<td>1.30</td>
</tr>
<tr>
<td>Nettle</td>
<td>930</td>
<td>53</td>
<td>1.60</td>
<td>----</td>
</tr>
<tr>
<td>Oil palm</td>
<td>248</td>
<td>3.20</td>
<td>25</td>
<td>0.7-1.55</td>
</tr>
<tr>
<td>Piassava</td>
<td>134-143</td>
<td>1.07-4.59</td>
<td>21.90-7.80</td>
<td>1.40</td>
</tr>
<tr>
<td>Pineapple</td>
<td>1.44</td>
<td>400-627</td>
<td>14.50</td>
<td>0.80-1.60</td>
</tr>
<tr>
<td>Ramie</td>
<td>560</td>
<td>24.50</td>
<td>2.50</td>
<td>1.50</td>
</tr>
<tr>
<td>Sisal</td>
<td>511-635</td>
<td>9.40-22</td>
<td>2.0-2.50</td>
<td>1.50</td>
</tr>
<tr>
<td>E-glass</td>
<td>3400</td>
<td>72</td>
<td>---</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Composites made of the same reinforcing material system may not give better results as it undergoes different loading conditions during the service life. In order to solve this problem hybrid composites are the best solution for such applications. A hybrid composite is a combination of two or more different types of fibre in which one type of fibre balance the deficiency of another fibre. The purpose of hybridization is to construct a new material that will retain the advantages of its constituents but not their disadvantages. The concept of hybridization gives flexibility to the design engineer to tailor the material properties according to the requirements, which is one of the major advantages of composites.

The performance of fibre reinforced polymer composites is affected by many factors such as properties of the fibres, orientation of the fibres, content of the fibres, properties of the matrix, fibre-matrix interfaces etc. Increase in volume content of reinforcements can increase the strength and stiffness of a composite to a point. If the volume content of reinforcements is too high then there will not be enough matrix to keep them separate, and they can become tangled. The mechanical properties of fibre reinforced composites are affected by the elastic and strength properties of the matrix, the fibres and the fibre-matrix bond which govern the stress transfer. Similarly, a crucial parameter for the design with composites is the fibre orientation. The arrangement or orientation of the fibres relative to one another within the matrix can affect the performance of a composite. In order to obtain the preferred material properties for a particular application, it is important to know how the material performance changes with the fibre content and fibre orientation under given loading conditions.

2. LITERATURE REVIEW

Study on Natural Fibre Based Polymer Composites

In the recent years there is a vast growth in natural fibre based polymer composites due to its various attractive features like biodegradability, no abrasiveness, flexibility, availability, low cost, light weight etc. Different researchers have performed various experiments to enhance the mechanical properties of natural fibre based polymer composites.

- Biswas studied the effect of length on mechanical behaviour of coir fibre reinforced epoxy composites and observed that the hardness is decreasing with the increase in fibre length up to 20 mm. A study on pulp fibre reinforced thermoplastic composite shows that while the stiffness is increased by a factor of 5.2, the strength of the composite is increased by a factor of 2.3 relative to the virgin polymer.
- Gowda investigated the mechanical behaviour of jute fabric-reinforced polyester composites and found that jute fibre based composites shows better strengths than those of wood based composites. The mechanical properties of coir fibre/polyester composites were evaluated and the effect of the moulding pressure on the flexural strength of the composites is studied.
- Luo and Netravali studied the tensile and flexural properties of polymer composites with different pineapple fibre content and compared them with the virgin resin.
Amash and Zugenmaier reported the effectiveness of cellulose fibre in improving the stiffness and reducing the damping in polypropylene cellulose composites.

Dynamic mechanical behaviour of natural fibres like sisal, pineapple leaf fibre, oil palm empty fruit bunch fibre etc. in various matrices has been studied by Joseph and George. A great deal of work has been done on various aspects of polymer composites reinforced with banana fibres.

Chawla and Bastos investigated the effect of fibre volume fraction on Young’s modulus, tensile strength and impact strength of untreated jute fibres in unsaturated polyester resin.

Schneider and Karmaker studied the mechanical behaviour of jute and kenaf fibre based polypropylene composites and reported that jute fibre provides better mechanical properties than kenaf fibre.

A systematic study on the properties of henequen fibre and pointed out that these fibres have mechanical properties suitable for reinforcement in thermoplastic resins by Cazaurang.

Shinichi have studied the effects of the volume fraction and length on flexural properties of kenaf and bagasse fibres based composites.

The mechanical behaviour of unidirectional hemp fibre reinforced epoxy composites is studied by Hepworth.

Sapuan and Leenie investigated the tensile and flexural behaviour of musaceae/epoxy composites.

Pavithran studied the fracture energies for sisal, pineapple, banana and coconut fibre reinforced polyester composites and reported that, except for the coconut fibre, increasing fibre toughness was accompanied by increasing fracture energy of the composites.

Harriette investigated the mechanical properties of flax/polypropylene composites. Tobias analysed the influence of fibre length and fibre content in banana fibre reinforced epoxy composites and reported that the impact strength increased with higher fibre content and lower fibre length.

Santulli investigated the post impact behaviour of plain-woven jute/polyester composites subjected to low velocity impact and reported that the impact performance of these composites is poor.

### Study on Synthetic Fibre Based Polymer Composites

A great deal of work has been done by many researchers on synthetic fibre based polymer composites.

- Huang studied on effect of water absorption on the mechanical properties of glass/polyester composites. It was concluded that the breaking strength and tensile stress of the composites decreased gradually with increased water immersion time because the weakening of bonding between fibre and matrix.
- Ota studied on the combined effect of injection temperature and fibre content on the properties of polypropylene-glass fibre composites observed that the melting flow index of the composites depend upon fibre content, fibre length distributions. The tensile strength and elastic modulus was increased with increasing in fibre contents.
- Jansons studied on the effect of water absorption, elevated temperatures and fatigue on the mechanical properties of carbon-fibre-reinforced epoxy composites.
- Kutty and Nando studied the effect of processing parameters on the mechanical properties of short Kevlar aramid fibre-thermoplastic polyurethane composite and observed that processing parameters like nip gap, friction ratio and mill roll temperature have extreme influence on the fibre orientation and hence on the mechanical properties of short Kevlar aramid fibre-thermoplastic polyurethane composite.
- Yuan studied reinforcing effects of modified Kevlar fibre on the mechanical properties of wood-flour/polypropylene composites and observed that the addition of kelvar Fibre improved the mechanical properties of Wood Flour/Polypropylene composites.
- Wang studied the mechanical properties of fibre glass and kevlar woven fabric reinforced composites and observed that mechanical behaviour depends strongly upon the fibre types.
- Cho studied the mechanical behaviour of carbon fibre/epoxy composites and found that the composites reinforced with nano particles improved mechanical properties such as enhanced compressive strength and in plane shear properties.
- Chauhan studied on the effect of fibre loading on mechanical properties, friction and wear behaviour of vinyl ester composites under dry and water lubricated conditions and reported that the density of composite specimens is affected marginally by increasing the fibre content.

### Study on Hybrid Fibre Based Polymer Composites

The composites obtained by incorporation of two or more fibres within a single matrix are called as hybrid or hybrid composites. Hybrid fibre composites may be the combination of two or more different natural fibres or it may be the combination of natural or synthetic fibres. The conventional material such as glass, carbon and boron fibres are quite expensive and the use of fibre like carbon or boron is justified only in aerospace application. Therefore it is meaningful to explore the possibility of using cheaper materials such as natural fibre as reinforcement. Various aspects of hybrid fibre based polymer composites has studied by various investigators.

- Jawaid studied the mechanical behaviour of hybrid composites based on jute and oil palm fibre. It has been found that the use of hybrid system was effective in increasing the tensile and dynamic mechanical properties of the oil palm-epoxy composite because of enhanced fibre/matrix interface bonding.
- Verma examined the mechanical properties of glass/jute hybrid composites. The jute fabrics were modified by treatment with different chemicals. It has been observed that titanate treatment of jute fabric results in enhanced performance characteristics and mechanical properties of hybrid composites.
Ashmed investigated the elastic properties and notch sensitivity of untreated woven jute and jute-glass fabric reinforced polyester hybrid composites, analytically and experimentally. The jute composites exhibited higher notch sensitivity than jute–glass hybrid composites.

Dixit reported a remarkable improvement in the tensile and flexural properties of hybrid composites compared to the unhybrid composites. It was also found that the hybrid composite offers better water absorption resistance.

Ahmed experimentally investigated the effect of stacking sequence on mechanical properties of woven jute and glass fabric reinforced polyester hybrid composites. The layering sequence has larger effect on the flexural and inter-laminar shear properties than tensile properties. On comparing the overall properties of the laminates it was concluded that the hybrid laminates with two extreme glass plies on both side has the optimum combination with a good balance between the properties and the cost.

Thew and Liao informed that mechanical properties of bamboo/glass fibre reinforced hybrid composites depends on fibre length, fibre weight ratio and adhesion characteristics between the matrix and the fibre.

Experimental investigation carried out by Mishra depicts that addition of quite small amount of glass fibre to the pineapple leaf fibre and sisal fibre-reinforced polyester matrix improves the mechanical properties of the resulting composites. The study also reported that the water absorption tendency of composites decreased because of hybridization and treatment of bio fibres.

Pandya found that on placing glass fabric layers in the exterior and carbon fabric layers in the interior of the hybrid composites gives higher tensile strength and ultimate tensile strain than hybrid composites with carbon fabric layers in the exterior and glass fabric layers in the interior.

Sreekala concluded that incorporation of small volume fraction of glass fibre in composites results in enhanced tensile and flexural properties.

Velmurugan studied the tensile, shear, impact and flexural properties of the palmyra/glass fibre hybrid composites. The properties of the hybrid were found to be increasing continuously with the addition of glass fibre.

Goud and Rao found a considerable increase in the tensile, flexural, impact and hardness properties of Roystonea regia/glass fibre hybrid composites with the increase in glass fibre loading. However, the dielectric constant and electrical conductivity values decreased with increase in glass fibre loading in the hybrid composites at all frequencies.

Pothan studied on the banana-glass hybrid composites and found layering pattern or the geometry of the composites has a profound effect on the dynamic behaviour of the composites.

Thiruchitrambalam studied the effect of Sodium Lauryl Sulphate (SLS) and alkali treatment on the mechanical properties of banana/kenaf hybrid composites. Investigation result indicates that SLS treated hybrid composites exhibit better properties than alkali treated ones.

Zhong informed that the surface micro fibrillation of sisal fibre improves the compression strength, stability, tensile strength, internal bonding strength and wear resistance of the sisal/ aramid fibre hybrid composites.

Sanjeevamurthy and Srinivas studied the effect of moisture absorption on the mechanical properties of the coconut coir and sisal fibre hybrid composites and compared it with the composites with dry fibres. It was found that the tensile and the flexural strength increased with increase in fibre loading of composites at dry condition. On the other hand at wet condition, the tensile and flexural strength have a high-level drop.

Venkateshwaran reported that the incorporation of sisal fibre in banana/epoxy composites of up to 50% by weight results in enhanced mechanical properties and decreased moisture absorption property.

Girisha found that the hybridized composite shows greater tensile strength compared to the composites with individual type of natural fibres as reinforcement.

OBJECTIVE OF THE WORK

Keeping in view of the current status of research the following objectives are set in the scope of the present research work.

Fabrication of a new class of polyester based hybrid composite reinforced with natural fillers like banana fibre and rice husk

To study the influence of fibre loading and fibre orientation on physical, mechanical and water absorption behaviour of composites.

To study the surface morphology using SEM study.

3. MATERIALS AND METHODS

Materials

The raw materials used in this works are

- Flax Fiber
- Epoxy Resin
- Catalyst(Methyl Ethyl Ketone Peroxide)
- Accelerator(Cobalt Naphthenate)

A. FLAX FIBER

Flax is the most strongest among the natural cellulosic fibers. It is a bast fiber. Flax fiber is extracted from the skin of the stem of the flax plant. Flax is manufactured into linen yarn for thread or woven fabrics. So it is also called linen. It is also one of the oldest
fibers, which was used more than 30,000 years before. Linen cloth made from flax was used to wrap the mummies in the early Egyptian tombs.

**Properties of Flax Fiber:**

Flax fiber is soft, lustrous, and flexible; bundles of fiber have the appearance of blonde hair. It is used to make most of the expensive cloth which is most **comfort to wear**. Flax fiber absorbs humidity well and is a very breathable fiber.

**Physical Properties of Flax Fiber:**

- **A. Tenacity:** Flax is a very strong fiber because it’s very crystalline polymer system permits its extremely long polymers to form more hydrogen bonds than cotton polymers. Tenacity varies from 6.5 to 8 gm/denier.
- **B. Length:** The average length of fiber various from 18-30 inch.
- **C. Color:** Brownish, light, ivory, grey.
- **D. Elongation at break:** The elongation at break is approximately 1.8% (dry) & 2.2% (Wet).
- **E. Specific Gravity:** Specific gravity is 1.54.
- **F. Effect of Heat:** Linen has an excellent resistance to degradation by heat. It is a good conductor of heat. So linen sheet are so cold in summer season.
- **G. Hygroscopic nature:** Flax fiber is very absorbent.
- **H. Effect of moisture:** Standard moisture regain is 10 to 12%.
- **I. Absorbency:** Absorbency is good. It absorbs moisture and dries more quickly. It is excellent for manufacturing towels and handkerchiefs.
- **J. Dimensional stability:** Good but easily tend to crease.
- **K. Resiliency:** Very poor.
- **L. Comfortable:** Linen is a comfortable fabric.
- **M. Good Abrasion Resistant:** As the linen fiber is good in strength, it also has good abrasion resistance.
- **N. Lusture:** It is brighter than cotton fiber and it is slightly silky.

**Thermal Properties of Flax Fiber:** Flax has the best heat resistance and conductivity of all the commonly used textile fibers. Excessive application of heat energy causes the flax fiber to scouch, char and burn. This is an indication that flax is not thermoplastic which may be attributed to the extremely long fiber polymers and the countless hydrogen bonds they form.

**Chemical Properties of Flax Fiber:**

- **Effect Acids:** Flax will withstand in weak acids but is attacked by hot dilute acids or cold concentrated acids.
- **Effect of organic solvents:** Resistant of common solvents (Acetone, ether, methyl, alcohol, Chloroform Etc.)
- **Bleaching Actions:** Cool chlorine and hypo-chlorine bleaching agent does not affect the linen fiber properties.
- **Effect of insects:** Flax is not attacked by moth, grubs or other insects.
- **Effect of Micro Organism:** Linen fiber is attacked by fungi and bacteria.
- **Effects of Alkalis:** Linen has an excellent resistance to alkalis. It does not affected by the strong alkalis.
- **Dye ability:** It has no good affinity to dyes. Direct and vat dyes are suitable for flax fiber.

**Uses of Flax Fiber:**

Flax is two to three times stronger than cotton fiber, but less elastic. The best grades are used to make linen fabrics such as damasks, sheeting and lace. Coarser grades are used for the manufacturing of rope and twine, and historically for canvases and webbing equipment. Flax fiber is also used as a raw material in the high-quality paper industry for the use of printed banknotes and rolling paper for tea bags and cigarette paper manufacture. It is also hypo-allergenic and so an excellent choice of fiber for those with allergies.

Flax fiber has an important application as composite material. It is a cellulosic fibers, like wood and plant fibers; it has the potential for use as load-bearing constituents in composite materials due to their attractive properties such as high stiffness-to-weight ratio that makes cellulosic fiber composites ideal for many structural applications.

Flax, in all its forms, is used in food production, personal care products, animal feeds, fiber and a number of other industrial uses

**B. EPOXY RESIN**

Epoxy resin density of 1.15-1.20g/cm³,mixed with hardener density of 0.97-0.99g/cm³, is used to prepared the composite material resin from purchased local source

**C. CATALYST (METHYL ETHYL KETONE PEROXIDE)**

Methyl ethyl ketone peroxide, also known as 2-butanone peroxide, is a strongly oxidizing (caustic) organic peroxide that is commonly used in the manufacture of acrylic resins and as a room temperature hardening and curing agent for fiberglass-reinforced plastics and unsaturated polyester resins (HCN, 2002; NTP, 1993). At room temperature, it is a colorless to yellow liquid with a characteristic or mint-like odor (NIOSH, 2007; NTP, 2016). As MEKP is shock, sunlight, and heat sensitive, it is typically sold commercially in a solution of 30 – 60% MEKP mixed with diluents like dimethyl phthalate, cyclohexane peroxide, or diallyl phthalate to prevent explosions (HCN, 2002; NIOSH, 2007). It can also undergo spontaneous ignition or explosion if mixed with oxidizable organic, flammable, or chemical materials (HCN, 2002; NOAA, 2015). When MEKP is used as a hardening or curing...
agent, the duration of the reaction is dependent on both the type of resin being cured as well as the formulation of the MEKP solution. Typical reactions contain approximately 1 - 2% MEKP. In a series of experiments, the ‘time to cure’ was roughly 40 - 50 minutes for a commercial MEKP formulation (CI, 1999). The ‘time to cure’ is the time from the initiation of the reaction to when the peak temperature is reached (often in excess of 350°F), which is not necessarily the end of the reaction. Though it is sometimes incorrectly called a catalyst, MEKP is not a true catalyst as it is consumed in the reaction (Juska & Puckett, 1997). Studies of the health effects of MEKP are limited and primarily focus on short-term exposures to relatively large amounts of the chemical. Rats and mice exposed to MEKP (45% in dimethyl phthalate) on their skin for two and thirteen weeks developed a spectrum of necrotic, inflammatory, and regenerative lesions at the application site. Increased formation of red and white blood cells in the spleen and bone marrow was also observed (NTP, 1993). Direct exposure to the eyes of rabbits resulted in damage, with severe injury occurring with two drops of 40% MEKP. Three percent MEKP caused a more moderate reaction that improved after two days (Hathaway & Proctor, 2014). Several studies have examined inhalation exposure in mice and rats; the concentration needed to kill 50% of the animals (known as the LC50) in four hours was 170 parts per million (ppm) in mice and 200 ppm in rats.

D. ACCELERATOR (COBALT NAPHTHENATE):

Accelerators are material which help the decomposition of peroxides and produce free radicals which start the propagation reaction resulting in the gelation and ultimate cure of polyesters. Soaps of Cobalt and certain amines act as accelerators in the homolytic fission of peroxides generating from radicals. Therefore, the role of organic peroxides differ in their reactivity and response to accelerators depending upon their chemical constitution. The choice of accelerators very much depends on the type of organic peroxides selected for use.

Cobalt naphthenate is widely used in polyester resins and paint driers. It is used as a curing accelerator, cross linker catalyst for unsaturated polyester resins. It is also used in the production of adhesives, varnishes and waterproofing agents for textiles. Further, it is used as corrosion inhibitors, lubricants, and fuel additives. It plays an important role as oil drying agents.

Fabrication of Composites

The fabrications of composite slab are carried out by conventional hand layup technique. flax fiber are used as reinforcement and epoxy resin is taken as matrix material with natural fillers (flax fiber). This mix consists of the resin, accelerator, fillers, and additives if any. The addition of accelerator to resin will not cause any cross linking until catalyst is added. The low temperature curing epoxy resin, catalyst and accelerator are mixed in a ratio of 1.0:0.5:0.5 by weight percentage. A plywood mould having dimension of (310 ×210× 20) mm3 is used for composite fabrication. The natural fillers are mixed with epoxy resin by the simple stirring and the mixture is poured into various moulds conforming to the requirements of various testing conditions and characterization standards. The mould should be thoroughly cleaned and free from dirt’s before the releasing agent is applied. Then, the mould surface is coated with silicone free wax (e.g. mansion polish). After some time the wax has to be removed to have a glassy finish on the mould surface. In certain cases release of the product is difficult with wax alone. So, a layer of poly vinyl alcohol (PVA) is applied. Since, PVA is water soluble material, 15% solution in water is applied with sponge. The brush application will leave the prints of brush lines so, sponge is preferable. After the water evaporates, a thin layer of PVA forms on the mould surface.

The PVA layer must be completely dry before the gel coat is applied perhaps it will create wrinkles called ‘elephant skin’. MEK or methyl cellulose, casein, carboxyl-methyl cellulose and methyl cellulose are the other film formers used as releasing agents. A releasing agent is used for facilitate easy removal of the composite from the mould after curing. If any entrapped air bubbles are there, then they are removed by a sliding roller and the mould is closed for curing at a room temperature for 24 h at a constant load of 25-30kg. After curing the specimens of suitable dimensions are cut for mechanical test as ASTM standard. The composition and designation of the composites prepared for this study are listed in the below table,

<table>
<thead>
<tr>
<th>S.NO</th>
<th>COMPOSITES</th>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C1</td>
<td>flax fibre (20 WT%) + Epoxy Resin(80%WT)</td>
</tr>
</tbody>
</table>

4. TEST TO BE PERFORMED

The following test are done for the prepared composite to determine its mechanical properties are listed and described briefly in the following session,

- Tensile test
-Flexural test
-Charpy impact test
-Hardness test

Tensile Test

Uniaxial Tensile Testing

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Uniaxial tensile test is known as a basic and universal engineering test to achieve material parameters such as ultimate strength, yield strength, % elongation, % area of reduction and Young's modulus. These important parameters obtained from the standard tensile testing are useful for the selection of engineering materials for any applications required. The tensile testing is carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length and cross sectional area perpendicular to the load direction) till failure. The applied tensile load and extension are recorded during the test for the calculation of stress and strain. A range of universal standards provided by Professional societies such as American Society of Testing and Materials (ASTM), British standard, JIS standard and DIN standard provides testing are selected based on preferential uses. Each standard may contain a variety of test standards suitable for different materials, dimensions and fabrication history. For instance, ASTM E8: is a standard test method for tension testing of metallic materials and ASTM B557 is standard test methods of tension testing and cast aluminium and magnesium alloy products A standard specimen is prepared in a round or a square section along the gauge length as shown below, depending on the standard used. Both ends of the specimens should have sufficient length and a surface condition such that they are firmly gripped during testing. The initial gauge length Lo is standardized (in several countries) and varies with the diameter (Do) or the cross-sectional area (Ao) of the specimen as listed in table 1. This is because if the gauge length is too long, the % elongation might be underestimated in this case. Any heat treatments should be applied on to the specimen prior to machining to produce the final specimen readily for testing. This has been done to prevent surface oxide scales that might act as stress concentration which might subsequently affect the final tensile properties due to premature failure. There might be some exceptions, for examples, surface hardening or surface coating on the materials. These processes should be employed after specimen machining in order to obtain the tensile properties results which include the actual specimen surface conditions.

Standard Tensile Specimens

The equipment used for tensile testing ranges from simple devices to complicated controlled systems. The so-called universal testing machines are commonly used, which are driven by mechanical screw or hydraulic systems. The below figure illustrates a relatively simple screw-driven machine using large two screws to apply the load whereas next figure shows a hydraulic testing machine using the pressure of oil in a piston for load supply. These types of machines can be used not only for tension, but also for compression, bending and torsion tests. A more modernized closed-loop servo-hydraulic machine provides variations of load, strain, or testing machine motion (stroke) using a combination of actuator rod and piston. Most of the machines used nowadays are linked to a computer-controlled system in which the load and extension data can be graphically displayed together with the calculations of stress and strain. General techniques utilized for measuring loads and displacements employs sensors providing electrical signals. Load cells are used for measuring the load applied while strain gauges are used for strain measurement. A Change in a linear dimension is proportional to the change in electrical voltage of the strain gauge attached on to the specimen.
Stress and Strain Relationship

When a specimen is subjected to an external tensile loading, the metal will undergo elastic and plastic deformation. Initially, the metal will elastically deform giving a linear relationship of load and extension. These two parameters are then used for the calculation of the engineering stress and engineering strain to give a relationship as illustrated in figure 3 using equations 1 and 2 as follows

\[ \sigma = \frac{P}{A_o} \]  

\[ \varepsilon = \frac{L_f - L_o}{L_o} = \frac{\Delta L}{L_o} \]  

Where
\( \sigma \) is the engineering stress
\( \varepsilon \) is the engineering strain
\( P \) is the external axial tensile load
\( A_o \) is the original cross-sectional area of the specimen
\( L_o \) is the original length of the specimen
\( L_f \) is the final length of the specimen

The unit of the engineering stress is Pascal (Pa) or N/m\(^2\) according to the SI Metric Unit whereas the unit of psi (pound per square inch) can also be used.

YOUNG'S MODULUS, \( E \)

During elastic deformation, the engineering stress-strain relationship follows the Hook's Law and the slope of the curve indicates the Young's modulus (E)

\[ E = \frac{\sigma}{\varepsilon} \]  

Young's modulus is of importance where deflection of materials is critical for the required engineering applications. This is for examples: deflection in structural beams is considered to be crucial for the design in engineering components or structures such as bridges, building, ships, etc. The applications of tennis racket and golf club also require specific values of spring constants or Young's modulus values.
YIELD STRENGTH, $\Sigma_Y$:

By considering the stress-strain curve beyond the elastic portion, if the tensile loading continues, yielding occurs at the beginning of plastic deformation. The yield stress, $\sigma_y$, can be obtained by dividing the load at yielding ($P_y$) by the original cross-sectional area of the specimen ($A_0$) as shown in equation 4.

$$\sigma_y = \frac{P_y}{A_0} \quad \ldots(4)$$

The yield point can be observed directly from the load-extension curve of the BCC metals such as iron and steel or in polycrystalline titanium and molybdenum, and especially low carbon steels, see figure 3 a). The yield point elongation phenomenon shows the upper yield point followed by a sudden reduction in the stress or load till reaching the lower yield point. At the yield point elongation, the specimen continues to extend without a significant change in the stress level. Load increment is then followed with increasing strain. This yield point phenomenon is associated with a small amount of interstitial or substitutional atoms. This is for example in the case of low-carbon steels, which have small atoms of carbon and nitrogen present as impurities. When the dislocations are pinned by these solute atoms, the stress is raised in order to overcome the breakaway stress required for the pulling of dislocation line from the solute atoms. If the dislocation line is free from the solute atoms, the stress required to move the dislocations then suddenly drops, which is associated with the lower yield point. Furthermore, it was found that the degree of the yield point effect is affected by the amounts of the solute atoms and is also influenced by the interaction energy between the solute atoms and the dislocations.

ULTIMATE TENSILE STRENGTH, $\Sigma_{TS}$

Beyond yielding, continuous loading leads to an increase in the stress required to permanently deform the specimen as shown in the engineering stress-strain curve. At this stage, the specimen is strain hardened or work hardened. The degree of strain hardening depends on the nature of the deformed materials, crystal structure and chemical composition, which affects the dislocation motion. FCC structure materials having a high number of operating slip systems can easily slip and create a high density of dislocations. Tangling of these dislocations requires higher stress to uniformly and plastically deform the specimen, therefore resulting in strain hardening. If the load is continuously applied, the stress-strain curve will reach the maximum point, which is the ultimate tensile strength (UTS, $\sigma_{TS}$). At this point, the specimen can withstand the highest stress before necking takes place.

$$\sigma_{TS} = \frac{P_{\text{max}}}{A_0} \quad \ldots(6)$$

Fracture Characteristics of the Tested Specimens

Metals with good ductility normally exhibit a so-called cup and cone fracture characteristic observed on either halves of a broken specimen as illustrated in figure 8. Necking starts when the stress-strain curve has passed the maximum point where plastic deformation is no longer uniform. Across the necking area within the specimen gauge length (normally located in the middle), microvoids are formed, enlarged and then merged to each other as the load is increased. This creates a crack having a plane perpendicular to the applied tensile stress. Just before the specimen breaks, the shear plane of approximately 45º to the tensile axis is formed along the peripheral of the specimen. This shear plane then joins with the former crack to generate the cup and cone fracture as demonstrated in figure 8. The rough or fibrous fracture surfaces appear in grey by naked eyes. Under SEM, copious amounts of micro voids are observed as depicted in figure 9. This type of fracture surface signifies high energy absorption during the fracture process due to large amount of plastic deformation taking place, also indicating good tensile ductility. Metals such as aluminium and copper normally exhibit ductile fracture behaviour due to a high number of slip systems available for plastic deformation. For brittle metals or metals that failed at relatively low temperatures, the fracture surfaces usually appear bright and consist of flat areas of brittle facets when examined under SEM as illustrated in figure 10. In some cases, clusters of these brittle facets are visible when the grain size of the metal is sufficiently large. The energy absorption is quite small in this case which indicates relatively low tensile ductility due to limited amount of plastic deformation prior to failure.
In summary, tensile properties should be considered as important design parameters for the selection of engineering materials for their desired application. Engineers have played a significant role in that they should be able to analyse and understand material behaviour and properties through these mechanical testing parameters.

**Materials and Equipment**

- Tensile specimens
- Micrometer or vernier callipers
- Universal testing machine
- Stereoscope

**Experimental Procedure**

- The specimens provided are made of composite materials. Measure and record specimen dimensions (diameter and gauge length) in a table provided for the calculation of the engineering stress and engineering strain. Marking the location of the gauge length along the parallel length of each specimen for subsequent observation of necking and strain measurement.
- Fit the specimen on to the universal Testing Machine (UTM) and carry on testing. Record load and extension for the construction of stress-strain curve of each tested specimen.
- Calculate Young's modulus, yield strength, ultimate tensile strength, fracture strain, % elongation and % area of reduction of each specimen and record on the provided table.
- Analyse the fracture surfaces of broken specimens using stereoscope, sketch and describe the results.
- Discuss the experimental results and give conclusions.

**Flextural Test**
Flexure tests are generally used to determine the flexural modulus or flexural strength of a material. A flexure test is more affordable than a tensile test and test results are slightly different. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum recorded force is the flexural strength of that particular sample. Unlike a compression test or tensile test, a flexure test does not measure fundamental material properties. When a specimen is placed under flexural loading all three fundamental stresses are present: tensile, compressive and shear and so the flexural properties of a specimen are the result of the combined effect of all three stresses as well as (though to a lesser extent) the geometry of the specimen and the rate the load is applied.

The most common purpose of a flexure test is to measure flexural strength and flexural modulus. Flexural strength is defined as the maximum stress at the outermost fiber on either the compression or tension side of the specimen. Flexural modulus is calculated from the slope of the stress vs. strain deflection curve. These two values can be used to evaluate the sample materials ability to withstand flexure or bending forces.

Flexure Test Types

The two most common types of flexure test are three point and four point flexure bending tests. A three point bend test consists of the sample placed horizontally upon two points and the force applied to the top of the sample through a single point so that the sample is bent in the shape of a “V”. A four point bend test is roughly the same except that instead of the force applied through a single point on top it is applied through two points so that the sample experiences contact at four different points and is bent more in the shape of a “U”. The three point flexure test is ideal for the testing of a specific location of the sample, whereas, the four point flexure test is more suited towards the testing of a large section of the sample, which highlights the defects of the sample better than a 3-point bending test.

A bend test is similar to a flexure test in the type of hardware and test procedure involved. Bend tests are used with ductile materials whereas flexural tests are used with brittle materials.

Procedure

- Prepare the test specimen
- Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.
- Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be $3d$ and the distance between the inner rollers shall be $d$. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.
- The test specimen shall be placed in the machine correctly centred with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.
- The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

Calculation

The Flexural Strength or modulus of rupture ($f_b$) is given by

$$f_b = \frac{pl}{bd^2} \quad (\text{when } a > 20.0\text{cm for 15.0cm specimen or } > 13.0\text{cm for 10cm specimen})$$

Or

$$f_b = \frac{3pa}{bd^2} \quad (\text{when } a < 20.0\text{cm but } > 17.0 \text{ for 15.0cm specimen or } < 13.3 \text{ cm but } > 11.0\text{cm for 10.0cm specimen.})$$

Where,

- $a$ = the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen
- $b$ = width of specimen (cm)
- $d$ = failure point depth (cm)
- $l$ = supported length (cm)
- $p$ = max. Load (kg)

Charpy Impact Test

Impact Tests

Impact tests are designed to measure the resistance to failure of a material to a suddenly applied force. The test measures the impact energy, or the energy absorbed prior to fracture. The most common methods of measuring impact energy are the:

- Charpy Test
Izod Test

Impact Energy

Impact energy is a measure of the work done to fracture a test specimen. When the striker impacts the specimen, the specimen will absorb energy until it yields. At this point, the specimen will begin to undergo plastic deformation at the notch. The test specimen continues to absorb energy and work hardens at the plastic zone at the notch. When the specimen can absorb no more energy, fracture occurs.

The Charpy Test

While most commonly used on metals, it is also used on polymers, ceramics and composites. The Charpy test is most commonly used to evaluate the relative toughness or impact toughness of materials and as such is often used in quality control applications where it is a fast and economical test. It is used more as a comparative test rather than a definitive test.

Charpy Test Specimens

Charpy test specimens normally measure 55x10x10mm and have a notch machined across one of the larger faces. The notches may be:

- V-notch – A V-shaped notch, 2mm deep, with 45° angle and 0.25mm radius along the base.
- U-notch or keyhole notch – A 5mm deep notch with 1mm radius at the base of the notch.

Procedure

The Charpy test involves striking a suitable test piece with a striker, mounted at the end of a pendulum. The test piece is fixed in place at both ends and the striker impacts the test piece immediately behind a machined notch.

Determination of Charpy Impact Energy

At the point of impact, the striker has a known amount of kinetic energy. The impact energy is calculated based on the height to which the striker would have risen, if no test specimen was in place, and this compared to the height to which the striker actually rises.

Tough materials absorb a lot of energy, whilst brittle materials tend to absorb very little energy prior to fracture.

Factors Affecting Charpy Impact Energy

Factors that affect the Charpy impact energy of a specimen will include:

- Yield strength and ductility
- Notches
- Temperature and strain rate
- Fracture mechanism

Yield Strength and Ductility

For a given material the impact energy will be seen to decrease if the yield strength is increased, i.e. if the material undergoes some process that makes it more brittle and less able to undergo plastic deformation. Such processes may include cold working or precipitation hardening.

Notches

The notch serves as a stress concentration zone and some materials are more sensitive towards notches than others. The notch depth and tip radius are therefore very important.
Temperature and Strain Rate

Most of the impact energy is absorbed by means of plastic deformation during the yielding of the specimen. Therefore, factors that affect the yield behaviour and hence ductility of the material such as temperature and strain rate will affect the impact energy.

This type of behaviour is more prominent in materials with a body centred cubic structure, where lowering the temperature reduces ductility more markedly than face centred cubic materials.

Fracture Mechanism

Metals tend to fail by one of two mechanisms, micro void coalescence or cleavage.

Cleavage can occur in body centred cubic materials, where cleavage takes place along the (001) crystal plane. Micro void coalescence is the more common fracture mechanism where voids form as strain increases, and these voids eventually join together and failure occurs. Of the two fracture mechanisms cleavage involved far less plastic deformation ad hence absorbs far less fracture energy.

Ductile To Brittle Transition

Some materials such as carbon steels undergo what is known as a ‘ductile to brittle transition’. This behaviour is obvious when impact energy is plotted as a function of temperature. The resultant curve will show a rapid dropping off of impact energy as the temperature decreases. If the impact energy drops off very sharply, a transition temperature can be determined. This is often a good indicator of the minimum recommended service temperature for a material.

Hardness Test

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting.

Measurement of Hardness

Hardness is not an intrinsic material property dictated by precise definitions in terms of fundamental units of mass, length and time. A hardness property value is the result of a defined measurement procedure. Hardness of materials has probably long been assessed by resistance to scratching or cutting. An example would be material B scratches material C, but not material A. Alternatively, material A scratches material B slightly and scratches material C heavily. Relative hardness of minerals can be assessed by reference to the Moh's Scale that ranks the ability of materials to resist scratching by another material. Similar methods of relative hardness assessment are still commonly used today. An example is the file test where a file tempered to a desired hardness is rubbed on the test material surface. If the file slides without biting or marking the surface, the test material would be considered harder than the file. If the file bites or marks the surface, the test material would be considered softer than the file. The above relative hardness tests are limited in practical use and do not provide accurate numeric data or scales particularly for modern day metals and materials. The usual method to achieve a hardness value is to measure the depth or area of an indentation left by an indenter of a specific shape, with a specific force applied for a specific time. There are three principal standard test methods for expressing the relationship between hardness and the size of the impression, these being Brinell, Vickers, and Rockwell. For practical and calibration reasons, each of these methods is divided into a range of scales, defined by a combination of applied load and indenter geometry.

The Brinell Hardness Test

The Brinell hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball subjected to a load of 3000 kg. For softer materials the load can be reduced to 1500 kg or 500 kg to avoid excessive indentation. The full load is normally applied for 10 to 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals. The diameter of the indentation left in the test material is measured with a low powered microscope. The Brinell hardness number is calculated by dividing the load applied by the surface area of the indentation. The diameter of the impression is the average of two readings at right angles and the use of a Brinell hardness number table can simplify the determination of the Brinell hardness. A well-structured Brinell hardness number reveals the test conditions, and looks like this, "75 HB 10/500/30" which means that a Brinell Hardness of 75 was obtained using a 10mm diameter hardened steel with a 500 kilogram load applied for a period of 30 seconds. On tests of extremely hard metals a tungsten carbide ball is substituted for the steel ball. Compared to the other hardness test methods, the Brinell ball makes the deepest and widest indentation, so the test averages the hardness over a wider amount of material, which will more accurately account for multiple grain structures and any irregularities in the uniformity of the material. This method is the best for achieving the bulk or macro-hardness of a material, particularly those materials with heterogeneous structures.
5. RESULT

Tensile Strength of Composites

The composite specimens are tested for tensile properties in universal testing machine and obtained tensile strength are shown in the below figure. The value of tensile strength obtained is

<table>
<thead>
<tr>
<th>TEST</th>
<th>SAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TENSILE</td>
<td>6.25</td>
</tr>
</tbody>
</table>

Flexural Strength of Composites

The flexural strength is one of the important factors in NFRPCs and the following figure shows the variations in the flexural strength of composites. The value of flexural strength obtained is

<table>
<thead>
<tr>
<th>TEST</th>
<th>SAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPRESSION</td>
<td>17.79</td>
</tr>
</tbody>
</table>

Impact Strength of Composites

The loss of energy during impact is the energy absorbed by the specimen during impact. The values are furnished in the following figure. The value of impact strength obtained is

<table>
<thead>
<tr>
<th>TEST</th>
<th>SAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMPACT</td>
<td>2</td>
</tr>
</tbody>
</table>

6. CONCLUSION

The experimental study on the hybrid composite with natural fillers on physical, water absorption, wear and mechanical behaviour test leads to the following conclusions

<table>
<thead>
<tr>
<th>S.No</th>
<th>TEST DETAILS</th>
<th>SAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>TENSILE TEST(KN)</td>
<td>6.25</td>
</tr>
<tr>
<td>2.</td>
<td>FLEXURAL TEST(KN)</td>
<td>17.79</td>
</tr>
<tr>
<td>3.</td>
<td>IMPACT STRENGTH(JOULES)</td>
<td>2</td>
</tr>
</tbody>
</table>

On the upcoming study the natural fillers are added with the prescribed weight ratio to the E glass polyester composite and its mechanical characteristics are analysed by the same testing procedure and by comparing the obtained results, the better material composition is finalized.

7. REFERENCE


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