Analysis of Mechanical Properties and Reprocessing Behavior of Green Composite from Bio-Degradable Polymers: A Review

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Abstract - *A bio-composite is a material made up of a matrix (or resin) with natural fibre reinforcement such as kenaf, jute, coir, sugarcane, and so on. These materials have structures that are similar to those found in living things. Matrix and reinforcement are combined in a bio-composite. In bio-composite, the matrix is a key component that shields the fibres from environmental deterioration and mechanical damage. Polymers sourced from sustainable and non-renewable resources are used to create the matrix phase. Matrix is the combination's backbone, transferring load through fibres. Many of the interior and exterior materials are made from renewable bio-composites. As a result, several researchers have observed that using biopolymers to reinforce natural fibres has good mechanical, thermal, and biodegradable qualities. The use of a compatibilizing agent resulted in an improvement in these properties. In comparison to alternative inorganic fillers, sustainable bio-composites manufactured from bacterium cellulose, rice straw, rice husk, natural fibre, lingo cellulose, cellulose, and paper sludge have a number of advantages. When compared to petroleum-based composites, bio-composites are the greatest alternatives and are more environmentally friendly.*

Key Words: **Bio-composites, Epoxy, Resin, Polymer Matrices, Fillers, D-638 specimen**

1. INTRODUCTION

A bio-composite is a type of composite that is made up of a matrix (resin) and natural fibre reinforcing with the help of hardeners. Because of their numerous superior features and applications, bio-composites have recently piqued the interest of large-scale companies. After many years of research, it has been determined that adding fibre reinforcement to certain polymers improves the mechanical properties of composites. Many aviation and automobile manufacturers prefer to reinforce polymers with synthetic fibres such as glass and carbon fibres. Advanced study has also found the rising performance of composites with two or three polymers/reinforcements or fillers. The utilisation of composites manufactured from petroleum is the consequence of this series of studies. Eco-friendly bio-composites must lower environmental effect in order to replace petroleum-based non-renewable resource-based composites. In general, bio- composites are made up of one or more phases of natural fibre reinforcing with organic matrix or biopolymers. Biopolymers such as maize resin, gelatine, and soy protein are renewable and biodegradable, as are manmade biopolymers like microbial fermentations such as microbial polyesters. Meanwhile, in another method, these bio-composites are made from renewable, recyclable, and sustainable agricultural and forestry feedstocks rather than food or feed, which might result in a better day-to-day improvement in the environment. As a result, bio-based polymers are being used as a reinforced matrix to create bio-composites.

1.1 Bio-degradable polymer matrices:

Many non-biodegradable petroleum-based polymers, such as polypropylene, polyethylene, polyvinylchloride, and polystyrene, have a number of environmental issues, including waste generation, accumulation in disposal systems, and reproducibility, to name a few. As a result, the volume of commercial and industrial wastes is increasing. As a result, many researchers are interested in creating environmentally friendly changes to current materials and inventing biodegradable polymer composites using naturally occurring components. A broad range of natural and manufactured polymers are degraded hydrolytically (polycaprolactone, polydioxanone, polylactides, polyhydroxyalkanoates) and enzymatically (polysaccharides, protein, poloxyalkanoates). Biodegradable polymers are made from chemically manufactured renewable resources. When exposed to external conditions, they are capable of decomposition. Biodegradable polymers have sparked a lot of attention due to their main feature of being fully biodegradable into simple organic components of hydrogen, carbon, and oxygen through interactions with microorganisms such as algae, bacteria, and fungi. Biodegradable polymers can contain a variety of biological components, the most common of which being starch and fibre derived from various types of plants.

1.1.1 Starch

Starch is a polysaccharide substance produced mostly by potatoes, corn, and rice, and is an extensively used natural biodegradable polymer. Starch is made up of granules of various compositions and sizes. The crystalline nature of thermoplastic starch can be obtained by applying heat or pressure to amorphous thermoplastic starch. Water sensitivity, brittleness, and low impact resistance are among its mechanical flaws. It has been discovered that fibre reinforced starch matrix can be utilised to improve the qualities of starch-composites, and that blending starch with other thermoplastic materials is another option. We can improve thermoplastic properties and heat stability by using the esterification method.

1.1.2 Poly-lactic acid

Chemically and physiologically, poly-lactic acid, such as Land D-lactic acid, can be generated. Poly-lactic acid is made from corn starch and has been discovered to have better characteristics than other plastic polymers. PLA's poor mechanical and thermal qualities prevent it from being used directly in a wide range of applications. These flaws in PLA can be overcome by using natural or synthetic fibres to reinforce them. They can also be transformed to crystalline PLA, which is extremely brittle and has less than 10% elongation at break.

1.2 Resins:

Resin is a solid or highly viscous substance that can be derived from plants or synthesised. It is usually a mixture of organic components that can be converted into polymer resins. Resins are viscous liquids that, after curing, can be transformed into hard polymers. They are biodegradable compounds that occur naturally, but are now frequently synthesised. Natural resins are more limited in their variety than synthetic resins. Some are made by esterifying organic chemicals, while others are more like thermosetting polymers, with the term "resin" referring to either the reactant or the result, and sometimes both. The term "resin" refers to one of the two monomers in a copolymer; the other monomer is referred to as a "hardener." The lone monomer compound in thermosetting plastics with only one monomer is referred to as "resin." When liquid methyl meth-2-acrylate is in a liquid or viscous state before polymerizing and setting into a solid, it is commonly referred to as "resin."

1.3 Epoxy:

Epoxies are the most common thermosetting polymers, which are created by combining two or more chemical constituents. Because of its chemical resistance, excellent adhesion, and durability, epoxy resins are employed in consumer and industrial applications.

The term "epoxy," or "epoxide," refers to a wide range of reactive compounds. The presence of an oxirane or epoxy ring, such as -epoxy, 1, 2-epoxy, and so on, distinguishes them. It is represented as a three-member ring with an oxygen atom that is uniquely connected to two carbon atoms.

As a result, the presence of a "epoxy" group in a chemical indicates that the molecular base might vary significantly, resulting in a wide range of epoxy resins. Epoxies have proven to be quite successful since they can manufacture a wide range of molecular structures using the same chemical technique. Epoxies cure quickly and are suitable with a wide range of substrates. They have a proclivity for easily wetting surfaces, making them ideal for composite applications. Their resin form has the following chemical applications: they are used to improve the physical and chemical properties of many polymers such as polyurethane, bi-ether-2- acrylate propanol unsaturated polyesters. The qualities of thermosetting epoxies are as follows:

- Their tensile strength ranges from 90 to 120 MPa
- Their tensile modulus ranges from 3100 to 3800 MPa
- Their glass transition temperatures (Tg) ranges between 150 to 220 ◦C

Due to the high degree of cross-linkage, epoxies tend to become brittle after curing, resulting in a loss in impact strength and other related qualities. Modification of epoxy monomers is required to improve their flexibility, toughness, and thermal characteristics.

In the development of bio-composites, the following three basic forms of epoxies are used:

- Aromatic glycidyl amines
- Phenolic glycidyl ethers
- Cycloaliphatics

Key Properties of Epoxy Resins:

- Excellent adherence to a variety of
- Excellent adherence to a variety of substrates
- Effective electrical insulation
- Chemical and solvent resistance
- Inexpensive and non-toxic

Epoxy resins have two major downsides, brittleness and moisture sensitivity, in addition to the qualities described above.

1.4 Fillers:

In epoxy resin compositions, fillers are also crucial. Reinforcing fibres like glass, graphite, and polyaramid help epoxies so that they may be used in a range of bio-composites structural applications. The following non-reinforcing fillers are used for various purposes:

- Mica can be utilised as a conductor of electricity.
- Alumina can be used for thermal conductivity
- Powdered metals can be used to improve electrical and thermal conductivity
- Alumina can be used for thermal conductivity
- Increases lubricity with graphite and carbon particles
- Increases lubricity with graphite and carbon particles
- Lowers costs with calcium carbonate and talc

The following are factors to consider while compounding with filler systems:

- Filler volume fraction
- Particle properties (size, share, surface area...)
- Filler aspect ratio
- Filler strength and modulus
- Filler adhesion to the resin
- Viscosity of the base resin
- Base resin toughness

2. TESTING

For mechanical characterisation of bio-composites, several tests are used, such as dynamic mechanical analysis test, impact test, tensile test, three point bending test, and so on. The experiments are being carried out in order to determine the structural analysis of bio-composites. The table below illustrates the number of tests that can be performed, their purpose, the machine that will be used (brand name), the estimated cost, and the capacity for characterisation of bio composites.

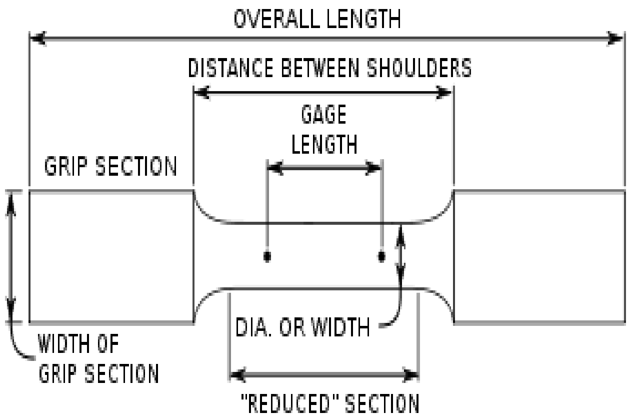


Fig -1: Tensile Test Specimen (Dog-Bone Type) line diagram

ASTM guidelines for bio-composite specimens:

- Specimen D-638 is a dumbbell-shaped specimen with a gauge length of 25 mm or 50 mm.
- The D-638 can be used to test a variety of polymers, both reinforced and non-reinforced.
- It can be used on rigid plastic samples with a thickness of 1mm to 14mm.
- In a tensile test, the phrase "gauge length" refers to the portion of the test specimen that actually participates in the elongation process.

Table -1: Various tests for Bio-Composites Characterization

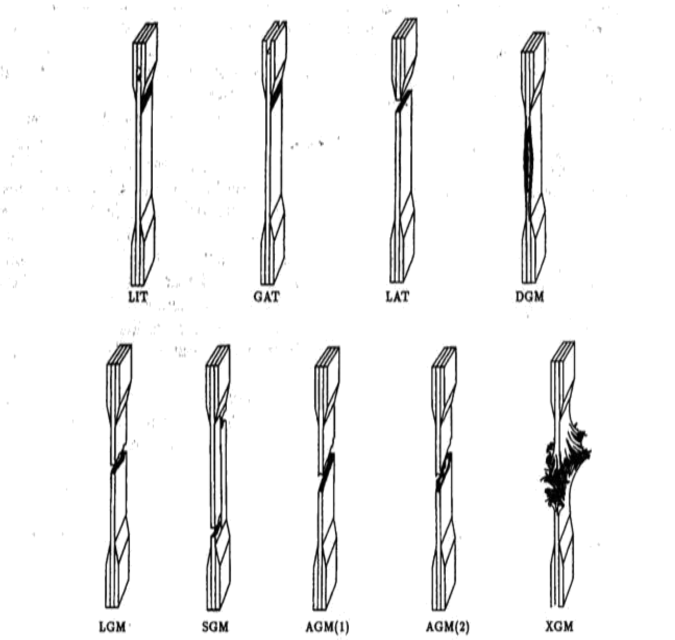
Experiments	Properties	Machine for testing
Tensile test	Maximum tensile load carrying, young's modulus	Universal testing machine
Three point bending test	Flexural strength, maximum load at failure, flexural modulus.	Universal testing machine
Impact test(Izod/Charpy)	Impact strength	Pendulum impact test
Hardness	Hardness	Hardness testing machine

Failure during testing:

The ultimate tensile strength, yield strength, and other mechanical parameters of a specimen are determined by performing a tension test in which the specimen is subjected to a uniaxial force until it fractures. The tension test specimen contains two shoulders and a gauge in the middle; the shoulders are large so that it can be grabbed firmly in the tension test machine, and the gauge portion is smaller so that deformation and failure can occur in this location.

The specimen is subjected to a three-point bending test to determine the material's flexural stress. The specimen is put on two supporting pins that are spaced evenly apart, and the third pin is slowly lowered from above until the specimen fractures. A gauge is placed on the shortened segment to measure elongation. It is critical that the elongation happen in this location for accurate readings.

For testing purposes, we not only reduce the diameter of the centre section to ensure that the break is in the section you're measuring for elongation, but you also (ideally) taper the reduced section slightly from the ends to the middle to ensure that the break is in the middle and the elongation doesn't spread outside the area you're measuring. Most machinists can't cut a specimen so accurately in practice, so you have to settle with a uniform reduced section and hope for the best. If the machine grips are moved, any plastic deformation of the grips will increase the measured elongation.



First Character

Failure Type	Code
Angled	A
edge Delamination	D
Grip/tab	G
Lateral	L
Multi-mode	M(xyz)
long. Splitting	S
eXplosive	X
Other	O

Second Character

Failure Area	Code
Inside grip/tab	I
At grip/tab	A
<1W from grip/tab	W
Gage	G
Multiple areas	M
Various	V
Unknown	U

Third Character

Failure Location	Code
Bottom	B
Top	T
Left	L
Right	R
Middle	M
Various	V
Unknown	U

Fig -2: Tensile Test failure codes/typical modes

3. CONCLUSIONS

After going through large number of research papers available on this topic, We arrive at the conclusion that renewable bio-composites play an important and decisive role in the manufacturing of the interior and exterior parts of various industries such as automobile, marine, sound absorbing wooden construction materials, and consumer applications after reviewing a large number of research papers on the subject. As a result, various studies have found that biopolymer reinforcement of natural fibres has good mechanical, thermal, and biodegradable qualities. “We do not inherit this earth from our forefathers; we borrow it from our children,” as the adage goes. As a result, a methodical strategy to bio-composite creation is required. Furthermore, it was discovered that adding a compatibilizing agent improved these qualities. We need to enhance our perspective because we are overlooking the chances they provide for new applications with added value. Although lightweight, high specific strength, and cheap cost are considered to be the most important criteria to meet but we should not ignore factors like as fire resistance, environmental durability, and embedded energy utilisation.

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Biographical note – Presently, the author is a 4th year student of Bachelor of Technology in M.E. department of JSS Academy of Technical Education, NOIDA, U.P. I am also conducting research on epoxy based bio-composites reinforced with sugarcane trash. I am hopeful that this review paper shall be very helpful in the development of cost efficient, bio-degradable composites.