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Synthesis of Bakelite Reinforced With Recycled Cellulose Fiber and Properties Optimization

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Abstract: *The Bakelite (poly-oxy-benzyl-methylene- glycol -anhydride) is the first kind of thermosetting plastic made from synthetic components. The paper deals with the preparation of this thermosetting with recycled cellulose fiber and optimization of mechanical properties of combined structure. When compared with the original material the composite materials have increased mechanical properties. The reinforcing material was recycled cellulose fiber. Here the composite synthesis of polymer is discussed. The original material is compared with mechanical properties like tensile strength and impact strength. The material was prepared by using compression molding machine and specimens were prepared with ASTM STD for testing the mechanical properties*

Keywords: *Bakelite, Thermosetting plastic, recycled cellulose fiber, mechanical properties, polymer.*

I. Introduction

Composites substances are having strong load tolerant material (known as reinforcement) inserted in weaker material (known as matrix). Reinforcement gives strength and rigidity, helping to brace structural load. The composites or binder (organic or inorganic) maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties; yet together they produce a combination of qualities which individual constituents would be incapable of producing alone.

Microcrystalline cellulose (MCC) is purely crystalline due to the removal of the amorphous regions during acid hydrolysis and categorized as a polymer with a high aspect ratio. While little research has occurred in the addition of cellulose into phenol formaldehyde composites, substitution into other bio based composites has recently been investigated. The addition of MCC into poly lactic acid was tried but the gains in strength were not realized due to the aggregation of cellulose during forming and pelletizing.

Historical examples of composites are abundant in literature. Significant examples include the use of reinforcing mud walls in houses with bamboo shoots, glued laminated wood by Egyptians (1500 BC) and laminated metals in the forging of swords (1800 AD). In 1930, modern composites were used, where glass fibers reinforced with resins. Aircraft and Boats were constructed out of these glass composites, commonly called fiberglass. After the 1970s, the application of composites has widely increased due to development of new fibers such as boron, carbon and aramids, and new composite systems with matrices made of metal and ceramics.

II. Types Of Composites

For the sake of simplicity composites can be grouped into categories based on the nature of the matrix each type possesses. Methods of manufacturing also vary according to chemical and physical properties of the matrices and reinforcing fibers. The Most advanced composites are Polymer Matrix Composites (PMCs). These blends consist of a polymer of thermosetting or thermoplastic reinforced by fiber (natural carbon or boron). These materials can be transformed into a different shapes and sizes. They give high strength and stiffness along with resistance to attrition. The cause for these being most common is their high strength, low cost, and simple manufacturing processes. Metal Matrix Composites (MMCs), as the name involved, have a metal matrix.

Examples of matrices in such composites comprise magnesium, titanium, and aluminum. The classical fiber includes carbon and silicon carbide. To suit the needs of design metals are mostly reinforced. For example, the metal’s elastic stiffness and strength can be increased, while metal’s large coefficient of thermal expansion and thermal and electrical conductivities can be minimized by the addition of fibers such as silicon carbide. Ceramic Matrix Composites (CMCs) have ceramic matrix such as calcium, alumina, aluminosilicate reinforced by silicon carbide. The advantages of CMC include hardness, high strength, high service temperature limits for low density, ceramics, chemical inertness.

Ceramic materials have a tendency to fracture and to become brittle which are naturally resistant to high temperature. Composites are well made with ceramic matrices reinforced with silicon carbide fibers. Without any high density these composites offer the same high temperature tolerance of super alloys. The breakable nature of ceramics makes composite fabrication problematic. Normally most CMC production method of preparation involves starting materials in pulverize form. Ceramics matrices are classified in four groups: glass (because of low softening temperatures it is easy to fabricate, include borosilicate and alumina silicates), conventional ceramics (silicon nitride, silicon carbide, zirconium oxide and aluminum oxide are fully crystalline), cement and concreted carbon components. Carbon fibers in a carbon matrix are used in Carbon-carbon composites (CCMs). Carbon-carbon composites are twenty times stronger and thirty times lighter than graphite fibers and which can be used at very high temperature environments of up to 6000 ^{o}F.

III. Polymer Resins

Polymer resins classified mainly into two categories

a. Thermosetting

Thermoset is a stiff and hard cross linked material that does not become moldable or soften or when heated. Thermosets do not stretch the way that elastomers and thermoplastics do. Many types of polymers have been used as matrices for natural fiber composites. Mostly used thermoset polymers are epoxy resins and other resins (Unsaturated polyester resins (as in fiber glass) Phenolic Epoxy, Vinyl Ester, Novolac and Polyamide). Unsaturated polyesters are extremely adjustable in properties and applications and have been a popular thermoset used as the polymer matrix in composites. They have many advantages and are produced industrially compared to other thermosetting resins including room temperature cure capability, transparency and good mechanical properties. The polyesters reinforced by cellulosic fibers have been widely reported. Polyester-sisal, Polyester-jute, polyester-coir polyester-banana-cotton, polyester-pineapple leaf, polyester-straw and polyester-cotton-kapok are some of the promising systems.

b. Thermoplastics

Thermoplastics are polymers that require heat to make them process able. After cooling, such materials retain their shape. In addition, these polymers may be reheated and reformed, often without signify cant changes in their properties. The thermosoftening plastic is used as matrix for natural fiber reinforced composites are as follows:

- High density polyethene
- Low density polyethene (LDPE)
- Chlorinated polyethylene (CPE)
- Polypropylene (PP)
- Normal polystyrene (PS)
- Poly (Vinyl chloride) PVC)
- Mixtures of polymers
- Recycled Thermoplastics

Only those thermoplastics are useable for natural fiber reinforced composites, whish's processing temperature (temperature at which fiber is incorporated into polymer matrix) does not exceed 230°C.

IV. Bakelite Preparation

a. Materials Required to prepare Bakelite

First of all need to prepare Bakelite so Glacial acetic acid, phenol, formaldehyde solution (40%), and Concentrated Sulphuric acid. Recycled Cellulose Fiber is reinforced to prepare composite material and hexamine is used as hardener.

b. Procedure for Preparation

- Take 5ml Glacial Acetic Acid in a 500 ml beaker
- Add 2.5ml of 40% Formaldehyde solution in a same beaker
- Take 2 grams of phenol and stirrer until saturated solution is obtained.
- Add few drops of Concentrated Sulphuric acid into the mixture with stirring continuously during addition carefully.
- Continuous stirring till to 5 minutes give large mass of plastic formed during process.
- The residue obtained is washed several times with distilled water, and filtered product is dried and yield is calculated.

V. Procedure To Prepare Reinforced Composites

The Bakelite was used as the matrix material. Recycled Cellulose fiber sheets were reinforced on the matrix. First, Recycled Cellulose fiber dried for 50 min at 75 ºC. After that, Recycled Cellulose fiber sheets are fully immersed into a mixture of Bakelite and hexamine (Hardener). In the process hexamine acts as a hardener for Bakelite. So the fiber became entirely wetted due to the mixture and laid down in a mold of closed silicone at 0.0082 bar compressive pressures and left for 24 hours for curing at room temperature. Then, the sheet was prepared and this was cut into ASTM Standard size for testing the mechanical properties.

VI. Result

For testing the mechanical properties, the mat was cut into ASTM D2344 for flexural strength, through which the property of RCF reinforced composite has increased 40% more when compared to the original material. Finally the presence of RCF significantly enhanced the impact toughness of the matrix and similarly, the impact strength of this composite also increased 76% more. The impact toughness for phenol-formaldehyde and RCF reinforced Bakelite is 0.8 and 1.4 kJ/m^2 respectively. This significant enhancement is due to the unique properties of cellulose fiber in withstanding bending forces and resisting fracture force. The result indicates improvement in the impact toughness of the composite material by recycled cellulose fibers.

VII. Conclusion

Here the composite preparation of Bakelite with reinforced cellulose fiber was described and material characterization of this composite was identified. Then, mechanical properties of this composite were found, through which the composite shows increased properties when compared to pure phenol formaldehyde. Similarly, the thermal properties were found through TGA that displayed decreased temperature with maximum degradation. So, RCF can be completely suitable for increasing thermal and mechanical properties.

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