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Coconut Shell Reinforced Epoxy Composites

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***Abstract*: The present literature review paper deals with the study of mechanical and flexural properties of coconut shell ash reinforced epoxy composites. Carbonization method was used to prepare the coconut shell ash by heat treating the crushed coconut shell at a temperature of 600 °C and 800 °C. Coconut shell ash epoxy composites were prepared by different filler concentration using hand lay-up technique. Specimens were cut from the fabricated laminate according to the ASTM standards for different experiments. For tensile and flexural test, samples were cut in dog-bone shape and flat bar shape respectively. It was observed that at 20% weight. of filler content, coconut shell ash which was heat treated at 800 °C gives the best results for micro-hardness, flexural strength and tensile strength properties of the composite under consideration.**

***Keywords*: Composite materials, aerospace and ecofriendly**

1. Introduction

A. *Coconut shell reinforced epoxy composites*

Composite materials were developed as a class of materials capable of advanced aerospace, electronics, structural, automotive and wear applications. The advantage of the composites materials is their tailored mechanism which includes low density, high specific strength. This composite material mixture used in our study was coconut shell powder and HDPE (High Density Polyethylene). The top five coconut producing countries are Indonesia, Philippines, India, Brazil and Sri Lanka. The places in India include Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Telangana, Bihar, Andhra Pradesh, West Bengal, Orissa and Assam. The coconut usually contains coconut water and core which is consumed and the remaining is left shell as waste. These shells are containing natural fibers and composites that are eco-friendly, cheap and renewable to the environment. High Density Polyethylene works like a hardener, the only type of polyethylene produced was low density polyethylene. A German scientist (Karl Ziegler), made the greatest contribution in producing high-density polyethylene. The mechanical properties change drastically over high-density polyethylene to the low-density polyethylene. In general, the degree of branching in polyethylene determines its mechanical properties. High-density polyethylene is more crystalline than the low-density polyethylene because it contains fewer branches. Unlike low-density polyethylene, Composite material mixture which consists of coconut shell powder with different hardeners like Coir Fibre Reinforced Polyester Composites, polymer matrix composites, Phenol Formaldehyde Epoxy Resin, and Polyester [1]-[4]. In this paper, the composites are tested by bending, impact and tensile tests. By these results it is proved as good composite material. It has been noticed that the limited mechanical properties (strength and hardness) of aluminium and its alloys are adversely affects its applications in automobile and aerospace industries (Lai, 2000; Wang, 2002). This constitutes a major concern in its fabrication to suit its different applications. Hence, there has been growing interest in the use of aluminium based metal matrix with improved mechanical properties and wear resistance, especially in the transport industries, where component weight reduction, enhanced friction and wear performances are key objective.

This growing requirements of materials with high Specific mechanical properties with weight savings characteristic has increased significant research activities in recent times focused primarily on further development of aluminium based composites (Ajoy Kumar Ray et al, 2002; Walker et al, 2005; Joel, 2009). Their distinctive properties of high stiffness, high strength and low density have promoted an increasing number of applications for these materials. The demand for structural materials to be cost effective and also to provide high performance has also resulted in continuous attempts being made particularly in areas of alloy design and the use of novel processing techniques to develop composites that will compete favorably with traditional engineering alloys (Lorella and Roberto, 2011). The largest improvement in properties (strength and stiffness) has obtained with the introduction of fiber reinforcements (Clyne and Withers, 1993; Guo et al, 1995), but the properties of fibre-reinforced composites are not isotropic. Particle-reinforced metal matrix composites (MMCs) are attractive in that they exhibit near-isotropic properties when compared with the continuously-reinforced matrices (Peng and Zhu, 2003) and have better wear resistance (Pruthvira, 2011; Rajaneesh and Kanakuppi, 2011). Most of the researches on MMCs that are carried out on the aluminium based composites to improve its mechanical properties involve incorporation of hard ceramic oxides, carbides or nitrides into the metal matrices. Typical reinforcements in particulate-reinforced MMC are ceramics, such as $Al2O3$ and SiC (Slipenyuk et al, 2006; Kainer, 2006; El-Daly et al, 2013). In AlSiC composites, the reinforcing SiC phase is incorporated in the form of particulate, fibre or whiskers into the matrix of aluminium metal by a large number of techniques (Soon-Jik et al 2003; Joel, 2009). The use of SiC as reinforced material to the aluminium metal matrix is restricted due to the reaction of Al with SiC above 720°C forming Al4C3, which has poor mechanical properties and severe corrosion problem (Ahmad, 2003). Low composite toughness may be another disadvantage of conventional SiC reinforcement particles with sharp pointed corners; because it has been shown that the reinforcement particle shape has a great effect on strain field localization in composites under stress (Qin et al, 1999). Fly ash has also been successfully used as reinforcement in Aluminium based MMCs (Rohatgi et al, 2006; Mohanty and Chugh, 2007; Sarkar et al, 2008). Composite materials are those in the mechanical, chemical and other properties of two or more different materials are combined to enhance them. The composite materials have their distinct properties and behavior under the different working conditions. Different composites are developed by using the agro waste material such as the bagasse fibers, fibers from leaves of different trees. Composites from coconut shell particles are also developed. The possibility of the developing the composites by using both coconut shell particles and bagasse particles together is proposed. The compressive strength of the coconut shell particles and the tensile strength of the bagasse particles is tried to combine in the composite. As the wood or furniture industry has very huge demand for the light weight and high strength material. Also, the cost is the prime factor. Thus, there are the possibility to develop such materials. Nowadays, the plywood sheets and laminates are used in the industry, and the factor of weight and cost are playing an important role. Hence, there are the scope to develop a new composite material using agro waste such as coconut shell particles and sugar cane waste particles, estimation of mechanical strengths of such material and also, to explore the possibility of finding out the alternatives composite for existing material used in furniture industries.

2. Literature review

Products manufactured from carbon are very important in modern life. The production of carbon black demands high cost for processing and energy consumption is also high. Therefore, an alternative for developing new starting materials for carbon material is needed in order to reduce the cost and fulfil every need of the carbon black consumer. Many researchers have evaluated the by-products of agricultural waste in a new way for the next carbon black generation. Carbon black is commercially used as a filler, it has its own grades and characteristics. The properties of carbon used in the composites mainly depends on the origin, processing conditions and chemical treatments. The particle size, surface activity, degree of interactions with polymer, chemical composition, and the degree of irregularity of filler shape are the factors affecting the behavior of the composites. Madhukiran.J (2006) in their work have chosen banana and pineapple as the raw material for preparation of carbon black and activated carbon and used the same as a filler material in polyester composites. Their results show good mechanical properties and high stiffness are obtained in the composite. Hence, the low density of proposed natural fibres compared to synthetic fibres (glass fibres, carbon fibres, etc.,), the composites can be regarded as a useful material in light weight applications. S. Luo and A.N. Netravali (2009) studied the tensile and flexural properties of the green composites with different pineapple fibre content and compared with the virgin resin. H. Belmares, A. Barrera, and M. Monjaras (2010) found that sisal, henequen and palm fibre have very similar physical, chemical, and tensile properties.M. Cazaurang, P. Herrera, I. Gonzalez, and V.M. Aguilar carried out a systematic study on the properties of henequen fiber and pointed out that these fibers have mechanical properties that are suitable for reinforcing thermoplastic resins. In India there are many potential natural resources, most of it comes from the forest and agriculture. Among all natural fibers, Coconut shell particles have high strength and modulus properties along with the added advantage of high lignin content. The high lignin content makes the fiber suitable for manufacturing composites. Coconut shell flour is also extensively used to make products like furnishing materials, rope etc. The shells are also absorbing less moisture due to its low cellulose content. R.D.T. Filho (2010) while studying on the effectiveness of coconut shell particles as a source of natural material for reinforced epoxy resins towards their flexural properties. Currently, various materials are used to produce activated carbon and some of the most commonly used agricultural wastes such as coconut shell, pistachio shell, and saw dust, Walnut shell and tropical wood.
Flexural and tensile properties of biomass carbon black as filler material in epoxy Composites have been studied by Abdul Khalil et.al. They performed several Characterization studies on composites prepared from bamboo stems, coconut shells and oil palm fiber bunches. Their results indicate better flexural stability of carbon black reinforced epoxy composites compared to un-reinforced samples. Coconut shells are available in abundance in tropical countries such as Sri Lanka, India, Thailand, Burma, Malaysia, and Indonesia as waste products following consumption of coconut water and meat. Such abundance will be able to meet gradually increasing the demand of filler-based composites while reducing the natural waste. Procurement and processing of coconut shells to generate coconut char is highly cost effective than most other man-made carbon. Sandhyarani Biswas, Sanjay Kindo (2012) studied the mechanical behavior of coir fiber reinforced polymer matrix composites and observed that that the mechanical properties of the composites such as micro-hardness, tensile strength, flexural strength, impact strength etc. of the composites are also greatly influenced by the fiber lengths. They also studied the processing and characterization of natural fiber reinforced polymer composites and observed that impact velocity, erodent size and fiber loading were the significant factors in a declining sequence affecting the erosion wear rate.

- Natural fiber composites are likely to be environmentally superior to glass fiber composites in most cases for the following reasons:

- Natural fiber production has lower environmental impacts compared to glass fiber production.
- Natural fiber composites have higher fiber content for equivalent performance, reducing more polluting base polymer content.
- The light-weight natural fiber composites improve fuel efficiency and reduces emissions in the use phase of the component, especially in automobile applications.
- End of life incineration of natural fibers results in recovered energy and carbon credits.

3. Types of components

Broadly, composite materials can be classified into three groups on the basis of matrix material. They are:

- Metal Matrix Composites (MMCs)
- Ceramic Matrix Composites (CMCs)
- Polymer Matrix Composites (PMCs)

A. *Metal matrix composites (MMCs)*

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

B. *Ceramic matrix composites (CMCs)*

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumina silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density.

C. *Polymer matrix composites (PMCs)*

The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the constituents the polymer composites often show excellent specific properties.

4. Types of natural rubber

Fibers are a class of hair-like materials that are continuous filaments or are in discrete elongated pieces, similar to pieces of thread. They can be spun into filaments, thread, or rope. They can be used as a component of composite materials. Natural fibers are of two types and they are classified based upon their origin.

A. *Vegetable fiber*

Vegetable fiber are generally composed of cellulose examples includes cotton, jute, flax, ramie, sisal, and hemp. Cellulose fiber serves in the manufacture of paper and cloth. This fiber can be further categorized into the following:

B. *Seed fiber*

Fiber collected from seeds or seed cases. E.g. cotton and kapok.

C. *Leaf fiber*

Fiber collected from leaves. E.g. fig, sisal, banana and agave.

D. *Bast or skin fiber*

Fiber are collected from the Skin or Bast surrounding the stem of their respective plant. These fibers have higher tensile strength than other fiber. Therefore, these fibers are used for durable yarn, fabric, packaging and paper. Some examples are flax, jute, kenaf, industrial hemp, and rattan and vine fiber.

E. *Stalk fiber*

Fiber are collected from the fruit of the plant. E.g. coconut (coir) fiber.

F. *Animal fiber*

Animal fiber generally comprise proteins such as collagen, keratin and fibroin; examples include silk, sinew, wool, catgut, angora, mohair and alpaca.

G. *Animal hair*

Fiber or wool taken from animals or hairy mammals e.g. sheep's wool, goat hair (cashmere, mohair), alpaca hair, horse hair, etc.

H. *Silk fiber*

Fiber secreted by glands (often located near the mouth) of insects during the preparation of cocoons.

I. *Avian fiber*

Fibers from birds, e.g. feathers and feather fiber

5. Material selection

A. *Coconut shell*

Coconut shell is one of the most important natural fillers produced in tropical countries like Malaysia, Indonesia, Thailand, and Sri Lanka. Many works have been devoted to use of other natural fillers in composites in the recent and past years and coconut shell filler is a potential candidate for the development of new composites because they have high strength and modulus properties along with the added advantage of high lignin content. The high lignin content makes the composites made with these fillers more weather resistant and hence, more suitable for application as a construction material. Coconut shell flour is also extensively used to make products like furnishing materials, rope etc. The shells also absorb less moisture due to its low cellulose content the report focuses on studying the effectiveness of coconut shell particles as a source of natural material for reinforcing epoxy resins towards their flexural properties.

6. Resins

The primary functions of the resin are to transfer stress between the reinforcing fibers, act as a glue to hold the fibers together, and protects the fibers from mechanical and environmental damages. Resins are divided into two major groups known as thermo set and thermoplastic. Thermoplastic resins become soft when heated, and may be shaped or molded while in a heated semi-fluid state and become rigid when cooled. Thermo set resins, on the other hand, are usually liquids or low melting point solids in their initial form. These thermosetting resins are “cured” by the use of a catalyst, heat or a combination of the two. Once cured, solid thermo set resins cannot be converted back to their original liquid form. Unlike thermoplastic resins, cured thermo sets will not melt and flow but will soften when heated (and lose hardness) and once formed, they cannot be reshaped. Heat Distortion Temperature (HDT) and the Glass Transition Temperature is used to measure the softening of a cured resin. The most common thermosetting resins used in the composites industry are unsaturated polyesters, epoxies, vinyl esters, and phenolic. There are differences between these groups that must be understood to choose the proper material for a specific application.

A. Thermoplastic resin

Thermoplastic resins, commonly used as composite matrix are as follows

- Low Density Polyethylene.
- High Density Polyethylene.
- Linear Low-Density Polyethylene.
- Polypropylene.
- Polyethylene Terephthalate
- Acrylonitrile Butadiene Styrene

B. Thermosetting resin

Thermosetting resins, commonly used as composite matrix are as follows

- Polyester
- Vinyl ester
- Epoxy
- Phenolic

C. Epoxy resins

Epoxy is a co-polymer formed from two different chemicals. These are referred to as the "resin" and the "hardener". The resin consists of monomers or short chain polymers with an epoxide group at either end. Most common epoxy resins are produced from a reaction between epichlorohydrin and bisphenol-A, though the latter may be replaced by similar 45 chemicals. The hardener consists of polyamine monomers, for example triethylenetetramine (TETA). When these compounds are mixed together, the amine groups react with the epoxide groups to form a covalent bond. Each NH group can react with an epoxide group, so that the resulting polymer is heavily cross linked, and is thus rigid and strong. Softener (ARALDITE LY 556) made by CIBA GEIGY limited having the following outstanding properties has been used as the matrix material.

7. Conclusion

The experimental investigation on mechanical properties viz. tensile strength, flexural strength and impact strength of coconut shell powder (CSP) polyester composite material is greatly influenced by the CSP filled volume fraction. The maximum tensile strength is obtained for the composite prepared with 20% CSP volume fraction. The literature paper shows that the tensile strength, modulus of elasticity, flexural strength and impact strength of CSP/PVC composites were improved compared to the pure PVC. For automotive interior parts such as seat covers and dashboards, the use of these composites can reduce the cost of PVC as well as improves the overall strength of the parts. In terms of weight, CSP can reduce the overall weight of these parts through lowering of the composite density, and hence can improve the fuel efficiency. For engine parts, these composites can replace steel (even PVC material in the air intake piping system) because of its advantages. By using these composites, it can reduce a cost of base polymer and also can decrease the effects of environmental issues concerning energy and carbon credits. When referring to strength, this literature paper shows that the strength increases when the fibre content increases. Hence, in the automotive industry (especially in the production of polymer), parts such as bumpers or interior parts can be protected if an accident occurs when compared to the pure PVC. In addition, it reduces the virgin material but improves the strength by the addition of this fiber. Therefore, this composite ‘Coconut Shell Powder (CSP)’ is very useful to the automotive industry for reduction of cost and weight and, at the same time, improvement of PVC strength performance. Consequently, the composite prepared with 20% CSP filled volume fraction is suitable for the application in the interior part of an aircraft, motor car and automobile where materials with good tensile strength, low density and low hydrophilic characteristic are required.

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