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Recent Advances in Green Composites – A Review

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Abstract - **Composites are one of the most widely used materials because of their adaptability to different situations and the relative ease of combination with other materials to serve specific purposes and exhibit desirable properties. Various composites like metal matrix composites, nano composites, fiber reinforced composites and hybrid composites commonly used in various industries. Now our attention is focused on development of green composites which are environment friendly. Green composites are a specific class of biocomposites, where a bio- based polymer matrix is reinforced by natural fibers, and they represent an emerging area in polymer science. Green composites obtained from biodegradable renewable resources have gained much attention due to environmental problems resulting from conventionally synthetic plastics and a global increasing demand for alternatives to fossil resources. This review aims at reporting on very recent developments in the, properties and applications of Green Composites. The applications of green composites increasing day by day like in transportation articles, sports goods, household applications, automotive sector, construction, etc. Recent developments of different biodegradable polymers and biocomposites are also discussed in this review article. Some recently developed green composites and their mechanical properties and applications also discussed in this paper. New trends in the selection of natural fibers, that is, from waste rather than from valuable crops are described.**

Keywords **-** composite, green composites, biocomposites

1. INTRODUCTION

Composites

A "composite" is when two or more different materials are combined together to create a superior and unique material. This is an extremely broad definition that holds true for all composites, however, more recently the term "composite" describes reinforced plastics

Benefits of Composites

In comparison to common materials used today such as metal and wood, composites can provide a distinct advantage. The primary driver and advantage in the adoption of composites is the lightweight properties. In transportation, less weight equates to more fuel savings and improved acceleration. In sporting equipment, lightweight composites allow for longer drives in golf, faster swings in tennis, and straighter shots in archery. While in wind energy, the less a blade weighs the more power the turbine can produce. Besides weight savings, the most important benefits of composites include: Non-corrosive, Non-conductive, Flexible, will not dent, Low maintenance, Long life, Design flexibility

Classification of composites: three main categories:

- Particle-reinforced (large-particle and dispersion-strengthened)-These are composed of particle of one or more material is suspended in a matrix of another material to make the material stronger
- Fiber-reinforced (continuous (aligned) and short fibers (aligned or random)- these are the long fiber of one material is embedded in the matrix of other material which turns out to be extremely strong.
- Structural (laminates and sandwich panels)- these are layers of two or more different material are bonded together by sandwiching two layers of strong.

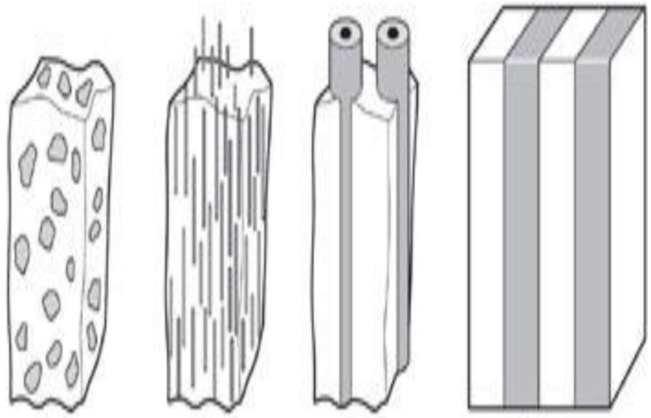

Figure 1 – Types of metal matrix composites (M.K. Surappa, 1997)

These types of composites cover a range of different material combinations. The most common type is polymer matrix composites, however, metal matrix composites, and ceramic matrix composites are also common, as are natural composites such as wood.

Why Green composites are needed

Ecological concerns have resulted in renewed interest in natural materials; Recyclability and environmental safety are becoming increasingly important to the introduction of materials and products. Petroleum based products such as resins in thermoset plastics, are toxic and non-biodegradable.The resins and fibres used in the green composites are biodegradable, when they dumped, decomposed by the action of microorganisms. They are converted into the form of H2O and CO2. These H2O and CO2 are absorbed into the plant systems.Green composite combines plant fibres with natural resins to create natural composite. Composites are a specific class of composites, where atleast one of the components (such as the matrix or the reinforcement) is obtained from natural resources(Netravali, Chabba, 2013, Sharma et al., 2014; Goyal et al., 2014). The term green composites, biocomposites and eco composites all bradly refer to the same class of materials(Nikolaos, 2011; Kumari et al., 2013). In ancient Egypt, 3000 years ago, people used straw as the reinforcing component for the mud based wall materials in houses. They made bricks of mud with straw as reinforcement and used these bricks to build walls.

Classification of green composites-Green composites on type of reinforcement and polymer materials, are divided into three main types as mentioned here.

(a) Totally renewable composites, in which both matrix and reinforcement are from renewable resources.
(b) Partly renewable composites in which matrix is obtained from renewable resources and reinforced with a synthetic material.
(c) Partly renewable composites in which synthetic matrix is reinforced with natural bio polymers.

Fibres used in green composites

- Natural / biofibres may be classified in two broad categories: Non-wood, Wood fibres.
- Natural fibres such as kenaf, flax, jute, hemp, and sisal have attracted renewed interest, especially as an E glass fibre substitute in the automotive industry.
- The other fibres used are Coir (Coconut), Bamboo , Pineapple , Ramie

Advantages of green composites over traditional composites : These are less expensive, reduced weight, increased flexibility, renewable resource, sound insulation, thermal recycling is possible where glass poses problems, friendly processing and no skin irritation.

2. **METHODS OF MANUFACTURING COMPOSITES –** The green composite are processes by various methods which are discussed here.

- Filament winding
- Lay up methods
- Resin transfer moulding
- Injection moulding
- Autoclave bonding

2.1Filament winding- Resin-impregnated continuous fibers are wrapped around a rotating mandrel that has the internal shape of the desired FRP product; the resin is then cured and the mandrel removed The fiber rovings are pulled through a resin bath immediately before being wound in a helical pattern onto the mandrel. The operation is repeated to form additional layers, each having a criss-cross pattern with the previous, until the desired part thickness has been obtained

2.2 Layup method- Hand lay–up, or contact molding, is the oldest and simplest way of making fibreglass–resin composites. Applications are standard wind turbine blades, boats ,etc..Hand lay-up : (1) mold is treated with mold release agent; (2) thin gel coat (resin)is applied, to the outside surface of molding; (3) when gel coat has partially set, layers of resin and fiber are applied, the fiber is in the form of mat or cloth; each layer is rolled to impregnate the fiber with resin and remove air; (4) part is cured; (5) fully hardened part is removed from mold.

2.3 Resin transfer method- RTM is a process using a rigid two-sided mould set that forms both surfaces of the panel. The mould is typically constructed from aluminum or steel, but composite molds are sometimes used. The two sides fit together to produce a mould cavity. The distinguishing feature of resin transfer moulding is that the reinforcement materials are placed into this cavity and the mould set is closed prior to the introduction of matrix material. Resin transfer moulding includes numerous varieties which differ in the mechanics of how the resin is introduced to the reinforcement in the mould cavity. These variations include everything from the RTM methods used in out of autoclave composite manufacturing for high-tech aerospace components to vacuum infusion (for resin infusion see also boat building) to vacuum assisted resin transfer moulding (VARTM). This process can be performed at either ambient or elevated temperature.

2.4 Injection moulding-Injection molding is noted for low cost production of plastic parts in large quantities. Although most closely associated with thermoplastics, the process can also be adapted to thermosets. Used for both TP and TS type FRPs• virtually all TPs can be reinforced with fibers. Chopped fibers must be used. Continuous fibers would be reduced by the action of the rotating screw in the barrel. During injection into the mold cavity, fibers tend to become aligned as they pass the nozzle.

2.5Autoclave bonding- A process using a two-sided mould set that forms both surfaces of the panel. On the lower side is a rigid mould and on the upper side is a flexible membrane made from silicone or an extruded polymer film such as nylon. Reinforcement materials can be placed manually or robotically. They include continuous fibre forms fashioned into textile constructions. Most often, they are pre-impregnated with the resin in the form of prepreg fabrics or unidirectional tapes. In some instances, a resin film is placed upon the lower mould and dry reinforcement is placed above. The upper mould is installed and vacuum is applied to the mould cavity. The assembly is placed into an autoclave. This process is generally performed at both elevated pressure and elevated temperature. The use of elevated pressure facilitates a high fibre volume fraction and low void content for maximum structural efficiency.

2. LITERATURE REVIEW RELATED TO GREEN COMPOSITES

Amnuay Wattanakornsiri, Katavut Pachana, Supranee Kaewpirom, Matteo Traina, Claudio Migliaresi (2012)discussed about green composites obtained from biodegradable renewable resources have gained much attention due to environmental problems resulting from conventionally synthetic plastics and a global increasing demand for alternatives to fossil resources. In this work we used different cellulose fibers from used office paper and newspaper as reinforcement for thermoplastic starch (TPS) in order to improve their poor mechanical, thermal and water resistance properties. The compo- sites were prepared from corn starch plasticized by glycerol (30% wt/wt of glycerol to starch) as matrix that was reinforced with micro-cellulose fibers, obtained from used newspaper, with fiber content ranging from 0 to 8% (wt/wt of fibers to matrix). Physical properties of composites were determined by mechanical tensile tests, differential scanning calorimetry, thermo- gravimetric analysis, water absorption measurement and scanning electron microscopy. The result showed that the tensile strength and elastic modulus, decrease in water absorption to 175%, 292% and 63%.. The results indicated that these green composites could be utilized as commodity plastics being strong, inexpensive, plentiful and recyclable. George Gejo et al. (2010), discussed about recent developments in the, properties and applications of green Composites. One very important aspect of green composites is that they can be designed and tailored to meet different requirements. Recent advances in natural fiber development offer significant opportunities for improved materials from renewable resources. Biocomposites offer a significant non-food market for crop-derived fibres and resins. Considerable growth has been seen in the use of biocomposites in the automotive and decking markets over the past decade or so, but application in other sectors has been limited. Recent developments of different biodegradable polymers and biocomposites were discussed in this review article.Panigrahi et al. (2008) found that western Canada has large acreage of oilseed flax, but unfortunately a small percentage of total crop residue (flax straw) produced annually was being commercially used. Therefore, farmers were still burning the flax straw. Flax fiber and straw has highest strength amongst the different natural fibers, therefore, the prospect of using them as biorenewable reinforcement in recycled/ virgin polymer matrices has gained attention in recent years. Flax strawboard has a potential to replace the currently used wood and other crop like wheat/barley straw boards for different industrial application. In this research Oilseed flax straw reinforced composite boards were developed using flax shives with biopolymer binder made out of recycled/ pure thermo plastic and flax fiber. Some advantages of such materials are high strength, low density, good insulation capacity against heat and moisture transfer, and biodegradability. Pure and recycled HDPE (High Density Polyethylene) with two different percentages of flax fiber and three percentages of flax shives were assessed to make biocomposite boards. The flax fiber was chemically treated to improve the bond between the fiber and polymer. The recycled plastic was also cleaned properly before processing. According to binder formulations, ingredients were mixed and extruded using a twin screw extruder. The extruded materials were ground and used as binder for flax shives at specific ratios. The bio-composite boards were manufactured by applying heat under compression. Physical and mechanical properties of the bio-composite boards were studied by performing ASTM tests.

B.C. Mitra(2014) discussed about biocomposites can supplement and eventually replace petroleum-based composite materials in several applications. Several critical issues related to bio-fiber surface treatments is to make it a more suitable matrix for composite application and promising techniques need to be solved to design biocomposite of interest. The main motivation for developing biocomposites has been and still is to create a new generation of fiber reinforced plastics material competitive with glass fiber reinforced ones which are environmentally compatible in terms of products, use and renewal. There is an immense opportunity in developing new biobased products, but the real challenge is to design suitable bio-based products through innovation ideas. Green materials are the wave of the future. Bio nanocomposites have very strong future prospects, though the present low level of production, some deficiency in technology and high cost restrict them from a wide range of applications. These materials find their way in commodity &non-structural applications such as casings of electronic products, interior parts of automobiles .Most of the bio-composites developed so far, has tensile & flexural strengths lower than 100 MPa which restricts their usage in high strength applications.Koichi Goda et al. (2014) discussed about the advances , challenges and opportunities in biocomposites. To reduce the emission of co2 and other greenhouse gases renewable energy source were developed and similarly work was done in making green composites. Intillay biodegradable plastic, polylactic acid (PLA) and polyhydroxyalkanoic acid (PHA), were among the leading biomass-derived materials, which were finally decomposed by microorganisms into water and carbon dioxide. Carbon fiber-reinforced plastic matrix composites (CFRP), in particular, have been recently used for primary structural components in airplanes and automobiles as well as sport goods and construction materials, because of their excellent mechanical properties. Biodegradable resin may also be reinforced with such fibers, similarly to the conventional petroleum- derived plastics. This idea of using natural fibers had already been adopted in the experimentally developed automotive body in 1940s by Henry Ford. Continuing this process the use of green composite become a trend in automobiles in automobiles company like Mercedes-Benz-1990, ToyotaMotors-2003- the constituents of which were kenaf fibers and PLA resin. The project known as Poverty and Environment Amazonia (POEMA) in Brazil, established by Daimler-Chrysler, also started in 1981. This organization contracted with the residents of the Amazon valley, and encouraged them to apply natural resources such as coconut fibers to car interior parts. H. Ku et al. (2011) discussed about the tensile properties of natural fiber reinforced polymer composites. Natural fibers have recently become attractive to researchers, engineers and scientists as an alternative reinforcement for fiber reinforced polymer (FRP) composites. Due to their low cost, fairly good mechanical properties, high specific strength, non-abrasive, eco-friendly and bio-degradability characteristics, they are exploited as a replacement for the conventional fiber, such as glass, aramid and carbon. The tensile properties of natural fiber reinforce polymers (both thermoplastics and thermosets) were mainly influenced by the interfacial adhesion between the matrix and the fibers. Several chemical modifications were employed to improve the interfacial matrix–fiber bonding resulting in the enhancement of tensile properties of the composites. In general, the tensile strengths of the natural fiber reinforced polymer composites increased with fiber content, up to a maximum or optimum value, the value will then drop. However, the Young's modulus of the natural fiber reinforced polymer composites increased with increasing fiber loading. Cheung et al. (2009) found that the mankind has realized that unless environment is protected, he himself will be threatened by the over consumption of natural resource as well as substantial reduction of fresh air produced in the world. Conservation of forests and optimal utilization of agricultural and other renewable resources like solar and wind energies, and recently, tidal energy have become important topics worldwide. In such concern, the use of renewable resources such as plant and animal based fibre-reinforce polymeric composites, has been becoming an important design criterion for designing and manufacturing components for all industrial products. Research on biodegradable polymeric composites, can contribute for green and safe environment to some extent. In the biomedical and bioengineered field, the use of natural fibre mixed with biodegradable and bioresorbable polymers can produce joints and bone fixtures to alleviate pain for patients. In this paper, a comprehensive review on different kinds of natural fibre composites will be given. Their potential in future development of different kinds of engineering and domestic products will also be discussed in detail.

F.P. La Mantia , et al. (2011) found that the rising concern towards environmental issues and, on the other hand, the need for more versatile polymer-based materials has led to increasing interest about polymer composites filled with natural-organic fillers, i.e. fillers coming from renewable sources and biodegradable. The composites usually referred to as "green", can find several industrial applications. On the other hand, some problems exist, such as worse processability and reduction of the ductility. The use of adhesion promoters, additives or chemical modification of the filler can help in overcoming many of these limitations. These composites can be further environment-friendly when the polymer matrix is biodegradable and comes from renewable sources as well.

Elisa Zini and Mariastella Scandola(2011) found that the use of natural fibers to reinforce polymers is a well-established practice, and biocomposites were increasingly used in sectors such as automotive and construction. Green composites are a specific class of biocomposites, where a bio-based polymer matrix is reinforced by natural fibers, and they represent an emerging area in polymer science. This work discussed about the environmental benefits deriving from the use of natural fibers in polymer composites and from substitution of oil-derived polymers by bio-based polymers as matrix material. New trends in the selection of natural fibers, that is, from waste rather than from valuable crops were described. Recently developed thermoplastic and thermosetting bio-based polymers were reviewed, and commercially available green composites obtained thereof were discussed. J.P. Torres(2013) found that nowadays, there was a growing interest for the use and development of materials synthesized from renewable sources in the polymer composites manufacturing industry; this applies for both matrix and reinforcement components. In the present research, a novel basalt fibre reinforced (BFR) bioepoxy green composite was proposed as an environmentally friendly alternative to traditional petroleum-derived composites. In addition, this material system was combined with cork as core material for the fabrication of fibre composite sandwich structures. Mechanical properties of both skin and core materials were assessed through flexural and tensile tests. Finite element (FEM) simulations for the mechanical stress analysis of the sandwich material were carried out, and a maximum allowable shear stress for material failure under bending loads was established. The proposed green-composite sandwich material was used for the fabrication of a long board as a case study for a sports equipment application. Numerical simulations of the mould filling stage allowed the determination of an optimal mould filling strategy. Finally, the load-bearing capacity of the board was studied by means of FEM simulations, and the presented design proved to be acceptable for service.

5. CONCLUSIONS

In this paper we have discussed about the type of green composites, processing of green composites and the research work going on in the field of green composites. The focus is on improving the processing of green composites in more economical way as the raw material cost in green composites is not very high. Researchers are using these green composites in various applications according to their properties.

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