FABRICATION OF DECORATIVE FLUORESCENT COMPOSITE MATERIAL

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<u>CERTIFICATE</u>

This is to certify that the thesis entitled "**Fabrication of Decorative Fluorescent Composite Material**" being submitted by **Subham Mahato** in partial fulfillment of the requirements for the award of the degree of Master of Science in Physics at National Institute of Technology, Rourkela is an authentic experimental work carried out by him under our supervision. To the best of our knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any degree or diploma.

Date:

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ABSTRACT

Decorative Composites are the composite materials having artistic characteristics in addition to functional characteristics. It is highly possible that the decorative composites may produce an entire new field on the fibrous composite industry. Natural fiber reinforced composite is gaining attention and considered as an eco-friendly material. Generally cellulosic fibers are used to reinforce the composites. In this paper, we proposed a method for producing artistic composite from artistic fabric by using sisal fiber. In order to expand applications of the fiber reinforced composite, we performed the hand lay-up method for the preparation of mold with the help of themocoul. Then using epoxy resin as matrix we prepared a decorative composite with sisal fiber as reinforced material. To make it more attractive, fluorescent materials have been added which disturbed the curing property of epoxy resin and took a lot more time. But finally we got decorative fluorescent composite materials with desired shape.

CONTENT

FABRICATION OF DECORATIVE FLUORESCENT COMPOSITE MATERIALS

1.1 Introduction

A composite is a structural material that consists of two or more combined constituents those are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles or flakes. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and epoxy reinforced with graphite fibers, etc.

The advantage of composite materials is that, if well designed, they usually exhibit the best qualities of their components and often some qualities that neither constituent processes.

Some of the properties that can be improved by forming a composite material are –

- Strength
- Stiffness
- Weight
- Corrosion resistance
- Fatigue life
- Thermal insulation
- Thermal conductivity
- Attractiveness

Naturally, not all of these properties are improved together nor is there usually any requirement to do so. The objective is to create a material that has only the characteristics needed to perform the design task.

1.2 Classification of composite materials

Four commonly accepted types of composite materials are –

i. Fibrous composite materials that consists of fibers in a matrix
ii. Laminated composite materials that consists of layers of various materials
iii. Particulate composite materials that are composed of particles in a matrix
iv. Combinations of some or all of the first three types

1.3 Characteristics of composites

A composite material consists of continuous and discontinuous phases. The discontinuous phase, which is usually harder and stronger than the continuous phase, is called reinforcement and the continuous phase is called matrix. The matrix is usually more ductile and less hard. Matrix is composed of any of the three basic material type i.e. polymers, metals or ceramics. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in enhanced properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, length and size distribution) influences the properties of the composite to a great extent. The shape of the fiber (which may be spherical, cylindrical or rectangular cross-sectioned), size, size distribution (which controls the texture of the material) and volume fraction (which determines the interfacial area) play important role in determining the extent of the interaction between the reinforcement and the matrix. Concentration, usually measured as volume or weight fraction, determines the contribution of a single constituent to the overall properties of the composites. It is not only the most important parameter influencing the properties of the composites, but also an easily controllable manufacturing variable used to change its properties.

1.4 Advantages and disadvantages of composites

1.4.1 Advantages

Summary of the advantages exhibited by composite materials, which are of significant use are as follows:

- High resistance to fatigue and corrosion degradation.
- High “strength or stiffness to weight” ratio. As enumerated above, weight savings are significant ranging from 25-45% of the weight of conventional metallic designs.
- Due to greater reliability, there are fewer inspections and structural repairs.
- Directional tailoring capabilities to meet the design requirements. The fiber pattern can be laid in a manner that will tailor the structure to efficiently sustain the applied loads.
- Fiber to fiber redundant load path.
- Improved dent resistance is normally achieved. Composite panels do not sustain damage as easily as thin gage sheet metals.
- It is easier to achieve smooth aerodynamic profiles for drag reduction. Complex double-curvature parts with a smooth surface finish can be made in one manufacturing operation.
- Composites offer improved torsional stiffness. This implies high whirling speeds, reduced number of intermediate bearings and supporting structural elements. The overall part count and manufacturing & assembly costs are thus reduced.
- High resistance to impact damage.
- Thermoplastics have rapid process cycles, making them attractive for high volume commercial applications that traditionally have been the domain of sheet metals. Moreover, thermoplastics can also be reformed.
- Like metals, thermoplastics have indefinite shelf life.
- Composites are dimensionally stable i.e. they have low thermal conductivity and low coefficient of thermal expansion. Composite materials can be tailored to comply with a broad range of thermal expansion design requirements and to minimize thermal stresses.
- Manufacture and assembly are simplified because of part integration (joint/fastener reduction) thereby reducing cost.

• The improved weather ability of composites in a marine environment as well as their corrosion resistance and durability reduce the down time for maintenance.

• Close tolerances can be achieved without machining.

• Material is reduced because composite parts and structures are frequently built to shape rather than machined to the required configuration, as is common with metals.

• Excellent heat sink properties of composites, especially Carbon-Carbon, combined with their lightweight have extended their use for aircraft brakes.

• Improved friction and wear properties.

• The ability to tailor the basic material properties of a Laminate has allowed new approaches to the design of aero elastic flight structures. The above advantages translate not only into airplane, but also into common implements and equipment such as a graphite racquet that has inherent damping, and causes less fatigue and pain to the user.

1.4.2 Disadvantages

Some of the associated disadvantages of advanced composites are as follows:

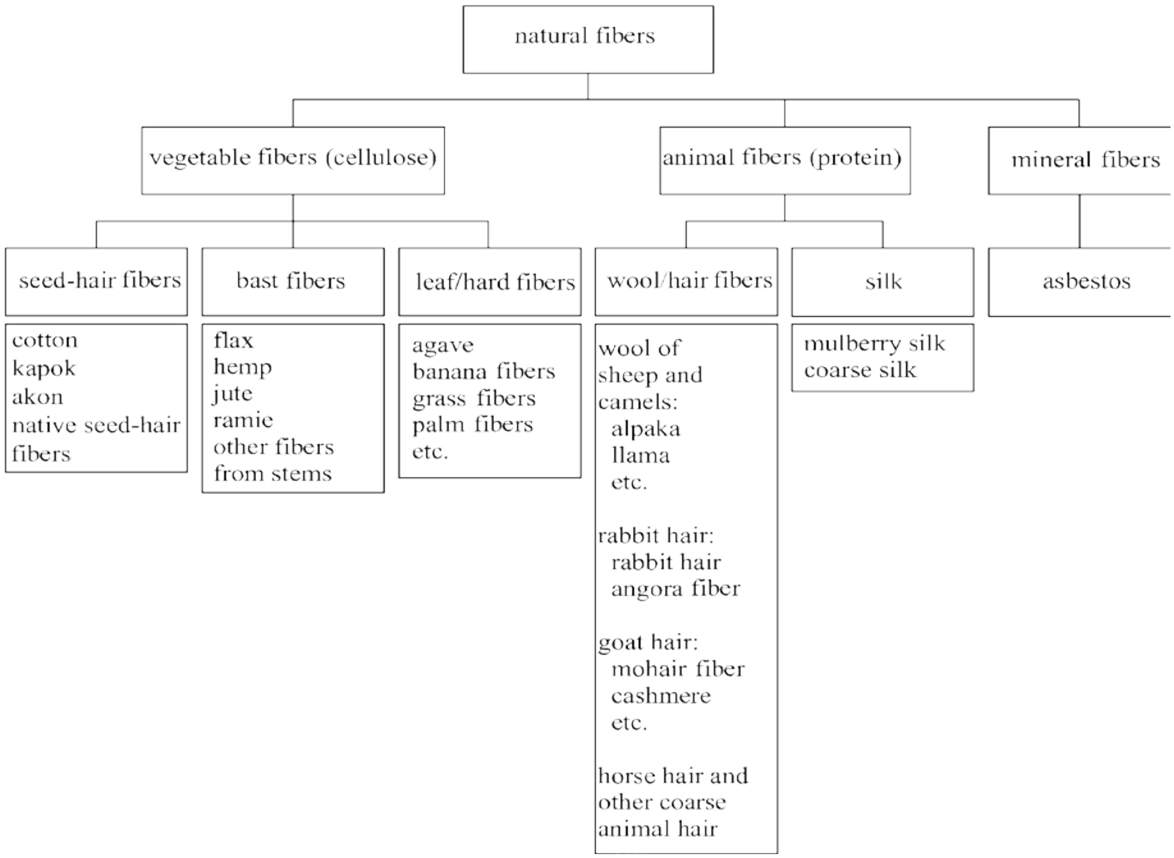
- High cost of raw materials and fabrication.
- Composites are more brittle than wrought metals and thus are more easily damaged.
- Transverse properties may be weak.
- Matrix is weak, therefore, low toughness.
- Reuse and disposal may be difficult.
- Difficult to attach.
- Repair introduces new problems, for the following reasons:
  a) Materials require refrigerated transport and storage and have limited shelf life.
  b) Hot curing is necessary in many cases requiring special tooling.
  c) Hot or cold curing takes time.
- Analysis is difficult.
- Matrix is subject to environmental degradation.

1.5 Natural Fiber Reinforced Composites

Manufacture, use, and the removal of traditional composite structures made of glass, carbon and aramid fibers is considered negative due to growing environmental consciousness. For this reason, composites with alternative reinforcement natural fibers have received attention recently.

The universe of "natural-fibers" is fairly broad. Natural fibers include those made from plant, animal and mineral sources. Natural fibers can be classified according to their origin. From a commercial standpoint, the most viable structural fibers come from purpose-grown textile plants and some fruit trees. Such fibers can generally be classified into three types. Bast fibers, such as flax, hemp, jute and kenaf, are noted for being fairly stiff when used as a composite reinforcement. Leaf fibers, including sisal, henequen, pineapple and banana, are noted for improving composite toughness with somewhat lower structural contribution. Finally, seed or fruit fibers — cotton, kapok and coir (from coconut husks) — demonstrate elastomeric type toughness, but are not structural. Animal fibers can be classified into two types – silk fiber (fiber collected from dried saliva of bugs or insects during the preparation of cocoons) and wool (fiber taken from animals or hairy mammals). Mineral fibers are naturally occurring fiber or slightly modified fiber procured from minerals.

The natural fibers can be used to reinforce both thermosetting and thermoplastic matrices. Thermosetting resins (such as polyester, polyurethane, phenolic, epoxy etc.) are commonly used today in natural fiber composites, which are being used in higher performance applications. They provide sufficient mechanical properties, in particular stiffness and strength, at acceptably low price. Considering the ecological aspects of material selection, replacing synthetic fibers by natural ones is only a first step. Restricting the emission of greenhouse gases such as CO_2 into the atmosphere and an increasing awareness of the finiteness of fossil energy resources are leading to developing new materials that are entirely based on renewable resources.



1.6 Advantages of natural fibers

The main advantages of natural fiber composite are,

- Low density (which gives higher specific strength and stiffness)
- Acceptable specific properties (good thermal and acoustic insulating properties)
- Ease of separation
- Enhanced energy recovery
- CO_2 neutrality (when burned, the natural fibers reportedly give off no more carbon dioxide [CO_2] than they consumed while growing)
- Biodegradability
- Recyclable nature (thermal recycling is possible)
- Low cost

1.7 Applications of composites

• Composites have high stiffness, strength, and toughness, often comparable with structural metal alloys. Further, they usually provide these properties at substantially less weight than metals. Their "specific" strength and modulus per unit weight is near five times that of steel or aluminum. This means the overall structure may be lighter, and in weight-critical devices such as airplanes or spacecraft this weight savings might be a compelling advantage.

• Composites can be made anisotropic, i.e. have different properties in different directions, and this can be used to design a more efficient structure. In many structures the stresses are also different in different directions; for instance in closed-end pressure vessels – such as a rocket motor case – the circumferential stresses are twice the axial stresses. Using composites, such a vessel can be made twice as strong in the circumferential direction as in the axial.

• Many structures experience fatigue loading, in which the internal stresses vary with time. Axles on rolling stock are examples; here the stresses vary sinusoidally from tension to compression as the axle turns. These fatigue stresses can eventually lead to failure, even when the maximum stress is much less than the failure strength of the material as measured in a static tension test. Composites of then have excellent fatigue resistance in comparison with metal alloys, and often show evidence of accumulating fatigue damage, so that the damage can be detected and the part replaced before a catastrophic failure occurs.

• Materials can exhibit damping, in which a certain fraction of the mechanical strain energy deposited in the material by a loading cycle is dissipated as heat. This can be advantageous, for instance in controlling mechanically-induced vibrations. Composites generally offer relatively high levels of damping, and furthermore the damping can often be tailored to desired levels by suitable formulation and processing.

• Composites can be excellent in applications involving sliding friction, with tribological ("wear") properties approaching those of lubricated steel.

• Composites do not rust as do many ferrous alloys, and resistance to this common form of environmental degradation may offer better life-cycle cost even if the original structure is initially more costly.

• Many structural parts are assembled from a number of subassemblies, and the assembly process adds cost and complexity to the design. Composites offer a lot of flexibility in processing and property control, and this often leads to possibilities for part reduction and simpler manufacture. Of course, composites are not perfect for all applications, and the designer needs to be aware of their drawbacks as well as their advantages.

• Not all applications are weight-critical. If weight-adjusted properties not relevant, steel and other traditional materials may work fine at lower cost.

• Anisotropy and other "special" features are advantageous in that they provide a great deal of design flexibility, but the flip side of this coin is that they also complicate the design. The well- known tools of stress analysis used in isotropic linear elastic design must be extended to include anisotropy, for instance, and not all designers are comfortable with these more advanced tools.

• Even after several years of touting composites as the "material of the future," economies of scale are still not well developed. As a result, composites are almost always more expensive – often much more expensive – than traditional materials, so the designer must look to composites‟ various advantages to offset the extra cost. During the energy-crisis period of the 1970‟s, automobile manufacturers were so anxious to reduce vehicle weight that they were willing to pay a premium for composites and their weight advantages. But as worry about energy efficiency diminished, the industry gradually returned to a strict lowest-cost approach in selecting materials. Hence the market for composites in automobiles returned to a more modest rate of growth.

• Although composites have been used extensively in demanding structural applications for a half-century, the long-term durability of these materials is much less certain than that of steel or other traditional structural materials.

1.8 Fluorescence

Fluorescence is the emission of light by a substance that has absorbed light or other electromagnetic radiation of a different wave length. Generally, emitted light has a longer wavelength, and therefore lower energy, than the absorbed radiation. But when the absorbed electromagnetic radiation is intense, then there is a possibility for one electron to absorb two photons. This two photons absorption can lead to emission of radiation having a shorter wavelength than the absorbed radiation.

Photo chemistry

Fluorescence occurs when an orbital electron of a molecule or atom is excited to a higher quantum state by some type of energy and then it relaxes to its ground state by emitting a photon of light.

Excitation: $S_0 + h\nu_{ex} \longrightarrow S_1$
Fluorescence (emission): $S_1 \longrightarrow S_0 + h\nu_{em}$ + heat

(Here, h = Planck's constant, ν = frequency of light, S_0 = ground state & S_1 = first excited state)

A molecule in excite states can relax in several ways. The most common way is that in which the excitation energy is dissipated as heat. Excited molecules can also be relaxed via conversion to a triplet state which may subsequently relax via phosphorescence or by a secondary non-radiative relaxation.

2. Literature survey

There has been a tremendous achievement in the science and technology of composite material in recent times. These materials have greatly improved since the 1970's and their use has expanded rapidly in the industrialized world. Their contribution is essential to different leading industry sectors. They are used because of their low mass and exceptional performance. Many composites of today are at the leading edge of materials technology with performance and costs justifying their ultra-demanding applications.

A composite consists of two or more combined constituents which are not soluble in each other. One constituent is called the reinforcing phase and the other one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles or flakes. The matrix phase material is generally continuous. Examples of composite system are concrete reinforced with steel and epoxy reinforced with graphite fibers. Wood with lignin matrix reinforced with cellulose fibers and bones and teeth with matrix of tough organic constituent called collagen reinforced with hydroxy apatite or osteons are the common examples of natural composites consisting two or more material together. Composite materials offer a number of potential advantages in various applications like aerospace, shipping, automotive, civil application due to the distinct advantages over many conventional materials like aluminium and steel. The major advantages are their low density, excellent durations, higher specific strength and stiffness, superior corrosion resistance, improved fatigue properties, life cycle cost reduction, design flexibility. Besides these advantages there are some disadvantages also. The most important disadvantage is their susceptibility to out-of-plane impact damage such as that imparted by the accidental fall of a tool. Often the impact damage repair processes are used to provide a solution, but they take time and present some practical difficulties, especially if they are applied in actual applications. The matrix phase of composites binds the fibers together and acts as the medium by which an extremely applied stress is transmitted and distributed to the fibers; only a very small proportion of an applied load is sustained by the matrix phase. The matrix material should be ductile. Also the elastic modulus of the fiber should be much higher than that of the matrix. The matrix also protects individual fibers from the surface damage as a result of mechanical abrasion or chemical reactions with environment.

2.1 Introduction to Polymer Composites

Polymer composites are gaining importance as substitute materials for metals in applications within the aerospace, automotive, marine, sporting goods and electronic industries. Their light weight and superior mechanical properties make them especially suited for transportation applications.

Fibrous composite materials typically have two or more distinct phases, which include high strength/stiffness reinforcing fibers and the encapsulating matrix material. Fibers can be either discontinuous (chopped) or continuous. Polymer matrices typically have two categories: thermoplastic and thermosetting polymers. Thermoplastic polymers are distinguished by their ability to be reshaped upon the addition of heat (above the glass transition temperature of the amorphous phase or the melting temperature of the crystalline phase). This cycle can be done repeatedly. On the other hand, thermosetting polymers undergo chemical reactions during curing which crosslink the polymer molecules. Once crosslinked, thermosets become permanently hard and only under the application of excessive heat undergo chemical decomposition. Thermosetting polymers have greater abrasion resistance and dimensional stability over that of thermoplastic polymers, which typically have better flexural and impact properties.

The fiber configuration or architecture (short, long, straight, woven, braided, laminated etc.) and the fiber surface treatment for the desired interface characteristics determine the final properties and the composite durability. The properties of polymer matrix composite are strongly dependent on the factors such as the matrix and fiber material and their volume fractions, the fiber orientation, the applied stress levels and strain rates as well as the loading conditions and the nature of the fiber polymer interface. The local response of the fiber matrix interface within the composite plays an important role in determining the gross mechanical performances. It provides a means of stress transfer from fiber to fiber through the matrix. In cold condition, due to different coefficients of thermal expansion of the fiber and the matrix high residual stresses can build up within the fibrous composite materials and at low temperature the polymer matrix experiences embrittlement which can also affects the properties of the composite. Due to qualities like versatility, low cost and light weight, use of polymers are increasing in many industries to substitute metals and ceramics. A wise choice of a suitable resin with the right mix of additives, fillers and reinforcements allows the production of materials with desired properties which is useful in a number of different fields of applications.

2.2 Fabrication of composites

There are numerous methods for fabricating composite components. Some methods have been borrowed, but many were developed to meet specific design or manufacturing challenges. Selection of a method for a particular part, therefore, will depend on the materials, the part design and end-use or application.

Composite fabrications processes involve some form of molding; a mold tool is required to give the unformed resin and its fiber reinforcements their shape prior to cure.

The most basic fabrication method for thermoset composites is “hand layup”, which typically consists of laying dry plies or prepreg plies by hand onto a tool to form a laminate stack. Resin is applied to the dry plies after layup is complete (e.g., by means of resin infusion). In a variation known as wet layup, each ply is coated with resin and “debulked” or compacted after it is placed.

Several curing methods are available. The most basic is simply to allow cure to occur at room temperature. Cure can be accelerated, however, by applying heat, typically with an oven, and pressure, by means of a vacuum. For the latter, a vacuum bag, with breather assemblies, is placed over the layup and attached to the tool, then evacuated before cure. The vacuum bagging process consolidates the plies of material and significantly reduces voids due to the off-gassing that occurs as the matrix progresses through its chemical curing stages.

Many high-performance thermoset parts require heat and high consolidation pressure to cure — conditions that require the use of an autoclave. Autoclaves, generally, are expensive to buy and operate. Manufacturers that are equipped with autoclaves usually cure a number of parts simultaneously. Computer systems monitor and control autoclave temperature, pressure, vacuum and inert atmosphere, which allows unattended or remote supervision of the cure process and maximizes efficient use of the technique.

When heat is required for cure, the part temperature is “ramped up” in small increments, maintained at cure level for a specified period of time, then “ramped down” to room temperature, to avoid part distortion or warp caused by uneven expansion and contraction. When this curing cycle is complete and after parts are demolded, some parts go through a secondary freestanding postcure, during which they are subjected for a specific period of time to a temperature higher than that of the initial cure to enhance crosslink density.

Electron-beam (E-beam) curing holds promise as an efficient curing method for thin laminates. In E-beam curing, the composite layup is exposed to a stream of electrons that provide ionizing radiation, causing polymerization and crosslinking in radiation-sensitive resins. X-ray and microwave curing technologies work in a similar manner. A fourth alternative, ultraviolet (UV) curing, involves the use of UV radiation to activate a photoinitiator added to a thermoset resin, which, when activated, sets off a crosslinking reaction. UV curing requires light-permeable resin and reinforcements.

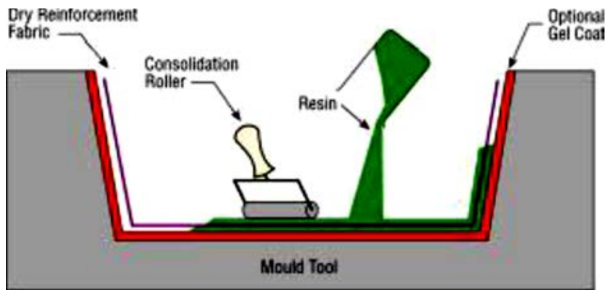
An emerging technology is the monitoring of the cure itself. Dielectric cure monitors measure the extent of cure by gauging the conductivity of ions — small, polarized, relatively insignificant impurities that are resident in resins. Ions tend to migrate toward an electrode of opposite polarity, but the speed of migration is limited by the viscosity of the resin — the higher the viscosity, the slower the speed. As crosslinking proceeds during cure, resin viscosity increases. Other methods include dipole monitoring within the resin, the monitoring of microvoltage produced by the crosslinking, monitoring of the exothermic reaction in the polymer during cure and, potentially, the use of infrared monitoring via fiber-optic technology.

A notable phenomenon is that of out-of-autoclave (OOA) curing for high-performance composite components. The high cost of autoclave systems has prompted many processors, particularly in aerospace, to call for OOA resins that can be cured with heat only in an oven (less capital-intensive and less expensive to operate than an autoclave, particularly with large parts), or at room temperature.

2.2.1 Open molding

Open contact molding in one-sided molds is a low-cost, common process for making fiberglass composite products. Typically used for boat hulls and decks, RV components, truck cabs and fenders, spas, bathtubs, shower stalls and other relatively large, noncomplex shapes, open molding involves either hand layup or a semi-automated alternative, spray up.

2.2.1.1 Hand Lay-up



Hand lay-up is a simple method for composite production. A mold must be used for hand lay-up parts unless the composite is to be joined directly to another structure. The mold can be as simple as a flat sheet or have infinite curves and edges. For some shapes, molds must be joined in sections so they can be taken apart for part removal after curing. Before lay-up, the mold is prepared with a release agent to insure that the part will not adhere to the mold. Reinforcement fibers can be cut and laid in the mold. It is up to the designer to organize the type, amount and direction of the fibers being used. Resin must then be catalyzed and added to the fibers. A brush, roller or squeegee can be used to impregnate the fibers with the resin. The lay-up technician is responsible for controlling the amount of resin and the quality of saturation.

2.2.1.2 Spray up

In an open-mold sprayup application, the mold is first treated with mold release. If a gel coat is used, it is typically sprayed into the mold after the mold release has been applied. The gel coat then is cured and the mold is ready for fabrication to begin. In the sprayup process, catalyzed resin (viscosity from 500 to 1,000 cps) and glass fiber are sprayed into the mold using a chopper gun, which chops continuous fiber into short lengths, then blows the short fibers directly into the sprayed resin stream so that both materials are applied simultaneously. To reduce toxic volatile organic compound (VOC) emissions, piston pump-activated, non-atomizing spray guns and fluid impingement spray heads dispense gel coats and resins in larger droplets at low pressure. Another option is a roller impregnator, which pumps resin into a roller similar to a paint roller.

In the final steps of the spray up process, workers compact the laminate by hand with rollers. Wood, foam or other core material may then be added, and a second spray up layer imbeds the core between the laminate skins. The part is then cured, cooled and removed from the reusable mold.

Hand layup and spray up methods are often used in tandem to reduce labor. For example, fabric might first be placed in an area exposed to high stress; then, a spray gun might be used to apply chopped glass and resin to build up the rest of the laminate. Balsa or foam cores may be inserted between the laminate layers in either process. Typical glass fiber volume is 15 percent with spray up and 25 percent with hand layup.

Spray up processing, once a very prevalent manufacturing method, has begun to fall out of favor in recent years. Styrene, the most common monomer used as a diluent in thermoset resins, is a volatile organic compound & hazardous air pollutant. Because worker exposure to and emission of styrene is difficult and expensive to control in the sprayup process, many composites manufacturers have migrated to closed mold, infusion-based processes, which better contain and manage styrenes.

Although open molding via hand layup is being replaced by faster and more technically precise methods, it is still widely used in the repair of composite parts.

2.2.2 Resin infusion processes

Ever-increasing demand for faster production rates has pressed the industry to replace hand layup with alternative fabrication processes and has encouraged fabricators to automate those processes wherever possible.

2.2.2.1 Resin transfer molding

A common alternative is “resin transfer molding (RTM)”, sometimes referred to as liquid molding. RTM is a fairly simple process. It begins with a two-part, matched, closed mold that is made of metal or composite material. Dry reinforcement (typically a preform) is placed into the mold and the mold is closed. Resin and catalyst are metered and mixed in dispensing equipment, then pumped into the mold under low to moderate pressure through injection ports, following predesigned paths through the preform. Extremely low-viscosity resin is used in RTM applications for thick parts to permeate preforms quickly and evenly before cure. Both mold and resin can be heated, as necessary, for particular applications. RTM produces parts that do not need to be autoclaved. However, when cured and demolded, a part destined for a high-temperature application usually undergoes postcure. Most RTM applications use a two-part epoxy formulation. The two parts are mixed just before they are injected. Bismaleimide and polyimide resins also are available in RTM formulations. Light RTM is a variant of RTM that is growing in popularity. In Light RTM, low injection pressure, coupled with vacuum, allow the use of less-expensive, lightweight two-part molds.

The benefits of RTM are impressive. Generally, the dry preforms and resins used in RTM are less expensive than prepreg material and can be stored at room temperature. The process can produce thick, near-net shape parts, eliminating most postfabrication work. It also yields dimensionally accurate complex parts with good surface detail and delivers a smooth finish on all exposed surfaces. It is possible to place inserts inside the preform before the mold is closed, allowing the RTM process to accommodate core materials and integrate "molded in" fittings and other hardware into the part structure. Moreover, void content on RTM'd parts is low, measuring in the 0 to 2 percent range. Finally, RTM significantly cuts cycle times and can be adapted for use as one stage in an automated, repeatable manufacturing process for even greater efficiency, reducing cycle time from what can be several days, typical of hand layup, to just hours — or even minutes.

2.2.2.2 Reaction injection molding

In contrast to RTM, where resin and catalyst are premixed prior to injection under pressure into the mold, "reaction injection molding (RIM)" injects a rapid-cure resin and a catalyst into the mold in two separate streams. Mixing and the resulting chemical reaction occur in the mold instead of in a dispensing head. Automotive industry suppliers combine structural RIM (SRIM) with rapid preforming methods to fabricate structural parts that don't require a Class A finish. Programmable robots have become a common means to spray a chopped fiberglass and binder combination into a vacuum-equipped preform screen or mold. Robotic spray up can be directed to control fiber orientation. A related technology, dry fiber placement, combines stitched preforms and RTM. Fiber volumes of up to 68 percent are possible, and automated controls ensure low voids and consistent preform reproduction, without the need for trimming.

2.2.2.3 Vacuum-assisted resin transfer molding

"Vacuum-assisted resin transfer molding (VARTM)" refers to a variety of related processes that represent the fastest growing new molding technology. The salient difference between VARTM-type processes and standard RTM is that in VARTM, resin is drawn into a preform through use of a vacuum rather than pumped in under pressure. VARTM does not require high heat or pressure. For that reason, VARTM operates with low-cost tooling, making it possible to inexpensively produce large, complex parts in one shot.

In the VARTM process, fiber reinforcements are placed in a one-sided mold, and a cover (rigid or flexible) is placed over the top to form a vacuum-tight seal. The resin typically enters the structure through strategically placed ports. It is drawn by vacuum through the reinforcements by means of a series of designed-in channels that facilitate wet out of the fibers. Fiber content in the finished part can run as high as 70 percent. Current applications include marine, ground transportation and infrastructure parts.

2.2.2.4 Resin film infusion

"Resin film infusion (RFI)" is a hybrid process in which a dry preform is placed in a mold on top of a layer or interleaved with layers of high-viscosity resin film. Under applied heat, vacuum and pressure, the resin is drawn into the preform, resulting in uniform resin distribution, even with high-viscosity, toughened resins, because of the short flow distance.

2.2.3 High-volume molding methods

2.2.3.1 Compression molding

"Compression molding" is a high-volume thermoset molding process that employs expensive but very durable metal dies. It is an appropriate choice when production quantities exceed 10,000 parts. As many as 200,000 parts can be turned out on a set of forged steel dies, using sheet molding compound (SMC), a composite sheet material made by sandwiching chopped fiberglass between two layers of thick resin paste. To form the sheet, the resin paste transfers from a metering device onto a moving film carrier. Chopped glass fibers drop onto the paste, and a second film carrier places another layer of resin on top of the glass. Rollers compact the sheet to saturate the glass with resin and squeeze out entrapped air. The resin paste initially is the consistency of molasses (between 20,000 and 40,000 cps); over the next three to five days, its viscosity increases and the sheet becomes leather-like (about 25 million cps), ideal for handling.

When the SMC is ready for molding, it is cut into smaller sheets and the charge pattern (ply schedule) is assembled on a heated mold (121°C to 262°C or 250°F to 325°F). The mold is closed and clamped, and pressure is applied at 24.5 to 172.4 bar (500 to 2,500 psi). As material viscosity drops, the SMC flows to fill the mold cavity. After cure, the part is demolded manually or by integral ejector pins.

A typical low-profile (less than 0.05 percent shrinkage) SMC formulation for a Class A finish consists, by weight, of 25 percent polyester resin, 25 percent chopped glass, 45 percent fillers and 5 percent additives. Fiberglass thermoset SMC cures in 30 to 150 seconds and overall cycle time can be as low as 60 seconds. Other grades of SMC include low-density, flexible and pigmented formulations. Low-pressure SMC formulations that are now on the market offer open molders low-capital-investment entry into closed-mold processing with near-zero VOC emissions and the potential for very high-quality surface finish.

Automakers are exploring carbon fiber-reinforced SMC, hoping to take advantage of carbon's high strength- and stiffness-to-weight ratios in exterior body panels and other parts. Newer, toughened SMC formulations help prevent microcracking, a phenomenon that previously caused paint "pops" during the painting process (surface craters caused by outgassing, the release of gasses trapped in the microcracks during oven cure).

Composites manufacturers in industrial markets are formulating their own resins and compounding SMC in-house to meet needs in specific applications that require UV, impact and moisture resistance and have surface-quality demands that drive the need for customized material development.

2.2.3.2 Injection molding

"Injection molding" is a fast, high-volume, low-pressure, closed process using, most commonly, filled thermoplastics, such as nylon with chopped glass fiber. In the bulk molding compound(BMC) injection molding process, a ram or screw-type plunger forces a metered shot of material through a heated barrel and injects it (at 5,000 to 12,000 psi) into a closed, heated mold. In the mold, the liquefied BMC flows easily along runner channels and into the closed mold. After cure and ejection, parts need only minimal finishing. Injection speeds are typically one to five seconds, and as many as 2,000 small parts can be produced per hour in some multiple-cavity molds.

Parts with thick cross-sections can be compression molded or transfer molded with BMC. Transfer molding is a closed-mold process wherein a measured charge of BMC is placed in a pot with runners that lead to the mold cavities. A plunger forces the material into the cavities, where the product cures under heat and pressure.

2.2.3.3 Filament winding

"Filament winding" is a continuous fabrication method that can be highly automated and repeatable, with relatively low material costs. A long, cylindrical tool called a mandrel is suspended horizontally between end supports, while the "head" — the fiber application instrument — moves back and forth along the length of a rotating mandrel, placing fiber onto the tool in a predetermined configuration. Computer-controlled filament-winding machines are available, equipped with from 2 to 12 axes of motion.

In most thermoset applications, the filament winding apparatus passes the fiber material through a resin "bath" just before the material touches the mandrel. This is called wet winding. However, a variation uses towpreg, that is, continuous fiber pre-impregnated with resin. This eliminates the need for an onsite resin bath. In a slightly different process, fiber is wound without resin (dry winding). The dry shape is then removed and used as a preform in another molding process, such as RTM.

Following oven or autoclave curing, the mandrel either remains in place to become part of the wound component or, typically, it is removed. One-piece cylindrical or tapered mandrels, usually of simple shape, are pulled out of the part with mandrel extraction equipment. Some mandrels, particularly in more complex parts, are made of soluble material and may be dissolved and washed out of the part. Others are collapsible or built from several parts that allow its disassembly and removal in smaller pieces. Filament-winding manufacturers often slightly modify off-the-shelf resin to meet specific application requirements.

In thermoplastics winding, all material is in prepreg form, so a resin bath is not needed. Material is heated as it is wound onto the mandrel — a process known as curing "on the fly" or in-situ consolidation. The prepreg is heated, layed down, compacted, consolidated and cooled in a single, continuous operation. Thermoplastic prepregs eliminate autoclave curing (cutting costs and size limitations) and reduce raw material costs, and the resulting parts can be reprocessed to correct flaws.

Filament winding yields parts with exceptional circumferential or "hoop" strength. The highest-volume single application of filament winding is golf club shafts. Fishing rods, pipe, pressure vessels and other cylindrical parts comprise most of the remaining business.

2.2.3.4 Pultrusion

"Pultrusion", like RTM, has been used for decades with glass fiber and polyester resins, but in the last 10 years the process also has found application in advanced composites applications. In this relatively simple, low-cost, continuous process, the reinforcing fiber (usually roving, tow or continuous mat) is typically pulled through a heated resin bath and then formed into specific shapes as it passes through one or more forming guides or bushings. The material then moves through a heated die, where it takes its net shape and cures. Further downstream, after cooling, the resulting profile is cut to desired length. Pultrusion yields smooth finished parts that typically do not require postprocessing. A wide range of continuous, consistent, solid and hollow profiles are pultruded, and the process can be custom-tailored to fit specific applications.

2.2.3.5 Tube rolling

"Tube rolling" is a longstanding composites manufacturing process that can produce finite-length tubes and rods. It is particularly applicable to small-diameter cylindrical or tapered tubes in lengths as great as 20 ft/6.2m. Tubing diameters up to 6 inches/152 mm can be rolled efficiently. Typically, a tacky prepreg fabric or unidirectional tape is used, depending on the part. The material is precut in patterns that have been designed to achieve the requisite ply schedule and fiber architecture for the application. The pattern pieces are laid out on a flat surface and a mandrel is rolled over each one under applied pressure, which compacts and debulks the material. When rolling a tapered mandrel — e.g., for a fishing rod — only the first row of longitudinal fibers falls on the true 0°

axis. To impart bending strength to the tube, therefore, the fibers must be continuously reoriented by repositioning the pattern pieces at regular intervals.

2.2.3.6 Automated fiber placement

"Automated fiber placement (AFP)" is a process in which the fiber placement process automatically places multiple individual prepreg tows onto a mandrel at high speed, using a numerically controlled, articulating robotic placement head to dispense, clamp, cut and restart as many as 32 tows simultaneously. Minimum cut length (the shortest tow length a machine can lay down) is the essential ply-shape determinant. The fiber placement heads can be attached to a 5-axis gantry, retrofitted to a filament winder or delivered as a turnkey custom system. Machines are available with dual mandrel stations to increase productivity. Advantages of fiber placement include processing speed, reduced material scrap and labor costs, parts consolidation and improved part-to-part uniformity. Often, the process is used to produce large thermoset parts with complex shapes.

2.2.3.7 Automated tape laying

"Automated tape laying (ATL)" is an even speedier automated process in which prepreg tape, rather than single tows, is laid down continuously to form parts. It is often used for parts with highly complex contours or angles. Tape layup is versatile, allowing breaks in the process and easy direction changes, and it can be adapted for both thermoset and thermoplastic materials. The head includes a spool or spools of tape, a winder, winder guides, a compaction shoe, a position sensor and a tape cutter or slitter. In either case, the head may be located on the end of a multiaxis articulating robot that moves around the tool or mandrel to which material is being applied, or the head may be located on a gantry suspended above the tool. Alternatively, the tool or mandrel can be moved or rotated to provide the head access to different sections of the tool. Tape or fiber is applied to a tool in courses, which consist of one row of material of any length at any angle. Multiple courses are usually applied together over an area or pattern and are defined and controlled by machine-control software that is programmed with numerical input derived from part design and analysis. Capital expenditures for computer-driven, automated equipment can be significant.

Although ATL generally is faster than AFP and can place more material over longer distances, AFP is better suited to shorter courses and can place material more effectively over contoured surfaces. These technologies grew out of the machine tool industry and have seen extensive use in the manufacture of the fuselage, wingskin panels, wingbox & tail of aircrafts.

2.2.3.8 Extrusion

Fiber-reinforced thermoplastic components now can be produced by "extrusion", as well. Breakthrough material and process technology has been developed with long-fiber glass-reinforced thermoplastic (ABS, PVC or polypropylene) composites to provide profiles that offer a tough, low-cost alternative to wood, metal and injection-molded plastic parts used in office furniture, appliances, semitrailers and sporting goods. A huge market has emerged in the past decade for extruded thermoplastic/wood flour (or other additives, such as bast fibers or fly ash) composites. These wood plastic composites are used to simulate wood decking, siding, window and door frames, and fencing.

2.3 Advantages of hand layup method

- Widely used for many years
- Simple principles
- Low cost tooling, if room-temperature cure resins are used
- Wide choice of suppliers and material types
- Higher fiber contents, and longer fibers than with spray lay-up

2.4 Advantages of epoxy

Epoxy resins are the most commonly used resins. They are low molecular weight organic liquids containing epoxide groups. Epoxide has three members in its ring: one oxygen and two carbon atoms. The reaction of epichlorohydrin with phenols or aromatic amines makes most epoxies.

Although epoxy is costlier than other polymer matrices, it is the most popular PMC matrix. More than two-thirds of the polymer matrices used in aerospace applications is epoxy based. The main reasons why epoxy is the most used polymer matrix material are

- High strength
- Low viscosity and low flow rates, which allow good wetting of fibers and prevent misalignment of fibers during processing
- Low volatility during cure
- Low shrink rates, which reduce the tendency of gaining large shear stresses of the bond between epoxy and its reinforcement
- Available in more than 20 grades to meet specific property and processing requirements

2.5 Objectives

The objectives of the project are outlined below.

- Fabrication of sisal fiber reinforced epoxy based composite.
- Form a decorative composite.
- In order to expand applications of the fiber reinforced composite, we performed the hand lay-up method for the preparation of mold with the help of themocoul.

3. Materials and methods

3.1 Introduction

This chapter describes the details of processing of the composites and the experimental procedures. The raw materials used in this work are

- Sisal fiber
- Resin (LY 556)
- Hardener (HY 951)

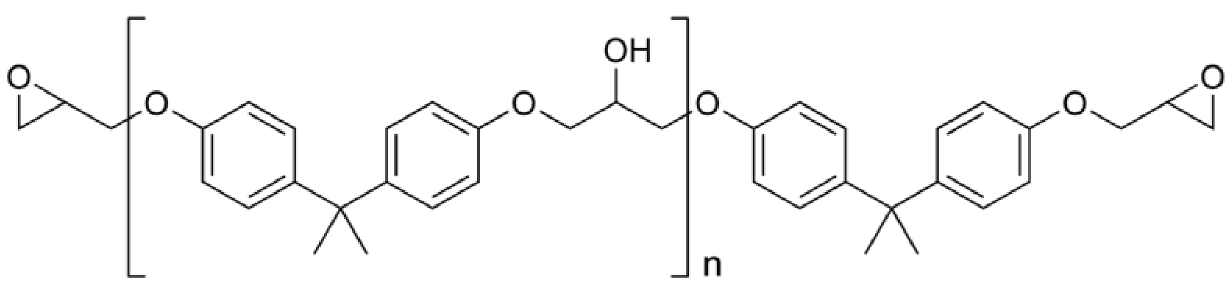
3.1.1 Sisal fiber

Sisal fiber is obtained from the leaves of the plant AGAVE SISALANA which was originated from Mexico and is now mainly cultivated in East Africa, Brazil, Haiti, India and Indonesia. It is grouped under the broad heading of the "hard fibers" among which sisal is placed second to maintain durability and strength.

It is one of the most extensively cultivated hard fibers in the world and it accounts for half the total production of textile fibers .The reason for this is due to the ease of cultivation of sisal plants, which have short renewing times, and is fairly easy to grow in all kinds of environments. A good sisal plant yields about 200 leaves with each leaf having a mass composition of 4% fiber, 0.75% cuticle, 8% other dry matter and 87.25% moisture. The fiber is extracted from the leaf either by retting, by scraping or by retting followed by scraping or by mechanical means using decorticators. The diameter of the fiber varied from 100mm to 300mm .The characteristics of the sisal fibers depend on the properties of the individual constituents, the fibrillar structure and the lamellae matrix. The fiber is composed of numerous elongated fusiform fiber cells that taper towards each end. The fiber cells are linked together by means of middle lamellae, which consist of hemicelluloses, lignin and pectin. Sisal fibers are anti-static, does not attract or trap dust particles and absorb moisture or water easily. The fine texture takes dyes easily and offers the largest range of dyed colours of all natural fibers. It exhibits good sound and impact absorbing properties. Its leaves can be treated with natural borax for fire resistance properties.

3.1.2 Epoxy resin

Epoxy is a copolymer; i.e. it is 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. Epoxy resins are produced from a reaction between epichlorohydrin and bisphenol-A.



These resins are thermosetting polymers and are used as adhesives, high performance coatings and potting and encapsulating materials. These resins have excellent electrical properties, low shrinkage, good adhesion to many metals and resistance to moisture, thermal and mechanical shock.

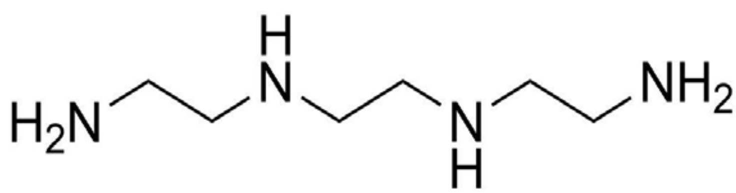
Viscosity, epoxide equivalent weight and molecular weight are the important properties of epoxy resins.

3.1.3 Curing Agents (Hardeners)

A wide variety of curing agent for epoxy resins is available depending on the process and properties required. The commonly used curing agents for epoxies include amines, polyamides, phenolic resins, anhydrides, isocyanates and polymercaptans. The cure kinetics of cured system is dependent on the molecular structure of the hardener. The choice of resin and hardeners depends on the application, the process selected, and the properties desired. The stoichiometry of the epoxy-hardener system also affects the properties of the cured material. Employing different types and amounts of hardener which, tend to control cross-link density vary the structure.

3.1.4 Amine based curing agents

Amines are the most commonly used curing agents for epoxy cure. The hardener consists of polyamine monomers, for example Triethylenetetramine.



Primary and secondary amines are highly reactive with epoxy. Tertiary amines are generally used as catalysts, commonly known as accelerators for cure reactions. Use of excessive amount of catalyst achieves faster curing, but usually at the expense of working life, and thermal stability. The catalytic activity of the catalysts affects the physical properties of the final cured polymer.

3.2 Curing of Epoxy Resins

When resin and hardener 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 thus becomes rigid and strong. The process of polymerization is called "curing". It can be controlled through temperature, choice of resin and hardener compounds, and the ratio of resin and hardener; the process can take minutes to hours. Some formulations benefit from heating during the cure period, whereas others simply require time, and ambient temperatures. Epoxy resins cure quickly and easily at practically any temperature from 5-150^{0}C depending on the choice of curing agent.

3.3 Processing of composites

The composite was prepared by Hand lay-up method. At first we made a mold by using thermocoul for the fabrication of composite. Then we chopped sisal fibers randomly. Then we stick a releasing sheet at the bottom of the mold and heavy duty silicon spray is applied on the releasing sheet for the easy removal of the composite. In the next step we distributed sisal fibers uniformly on the bottom of the mold. Then we prepared the mixture of epoxy resin (LY 556) and hardener (HY 951) in the ratio 10:1 to form a matrix. The fiber and matrix are taken in the weight percentage ratio of 15:85. Then we poured the matrix over the chopped fibers into the mold. Finally we covered it with a releasing sheet spread with silicon spray and pressed it down with an iron roller to release the entrap air. After 12 hours curing we got the required shape of decorative composite and extracted it out of the mold.

In order to fabricate a fluorescent decorative fluorescent material we added the ink of highlighter pen in the mixture of epoxy resin and hardener. The curing property of the epoxy resin got disturbed and it took a lot more time to cure. After 12-15 days our required fluorescent decorative composite is formed.

4. Conclusion

In the recent environmental concern the decorative bio composites are emerging as a low cost, biodegradable alternative for synthetic, carcinogenic composites. The wood like appearance makes it suitable alternative of dwindling wood resources.

In this project work the properties of composite materials, their classification, advantages and disadvantages and also their application has been studied. It came to know that decorative composite materials have artistic characteristic in addition to functional characteristic. An artistic composite from artistic fabric has been prepared by using sisal fiber. To make it more attractive fluorescent materials has been added which disturbed the curing property of epoxy resin and took a lot more time to cure but finally we got decorative fluorescent composite materials with desired shape.

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