Fabrication of Paper-Card Reinforced Epoxy Composite Through Hand Layup Process

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ABSTRACT

This lab report will discuss the hand layup procedure used to create composite materials. A hand lay-up involves the simultaneous application of a glass fiber-reinforced material (30-45%-by volume) and a liquid thermosetting resin to a male or female mould. The finished product is cured by let it to sit out at room temperature or by applying heat to speed up the process (dry composite). We used this hand layup technique to make a composite out of fibre fabric and epoxy, which was then reinforced with paper card.

Keywords: Hand layup, Liquid Thermosetting Resin, Dry Composite, Epoxy

INTRODUCTION

Composites are made up of at least two distinct materials and have their own unique properties in addition to those of their individual components, yet their macroscopic structures are typically rather similar. The ability to combine these different features is what makes composites so unique; it allows the properties to be tailored to the needs of a certain application. Mechanical qualities can be modified by changing the formulation of the matrix, the binder constituent that binds the reinforcement together, or by varying the kind and loading of reinforcement(s), the load-bearing constituent of a composite. Furthermore, the relationship between these two primary components significantly impacts the composite's end result.

Fibres or textiles, as well as particles and fillers, are common types of reinforcement constituents in composites. Particulate composite is the name given to the end result when micron-sized particles are present. As a result of advancements in nanotechnology, a material is called a nanocomposite if the reinforcement is a nanoparticle like a carbon nanotube (CNT) or graphene. Fibre reinforced composites, which are produced through a hand layup process and consist of fibres well encased by the binding matrix laminate and stacked in the through-the-thickness direction, are an example of laminated composites; they are a layered product consisting of plies of fibres embedded in the matrix, as shown in fig. 1.

Fig. 1: Composite Laminate

Role of Fillers in Fiber Reinforced Composite:

Fillers' primary function in fiber-reinforced composites has been to replace relatively inexpensive elements, so lowering production costs while simultaneously enhancing the material's performance in certain respects. Fillers are commonly made from wood flour, saw dust, or calcium carbonate. Meanwhile, it can be the most costly part of a fibre reinforced composite structure. High-toughness particles are added to a brittle matrix formulation to improve mechanical qualities, as seen in the composite fuselage of commercial aeroplanes. In addition, brittle particles are added to inexpensive thermoplastic resins to strengthen the composite's characteristics. Colour, flame resistance, protection from ultraviolet light, electrical conductivity, mould resistance, and so on can all be added to a matrix with the use of additives. Because of their potential to alter the composite's mechanical properties, fillers and additives are also taken into account as reinforcements.

Microstructure of fiber Reinforced Composite:

The microstructure of a fibre reinforced composite consists of the fibre, the matrix, and the interphase areas (fig. 2). The fibre and the matrix are the composite's primary building blocks. As a result of thermal, chemical, and mechanical effects, the interphase is an area with unique physical, mechanical, and chemical properties compared to the original fibre and matrix. Crosslink density and molecular weight variation, trans crystallinity, impurities, sizing, voids, fibre surface chemistry, fibre topography, and morphology are only some of the factors that can be found in the interphase area.

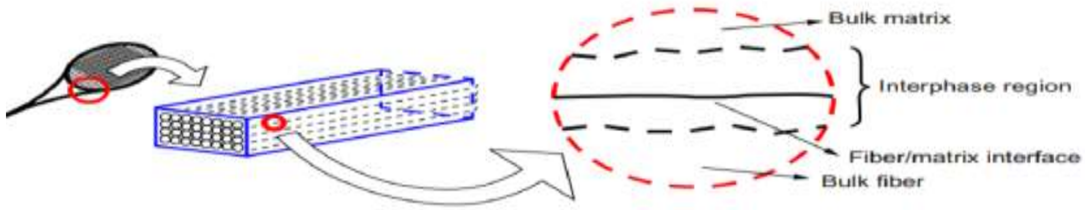

Fig. 2: Shows fiber Reinforced Composite Product from Macro-Scale to Micro-Scale with a focus on the Interphase Region

The hand layup process is a manual method used for fabricating composite materials. It involves the simultaneous application of reinforcing fibers and a liquid thermosetting resin onto a male or female mold. In the case of the described process, glass fiber-reinforced material (30-45% by volume) and a liquid thermosetting resin are used.

Here's a step-by-step Explanation of the hand layup Process:

Preparation: The mold is prepared by applying a release agent to ensure easy removal of the cured composite part. The reinforcing fibers, such as glass fibers, are pre-cut to the desired shape and size. The resin, usually an epoxy, is prepared according to the manufacturer's instructions.

Layering: The process begins by placing a layer of resin onto the mold surface. The resin can be applied using a brush, roller, or spray gun. Then, the pre-cut reinforcing fibers (glass fiber cloth in this case) are carefully laid onto the wet resin layer. The fibers are positioned and arranged to achieve the desired strength and orientation within the composite.

Impregnation: Another layer of resin is applied over the fiber cloth to ensure complete impregnation. The resin is spread and worked into the fibers using tools like brushes or rollers. This step is crucial for achieving good bonding between the fibers and resin matrix.

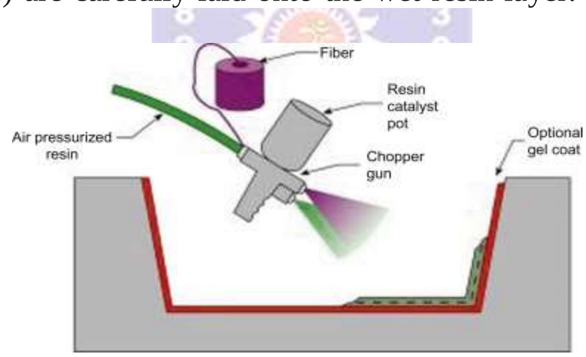

Fig. 3 : Step-by-step Explanation of the hand layup Process

Building up: Steps 2 and 3 are repeated, adding more layers of fiber cloth and resin until the desired thickness and reinforcement volume are achieved. Each layer is carefully positioned and impregnated with resin.

Consolidation: After all the layers are applied, the composite is consolidated by removing any trapped air or excess resin. This is typically done by applying pressure using a roller or squeegee. The consolidation step ensures proper bonding between the layers and reduces voids within the composite.

REVIEW OF RELATED LITERATURE

"Composite manufacturing processes" by Suresh G. Advani and Stephane L. Lomov:

This comprehensive book provides an overview of various composite manufacturing processes, including hand layup. It discusses the principles, techniques, and challenges associated with hand-layup fabrication. The authors highlight the importance of fiber orientation, ply stacking sequence, and resin impregnation in achieving desired mechanical properties.

"Composite Materials: Fabrication Handbook" by John Wanberg:

John Wanberg's book offers a practical guide to composite fabrication techniques, including hand layup. It covers topics such as mold preparation, fiber selection, ply layup, and curing. The author emphasizes the importance of proper tooling, surface preparation, and resin application for successful hand layup processes.

"Handbook of Composites" edited by George Lubin:

This comprehensive reference book covers various aspects of composite materials, including their manufacturing processes. It includes a chapter on hand layup, discussing the materials, techniques, and quality control aspects. The chapter highlights the significance of worker skill and experience in achieving consistent and high-quality hand-layup composites.

"Composite Materials: Science and Engineering" by Krishan K. Chawla:

Krishan K. Chawla's book provides an in-depth understanding of composite materials, their properties, and manufacturing techniques. It includes a section on hand layup, focusing on the role of fiber architecture, resin selection, and curing parameters. The author discusses the challenges and opportunities associated with hand-layup processes in producing tailored composites.

"Processing of Polymer Matrix Composites" by Vijay Kumar Thakur and Manju Kumari Thakur:

This book discusses various processing techniques for polymer matrix composites, including hand layup. It explores the factors influencing the quality of hand-layup composites, such as fiber arrangement, resin impregnation, and consolidation. The authors present case studies and practical examples to illustrate the advantages and limitations of hand-layup processes.

MATERIALS REQUIRED

Mold: To acquire the correct shape while creating parts with the lay-up technique, a mould is typically utilised to place the layer in or on. In this lab, however, we won't be using a mould but rather a flat surface to hold the layup's form.

Releasing Agent : A releasing agent is used to reduce the likelihood of resin sticking to the mould. For this experiment, a plastic sheet will serve as the releasing agent and cover the tabletop. Wax, spray releases, release films, and internal releases (added to gel coat or resin system) are some more release agents utilised in industry.

Resins: Component stresses that may operate on the part are transferred to the fibres in the composite via the resin, which serves as the composite's matrix. Tolerating the intended stresses is a primary consideration in the design and selection of the fibres used. Epoxy and hardener resin will be utilised in this experiment. Different jobs call for different speeds (or amounts of time) of hardeners. Unsaturated polyesters are one type of resin that sees extensive use in manufacturing.

Epoxies; High-Performance and Specialty Thermosets (vinyl esters);

Fibre Reinforcement: A composite can be assembled from a wide variety of fibres, each of which is available in a variety of forms. Both of these factors are design options that can be used within the final product's design restrictions and play a key role in the material selection procedure. Fabric scraps and card stock are used as reinforcing fibres in this project. Woven fabric material - many different weaves and weave patterns can be used to yield different finished properties. Different orientations and organisation of the fibres on the woven fabric (Plain weave, satin finish, twill, etc.). Other reinforcing fibres, such as: Different materials (Fibreglass, carbon fibre, aramid, etc.). Different formats and chopped mat material (randomly oriented chopped fibres or swirled continuous fibres).

METHODOLOGY FOR EXPERIMENTS

1. Workstation Preparation :

The first step in working with composites is to set up your workstation by gathering all of the necessary materials and tools. In particular, the rate at which the hardener chemically reacts with the epoxy to produce an exothermic reaction limits the working time (before the resin mix gels) after the resin and hardener have been combined. The woven fabric also needs to be cut to size as part of the preliminary steps.

2. Mold Preparation:

The lay-up procedure cannot begin unless the mould has been properly prepared. To prevent the resin from sticking, you must first clean the mould and then apply a release agent to its surface. To prepare the mould for this experiment, we will just tape a sheet of plastic to the work surface. In any case, the following procedures are followed to clean the mould: Wipe the mould down with a fresh towel, apply and spread release agent in the mold's surface, wait until the release agent has set, and buff.

3. Lay-up Process :

Step three of the lay-up procedure is to combine the resin and hardener. The ratios are typically provided by the manufacturer and listed on the packaging for the hardener and resin. Care must be taken to avoid incorporating air bubbles into the resin as the mixing is performed in the mixing containers using the mixing stick. Take your time and mix thoroughly and thoughtfully for two full minutes before using. A "flat" stick, like a tongue depressor, is ideal; a round stick is ineffective because it doesn't 'paddle' the ingredients together to incorporate them. Epoxy resin should be mixed in containers designed for that purpose because plastic ones may melt during the exothermic process. Then, pieces of paper cards are pressed into the mould, and a mixture of resin and hardener is brushed or rolled over the entire surface. Adding too much resin will result in a coating that is too thick, while adding too little will result in holes on the cured surface of the item. After that, the first layer of reinforcement fibres is woven in. To ensure that the resin used in the previous step wicks up through the fibreglass fabric, this layer must be wetted with resin and then gently pressed using a brush or a roller. More resin can be placed on top and worked into the fibre if necessary. At this point, a second layer of glass fibre (cloth scraps) is placed, and it's crucial that any remaining air bubbles are carefully popped. To do this, you can either use a small hand rolling tool to press out the bubbles or a paintbrush to brush them away. As many times as necessary to achieve the appropriate thickness. Clocking refers to the practise of orienting individual glass fibre layers at different angles as they are added to create laminates and total part thickness in order to achieve a desired level of strength along the direction of the reinforcement weave. In order to minimise dust and squeeze out extra resin as successive layers of reinforcement are built up, it is often necessary to place a plastic cover sheet over the layup and roll it up with the layers underneath. When the correct amount of resin has been used for the layup, any leftover resin in the cup should be poured over and into a noncombustible surface, like a concrete washbasin or slab.

4. Curing

The fourth step, "curing," can be completed either in a hot oven or at room temperature. The correct curing time and working time for each type of resin-hardener is often listed by the manufacturer on the containers' backs. In this experiment, curing at ambient temperature is sufficient when employing an epoxy resin system.

5. Cleaning

After the part has been cleaned, it can be cured in the proper environment. It can be put in a curing oven or left out overnight to finish curing. Then, it's time to perform some tidying up. Cleaning the table and all the tools (brushes, rollers, mixing tools, scissors) with acetone and a cloth is required.

DISCUSSION

During the design phase, it is possible to customise the properties of the resulting composite materials to the needs of the intended application by choosing from a number of different reinforcement and matrix types. The "fibre volume fraction" (vf) definition, the ratio of fibre volume to matrix volume, is used to approximate composite qualities. This is also referred to as the "fibre loading level" and is achieved in practise as a percentage of total weight. Knowing the fibre volume fraction and the identical parameters of each ingredient allows one to determine the density, thermal expansion, elasticity, shear modulus, Poisson's ratio, and tensile strength of a composite material. Despite its apparent simplicity, this technique for producing polymer composites requires a great deal of attention to detail checked. For the polymer layers to adhere to one another, it is crucial to use the correct amount of resin. It's possible for the layers to come apart after the glue has hardened if it's not robust enough. Any form of air bubble between the layers must be removed, as they can cause a wide variety of flaws. Corrugation of gel coat, also known as a wrinkle, can arise if the coating is too thin, the initiator and promoter dosage is inadequate, or the gel coat is uneven. Chafing cracks of gel coat can happen if the gel coat is too thick, too much initiator and promoter are employed, and the curing temperature is too high. Shrinkage flaws can be caused by a number of factors, including an uneven gel coat, a product with an excessive thickness in one area, difficulty in removing the gel coat from the mould during stripping, and a curvature radius that is too tiny at the corner. Warping and deformation can also occur if the product is of insufficient thickness, if the heat treatment is not uniform, if the release and cure are premature or incomplete, if too much of an initiator or promoter is used, or if the product is asymmetrical. In order to get desirable outcomes, certain parameter settings are required.

APPLICATIONS

Composites can be found in the wild. Structures in plants and bones are common examples. Bone is made up of hydroxyapatite and collagen, while wood is made up of cellulose fibres bonded by lignin. However, man-made composites have been around at least as long as the first mud-and-straw huts. Another example is modern concrete, which in addition to the traditional aggregate, cement, and sand, also includes steel reinforcing bars. Glass fibre reinforced polyester matrix (GFRP) is a typical modern composite material. Boats, water tanks, early automobiles, etc. are made extensively from this composite material. Composites are employed in a wide variety of industries today, from the energy and marine sectors to sports, automobiles, aerospace and aeronautics, medicine and civil engineering, and even the music business.

Both the Airbus A380 and the Boeing 787 Dreamliner use composites extensively in their construction; the former uses them in 25% of its weight's worth of parts, and the latter uses them in 50%.

Aerospace and Aviation: Hand-layup composites are extensively used in the aerospace and aviation industry for manufacturing lightweight and high-strength components. These components include aircraft wings, fuselages, fairings, control surfaces, and interior parts. The hand-layup process allows for the fabrication of complex shapes and customized designs, meeting the specific requirements of aircraft manufacturers.

Automotive: In the automotive industry, hand-layup composites find applications in the production of lightweight body panels, chassis components, and interior parts. The use of composites helps improve fuel efficiency, reduce vehicle weight, and enhance overall performance. Hand layup allows for the production of complex geometries and optimized structures, making it suitable for low-volume or custom vehicle manufacturing.

Marine: Hand-layup composites are widely utilized in the marine industry for manufacturing boat hulls, decks, superstructures, and other components. The lightweight nature of composites contributes to improved fuel efficiency and speed. Additionally, composites offer excellent resistance to corrosion and provide enhanced durability in harsh marine environments.

Wind Energy: The hand-layup process is employed in the production of wind turbine blades, which require high strength, stiffness, and durability. Composites offer advantages such as reduced weight, improved aerodynamics, and increased energy efficiency. Hand layup allows for precise fiber orientation and control over laminate thickness, enabling the production of optimized wind turbine blades.

Sports and Recreation: Hand-layup composites have significant applications in sports and recreational equipment manufacturing. These include tennis rackets, golf club shafts, bicycle frames, skis, snowboards, and kayak paddles. Composites provide exceptional strength-to-weight ratio, allowing for better performance and durability in these applications.

Construction and Infrastructure: Hand-layup composites are utilized in the construction industry for various applications such as bridges, columns, beams, and façade panels. Composites offer advantages such as high strength, corrosion resistance, and design flexibility. The hand-layup process allows for the fabrication of custom-made components with specific structural properties.

Consumer Goods: Hand-layup composites are also found in consumer goods like furniture, sporting equipment, musical instruments, and electronic enclosures. Composites provide aesthetic appeal, durability, and improved functionality in these products.

CONCLUSION

Using just fibre cloth, paper card, and epoxy, we were able to create the composite materials using a straightforward layup method. We used the optimal technique and its settings to create a composite that should be significantly tougher, stiffer, more stable, and denser than its predecessors.

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