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Fabrication and Characterization of Plant Fiber Composite Material: A Review

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Abstract: In general, the aim of the present review was to look into the effects of composite fabrication attributes like fabrication method, reinforcing fibre orientation, fibre type, matrix phase type, and volume fraction of reinforcing phase on the tensile properties of composites used in aerospace, military, civil construction, and automotive applications. Furthermore, the authors made every effort to make this research a reputable source in the field of mechanical properties of composites in the future. Recent research has showed that epoxy resin is an excellent choice for the fabrication of large polymeric composites because to its exceptional tensile, compression, and resistance to corrosion. The purpose of this work is to provide a complete assessment of modern research on the influence of manufacturing variables on composite tensile durability.

Keywords: Hand Layup, Resin Transfer Molding, Injection Molding, Tensile Strength, Matrix etc.

I. INTRODUCTION

'The utilisation of lighter, environment-friendly, and stronger materials for industrial applications' has been emphasised in recent decades, influenced by several issues such as the geological phenomenon, the reduction of renewable energy resources, the rise of fossil fuel prices, and the strictness of environmental regulations [1]. At the moment, one of the practical and acceptable techniques to overcoming these types of difficulties is the use of composite materials [2]. Conventional buildings were built of monolithic materials such as metals (aluminum and steel) are typically quite heavy, which raises construction costs and fuel usage, particularly in the aerial, road, marine, and passenger rail industries [3]. Furthermore, certain materials, such as aluminium alloys, are highly corrosive and degrade the structure's strength and available life, resulting in an increase in maintenance and repair expenses [4]. As a result, industries and research institutions have made considerable efforts to substitute centralised materials with composites in order to strengthen their mechanical properties, such as strength as well as lifetime service, and to reduce power consumption as well as structure construction and maintenance costs. It is worth noting that about 63 percent of all parts and equipment used in commercial aerial transportation are made of composite materials, demonstrating the importance of incorporating and optimising the composite manufacturing industry into people's daily lives.

The volume percentage, alignment, and composition of the fibres are the most important characteristics that govern the composite performance and strength in fiber-reinforced composites. In general, the highest strength in fiber-reinforced composite materials is achieved along the fibre path, while other orientations demonstrate very low mechanical properties. [5]. This is a major drawback of such composites. Except from that, the most often utilised types of fiber-reinforced composites in the industry are glass fibre reinforced polymer (GFRP), carbon fibre reinforced polymer (CFRP), and aramid fibre reinforced polymer (AFRP). Because of its outstanding properties, such as corrosion resistance, easy fabrication costs, smooth surface, and long service life, this type of composite has been widely used in aeronautical, electrical components, water towers, automotive sectors, and power generating domains. Furthermore, glass fibres are used to increase the strength of polymeric parts. The foundation phase of this type of composite is made up of thermoset polymers such as epoxy, thermoplastic, polyester resins, and vinyl ester [6].

II. COMPOSITE FABRICATION PROCESS

There are various methods for making composites available today. Their selection, however, is influenced by usable facilities, composite use, composite kind, applied materials, and financial budget rate. To summarise, each fabrication method has advantages and downsides [7]. For illustration, many processes are quick and have high costs, whilst others are slow and have low composite production costs. Furthermore, the cost of production is strongly connected to the accuracy and quality of the produced composite [8]. It is worth noting that not all fabrication procedures are appropriate for making every composite type, since some require specific moulds to shape the reinforcing and matrix phases into the desired final form.

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A. **Hand Layup**

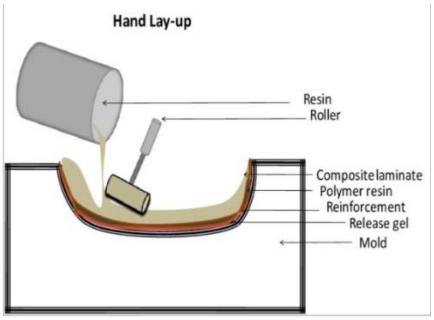

Figure1: Schematic diagram of Hand Layup process

This is among the most basic and fundamental methods for creating compounds with the thermosetting phase. During the manufacturing processes, the fibre inserts are carefully placed down opposite each other and till it laminate is formed, and then resin can be used to bind them together. The fibre plies first were packed with resin and afterwards wrapped in another procedure known as wet hand layup.

B. **Resin Transfer Molding (RTM)**

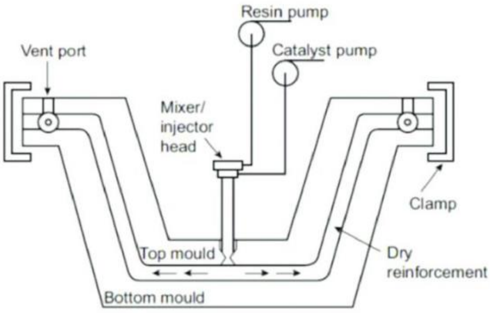

Figure 2: Schematic diagram of Resin Transfer Molding process

The fabrication procedure is significantly faster with this method, whose mould is constructed from two comparable components. Reinforcing fibres are put into the mould from the beginning. Following that, a low-viscous resin is injected into the mould at a low pressure. Overall, this composite production approach offers several advantages, including low cost and resin holding conditions at room temperature. Despite the fact that this method is faster than open contact and hand layup fabrication methods, its use reduces composite post-fabrication operations.

C. **Vacuum-Assisted Resin Transfer Molding (VARTM)**

Vacuum-Assisted Resin Transfer Molding, a revolutionary composite production technology, will be widely used in the industrial industry. The vacuum-impacted resin flows into the mould in this approach, and the pressurised pumping method is not accessible. Among the advantages of using this technology is the ability to fabricate large and complex parts in a single step.

D. **Injection Molding**

Injection Molding is a quick, limited, and cost-effective method of large scale production. Laminated composites are crushed into a mould during the production process, and then resin is injected through the pores inherent inside the mould. One of the most significant advantages of this production technology is the reduced need for surface finishing following the curing and extraction procedures.

E. **Electrode position Resin Molding**

Reinforcing fibres are negative terminal pole in this production procedure, and colloidal suspended particles (resin or matrix phase) deposit on the reinforcing fibres in the liquid medium as a result of the electric field effect. Colloidal suspended particles can be metal, polymer, or ceramic in general.

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F. **Autoclave Curing Process**

There are two physical and chemical steps to this fabrication process. The autoclave curing process is one of the most used methods for producing thermoset matrix composites. Pressure and vacuum are used in this first phase to release the imprisoned air and put fibres and plies next to one another. The temperature rises dramatically in the second phase to narrow the resin viscosity or matrix phase. As a result, the resin embraces all of the fibre plies, yielding the final form of the composite.

G. **Filament winding**

One of the mechanised approaches is the production of composite pieces with axial symmetry. The simplest items manufactured by this approach are tubes and cylindrical parts (such as golf club shafts, automotive shaft drives, and spacecraft constructions). Continuous fibres are wrapped around a rotating mandrel after being impregnated with resin in a regular and regulated manner, with the design engineer deciding on a unique configuration. The major benefit of filament winding that has gained a lot of attention is its low fabrication cost. However, one of the downsides of this production approach is that it is largely limited to wedge shaped components.

H. **Compression moulding**

Figure 3: Machining setup of Compression molding process

Thermosetting polymers are utilised in compression moulding. The thermoset plastic substance can be either available granular or viscous. The material is placed in a hot mould, which is then closed with a hydraulic press. A typical compression moulding technique is performed at 350°F mould temperature and 100 psi mould pressure (170°C and 710 kPa), with a cure period of 3 minutes. The mould is opened and the plastic package is pushed out after the material has cured. Compression moulding is a low-cost, high-volume manufacturing technology.

III. MECHANICAL CHARACTERIZATIONS

A. **Investigation of stress-strain variations**

Stress - strain curve, often known as stress testing, is the most fundamental sort of material mechanical test. In summary, tensile testing machine tools can be used to determine the reaction of materials to applied forces. The force displacement graph is the result of the first phase test. The specimen then enters the second phase (plastic region), where the stress-strain curve is formed in order to further investigate the mechanical behaviour of engineering materials.

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Figure 4: Testing Equipment setup of Tensile and Flexural test

B. **Fractured specimens and**

The most crucial concerns to consider in important applications are composite fatigue and long-term durability. Aside from that, the cracking phenomenon and failure modes are critical in determining the effective lifetime of composites. As a result, an accurate and comprehensive analysis might be useful in calculating the life span of a composite. Displacement follows a three-phase rule with cyclic loading: (1) crack initiation, (2) crack growth, and (3) breakage and crack growth instability. An investigation of the tension-resultant failure modes demonstrates that in an antisymmetric CFRP composite, damage in the composite layer such as delamination and matrix cracking occurs with greater likelihood. Fiber breakage is the most important component in determining the level of tensile stress in a carbon fiber-reinforced composite. The key breakage factor of the composite structure during the initial loading phases is the poor surface adhesion between the fibres and matrix, as well as the occurrence of micro fractures in this region. In terms of the effect of diverse delamination geometries in a GFRP composite, the presence of many pre-developed delaminations with relatively high sizes over the composite layer can have a minor impact on tensile strength.

Figure 5: Izod Charpy setup for toughness test of specimen

C. **Water uptake**

For the water uptake test, the composites were sliced to a tiny size (10*2*0.2 cm). For varied times, the composite samples were immersed in a beaker containing 1000 ml of water at room temperature (15 min, 30 min, 3 h, 12 h, and 26 h). Tissue paper was used to remove samples from the beaker. Using the beginning and end weights, the water uptake of the composites was computed. The water uptake was calculated using the following equation.

$$\text{Water uptake (\%)} = ((\text{Final weight} - \text{Initial weight})/\text{Initial weight})*100$$

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D. **SEM images**

SEM was used to investigate the fracture surface of the composite following the tensile test (SEM). For 20 seconds, samples were stuck on a carbon tap and coated with gold. All of the photos were obtained at a voltage of 5 KV.

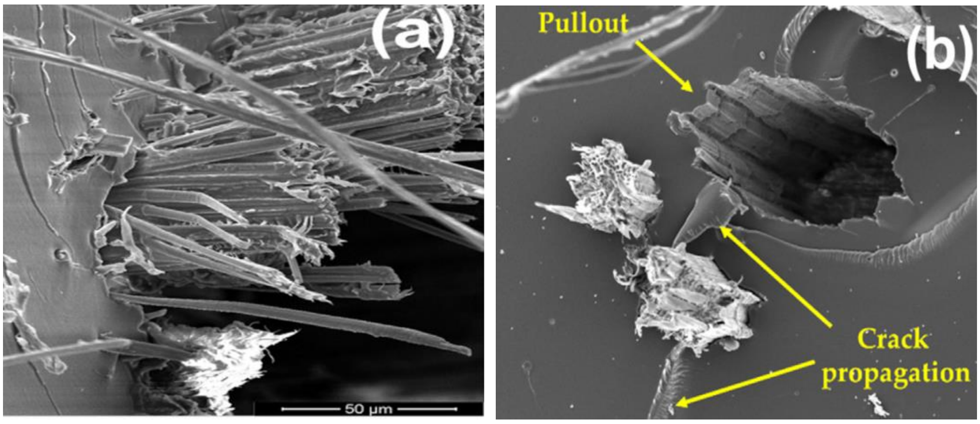

Figure 6: SEM images of fiber pullout and crack propagation.

IV. CONCLUSION

Because of their appealing mechanical properties, such as low density and better strength than typical monolithic materials such as steel, composites are recognised as one of the most cutting-edge and applicable materials in today's society. Furthermore, tensile strength is one of the most essential criteria determining the type of application and composite performance level.

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