FABRICATION AND MECHANICAL STUDIES OF FIBER REINFORCED POIYMER COMPOSITES

N.SHIVARAMA KRISHNA
M.Tech, Production Engineering,
Ellenki engineering college of siddipet.
E-mail: nsrk0701@gmail.com

G.GOPINATH
Assistant Professor,
Dept. of Mechanical Engineering,
Ellenki engineering college of siddipet.

ABSTRACT:
Polymer-matrix composites (PMCs) have been used for a variety of structural memberships for chemical plants and airplanes, since they have outstanding performances, such a lightweight and good fatigue properties. To hold the long-term durability and to estimate the residual life of the composites under some hostile environments, it is an important issue to clarify the facture and/or the failure mechanism in each service conditions. Degradation of components made from polymeric materials occurs in a wide variety of environments and service conditions, and very often limits the service lifetime. Degradation occurs as the result of environment-dependent chemical or physical attack, often caused by a combination of degradation agents, and may involve several chemical and mechanical mechanisms. The main concern of this review will be to examine the causes of degradation of polymeric components from the completion of fabrication to ultimate failure.

INTRODUCTION:

REINFORCING FIBERS are a key component of polymer-matrix composites (PMCs), ceramic-matrix composites (CMCs), and metal- matrix composites (MMCs). They impart high strength and stiffness to the matrix material that they modify, and in addition, may offer other valuable properties such as low dielectric constant, high temperature resistance, or high creep resistance. Depending on the design requirements, it is possible to select an appropriate composite-reinforcing fiber to manufacture a commercial composite part having high value-in-use. The composite will achieve the desired property values for a specific or generic application at a reasonable cost, even though the cost of the fibers themselves may appear high

LITERATURE REVIEW:

Bakelite was the first fibre-reinforced plastic. Dr. Baekeland had originally set out to find a replacement for shellac (made from the excretion of lac beetles). Chemists had begun to recognize that many natural resins and fibres were polymers, and Baekeland investigated the reactions of phenol and became a market success, then turned to developing a binder forasbestos which, at that time, was moulded with rubber. By controlling the pressure and temperature applied to phenol and formaldehyde, he found in 1905 he could produce his dreamed-of hard mouldable material (the world's first synthetic plastic): bakelite. He announced his invention at a meeting of the American Chemical Society on February 5, 1909. The development of fibre reinforced plastic for commercial use was being extensively researched in the 1930s formaldehyde. He first produced a soluble phenol-formaldehyde shellac called "Novolak" that never. In the UK, considerable research was undertaken by pioneers such as Norman de Bruyne. It was particularly of interest to the aviation industry. Mass production of glass strands was discovered in 1932 when a researcher at Owens-Illinois accidentally directed a jet of compressed air at a stream of molten glass and produced fibres. Owens joined up with the Corning company in 1935 and the method was adapted by Owens Corning to produce its patented "fibreglas" (one "s"). A suitable resin for combining the "fibreglas" with a plastic was developed in 1936 by du Pont. The first ancestor of modern polyester resins is Cyanamid's of 1942. Peroxide curing systems were used by then. Ray Greene of Owens Corning is credited with producing the first composite boat in 1937, but did not proceed further at the time due to the brittle nature of the plastic used. In 1939 Russia was reported to have constructed a passenger boat of plastic materials, and the United States a fuselage and wings of an aircraft. The first car to have a fibre-glass body was the 1946 Stout Scarab. Only one of this model was built.The first fibre reinforced plastic plane fuselage was used on a modified Vultee BT-13A designated the XBT-16 based at Wright Field in late 1942. In 1943 further experiments were undertaken building structural aircraft parts from composite materials resulting in the first plane, a Vultee BT-15, with a GFRP fuselage, designated the XBT-19, being flown in 1944. A significant development in the tooling processes for GFRP components had been made by Republic Aviation Corporation in 1943. Carbon fibre production began in the late 1950s and was used, though not widely, in British industry beginning in the early 1960s, aramid fibres were being produced around this time also, appearing first under the trade name Nomex by DuPont. Today each of these fibres is used widely in industry for any applications that require plastics with specific strength or elastic qualities. Glass fibres are the most common across all industries, although carbon fibre and carbon fibre aramid composites are widely found in aerospace, automotive and sporting good applications. Global polymer production on the scale present today began in the mid 20th century, when low material and productions costs, new production technologies and new product categories combined to make polymer production economical. The industry finally matured in the late 1970s when world polymer production surpassed that of Steel, making polymers the ubiquitous material that it is today. Fibre reinforced plastics have been a significant aspect of this industry from the beginning. There are three important categories of fibre used in FRP, glass, carbon, and aramid.

EXPERIMENTAL

<u>Selection of material</u>

Since E-Glass is a conventional fiber for structural applications at high temperature. It is also the insulating and since it is cheap in cost and easily available which is being used for many aerospace applications, hence it is selected. Thought the rayon carbon is very expensive, it is amorphous material for ablative and is having vast applications in aerospace industry, hence it is selected Phenolic resin is the convectional matrix material which is used for aerospace applications to with stand high temperatures. The properties and specification of these materials are as follows

E-Glass (V-9GRADE):-General Technical specifications

Nomenclature: E-GLASSFABRICV-9,
Thickness: 0.78-0.82mm, Width: 1000(nominal) mm,
Areal density: 8 Harness satin gm/sqm, Breaking strength -Warp, kg/inch :148 minimum Weft, kg/inch :119 minimum

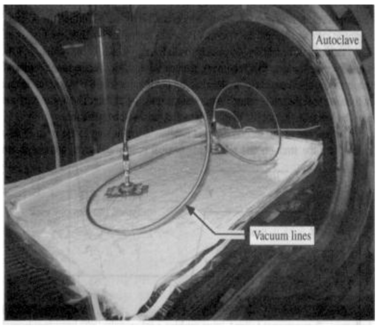
Lay-up and Autoclave curing: The Lay-up of each step must follow in successive fashion in order to obtain a high-quality composite laminate after final processing. A description of these steps follows.

- The surface of the tool is cleaned and a release agent is applied. If the surface is not clean, then the release agent will not function properly. The release agent can be in liquid form, or it may be a solid film.
- An optional sacrificial layer is laid up on the tool surface. This layer is usually a fiberglass fabric made with the same resin system as the composite laminate. The sacrificial layer protects the laminate from surface abrasion and surface irregularities during manufacturing.
- A peel ply is placed on top of the sacrificial layer. The peel ply will be removed after processing.
- The pre-preg are cut according to design specifications. They can be cut by hand using shears or a steel blade knife.
- The first pre-pregg ply is oriented and placed upon the tool or mold. Subsequent plies are placed one upon another; a roller or other small hand tool is used to compact the plies and remove entrapped air that could later lead to voids or layer separations. It is important that the pre impregnated material have sufficient tack so that it sticks slightly to the peel ply and to the adjacent plies. Tackiness, a characteristic of pre impregnated material, quantifies the relative stickiness of the plies at room temperature. As the pre-pregg ages, its tackiness is reduced. Eventually, the plies no longer stick together and they may have to be heated slightly to soften them during lay-up. Oils and dirt on the surface of the pre impregnated plies will contribute to reducing composite strength after processing. Technicians should wear gloves during lay-up so that oils and dirt from the hands do not contaminate the pre-pregg plies during lay-up. In some cases the hand lay-up procedure may be carried out in a clean room to reduce the risk of contamination of the pre-pregg plies.
- A flexible resin dam is anchored to the sacrificial layer approximately 3 mm from the edge of the laminate. The dam prevents resin flow out of the laminate, in the plane of the laminate. Flexible dams can be made from silicon rubber, cork, or release coated metal.
- Another peel ply is placed on top of the laminate to protect the laminate surface.
- A sheet of porous release film is laid over the dam and the laminate.

The porous release film will serve as a barrier to prevent bonding of the composite laminate to the secondary materials to follow.

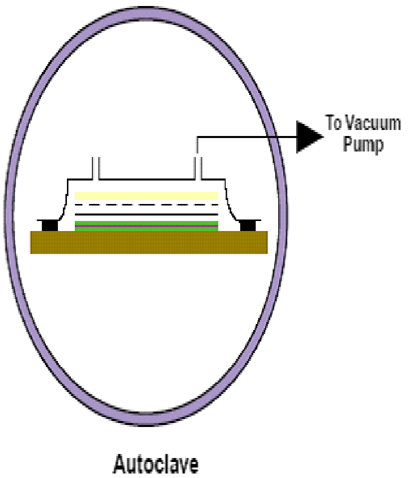
- Next, bleeder plies are laid up over the release film, in this case the peel ply. The bleeder plies extend to the edge of the laminate. The number of bleeder plies to be used for a given laminate can be determined by using a resin flow process model or through empirical observation. This prevents excessive resin flow into the breather material while maintaining a vacuum pathway into the composite laminateBreather plies are placed over the entire lay-up. The breather plies will conduct the vacuum path into the laminate. It is critically important that sufficient breather material is used throughout the entire laminate. Creases and areas with shallow curvature are sometimes reinforced with additional layers of breather material to ensure that the breather plies do not collapse in these areas. An edge bleeder is used to connect to the vacuum ports. An edge bleeder is nothing more than a strip of breather material folded along its length several times. It is placed so that it overlays the breather material surrounding the laminate and extends out to a convenient location for the placement of the vacuum port.
- Sealant tape is placed around the entire periphery of the lay-up.
- The vacuum bag is cut to size and placed over the lay-up.
- The bag is sealed by pressing the bag over the sealant tape. It is critically important to ensure that the bag is adequately sealed before proceeding to the processing cycle. Many parts are scrapped because the vacuum fails during processing, causing excessive voids, inadequate resin flow, or incomplete consolidation.
- The vacuum port is installed through the bag and the contents are evacuated. The bag is now checked for leaks. If any are detected, they are repaired before processing. Usually a leak test calls for application of a vacuum to some specified level (cm of Hg), followed by a 30-60 minute hold. During the hold the bag is disconnected from the vacuum source and the pressure level within the bag is monitored. If the bag is sealed well and there are no leaks, then the vacuum level should not change for the 30-60 minutes. Some leaking generally occurs, so it is a question of having sufficient vacuum pump capacity to maintain the specified vacuum level. When the vacuum is satisfactory, the composite part is ready for processing. The specific processing steps depend on the particular composite material being used, and the operation of the autoclave depends on the specific make and model. General discussions of processing and autoclave features are presented in the sections to follow.
- Obviously, there is a significant amount of skilled labor necessary

for the hand lay-up of composite parts. Each step has a specific purpose and function. This type of fabrication is the most time-consuming, but it is also the most flexible and when combined with autoclave processing, it results in high-quality parts.



Preparation Vacuum bagging
Autoclave curing of Laminate

Autoclave curing : Autoclaves have been used extensively for processing high-performance composite materials in the civilian and military aerospace industries. An autoclave consists of a large cylindrical metal pressure vessel with end enclosures that is thermally insulated and heated. Most autoclaves have a forced-hot-gas circulation system as well. An autoclave is pressurized using air or an inert gas such as nitrogen. What distinguishes the autoclave from the curing oven and hot press, to be discussed later, is the ability to cure parts using large, hydrostatic like pressure. A typical autoclave can pressurize up to 20 atm. The large majority of composite structures can be processed using autoclaves with 2-4 m internal diameter, although some extremely large aerospace structures require autoclaves over 20 m in diameter. The capital equipment costs and operating costs for large autoclaves make this type of processing very costly. However, the high quality and high performance of autoclaved parts makes them attractive for certain applications. The primary component is the pressure vessel itself, which is cylindrical and contains embedded heaters and cooling coils. A door at one end allows access to the interior to load parts and perform periodic maintenance. Also, several ports may be installed through the autoclave wall for access to the interior. Some of these ports are dedicated to vacuum lines connected to the parts to be cured. Others are used for control functions such as thermocouples, dielectric sensors, and pressure sensors, all of which help monitor the curing of the material. The interior of the autoclave is heated by radiation from the vessel walls and convection of hot gases as they circulate through the vessel. A circulating fan forces the hot gases through a series of baffles within the autoclave in a circulation loop that runs the length of the autoclave. Typically, this fan is housed at one end of the autoclave and the interior gases are drawn from the central portion of the cylinder, through the baffles, and they return to the other end through a jacket that covers the interior wall. The autoclave applies a pressure to the outer surface of the composite part through pressurization of the interior gases. This pressure is then transferred through the tool plate(s), breather plies, bleeder plies, and other secondary materials to the laminate surface. From there the pressure is shared between the fiber and matrix during curing. The most important aspect is the matrix resin pressure during cure. If it is too low, then voids can grow in the resin or inadequate resin bleeding may occur. In general, composite structures which have been processed in an autoclave exhibit uniform thicknesses, good consolidation, and very low void content.



Typical Autoclave cure cycle

Characterization of composite Laminate:

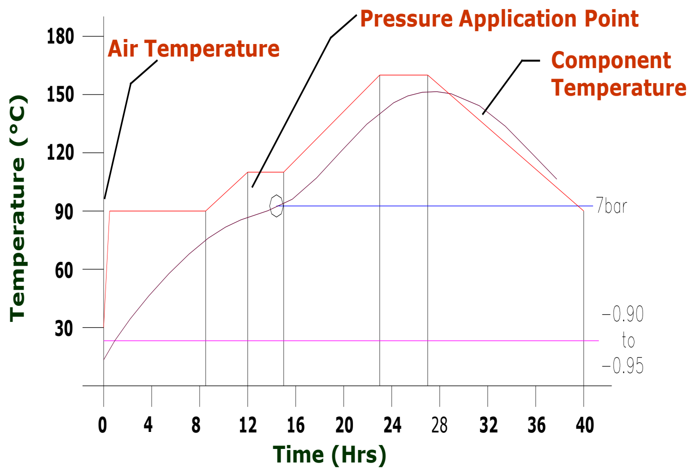
The destructive tests are to determine the physical properties of the material. For the laminates that we made with fibre reinforcement's and matrix the destructive tests are done according to the ASTM standards. The test procedures are as follows.

Density test (ASTM-D-792): Density of composite is determined by Archimedes principle according to it, any object, completely or partially immersed in a fluid is buoyed by a force equal to the weight of the fluid displaced by the object.

i.e., apparent immersed weight = actual weight – weight of displaced fluid

Then it is inserted into the quotient of weights, which has been expanded by the mutual volume. Thus the density of the immersed object relative to the density of the fluid can easily be calculated without measuring any volumes as follows.

Resin content test: This test is done by burn off method because the fabric in laminate is E-Glass v-9 For rayon fiber we use nitric acid digestion method.



temperature and fabric plies are remained in the furnace

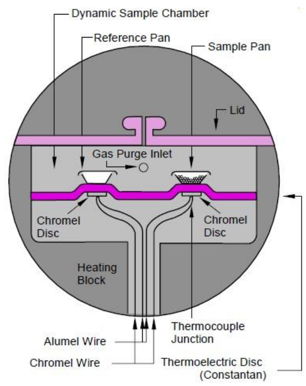
- The weight of the fabric plies should be measured
- The different between total weight of the test piece and fabric plies will give the percentage of resin content in the laminate

Nitric acid digestion method (ASTM D-3171):

- This test is done using nitric acid
- Measure the temperature of the Rayon carbon using pykinometer
- Keep the rayon carbon in the nitric acid until they are digested as shown in the figure7.3.
- Then separate the acid and fibre

- Now the fibre is free of resin, hence measure the weight of that fibre
- Calculate the difference between the total test specimen and the fibre is resin content value

Differential Scanning Calorimeter: Differential Scanning Calorimetry (DSC) measures the temperatures and heat flows associated with transitions in materials as a function of time and temperature in a controlled atmosphere. These measurements provide quantitative and qualitative information about physical and chemical changes that involve endothermic or exothermic processes, or changes in heat capacity.



DSC Schematic Diagram

RESULT AND DISCUSSION

Laminate characteristics with respect to pressure application region have been characterized for thickness, solid resin content, void content, ultrasonic attenuation and fiber volume fraction. The results were tabulated in **Table 1**

Type of Laminate	Density	Resin Content (%)	Fibre Content (%)	DSC
RCF/Phenolic	1.379	40	60	No Exotherm
E-glass/Phenolic	1.87	38	61	No Exotherm

Mechanical Properties of Laminates: The following Mechanical properties of prepared laminates were studied and results were given in table 2.

Tensile Strength, ILSS: 3/4xP/bd, Flexural Strength: FS=3PL/2bdd

Table 2. Mechanical Properties of composite Laminates

Type of Laminate	Tensile strength	Flexural strength	ILSS (Mpa)
RCF/Phenolic	150	270	27.88
E-glass/Phenolic	220	350	26

Degree of Cure To estimate the degree of cure DSC was carried. The thermal gradient is estimated by measuring the temperature difference of thermocouples, incorporated at different layers. **Fig** shows the thermo grams obtained from DSC analysis is showed no exothermic peak was observed. It indicated the laminates were fully cured. To improve the ablative performance, the structure should contain maximum resin content and minimum void content.

DISCUSSION:

In this report we are discussing the Rayon carbon/Phenolic composites and E-glass/Phenolic composites their fabrication and autoclave curing. The thermal and mechanical properties of Laminates were studied.

CONCLUSIONS

1. Hand lay-up prepegging of E-glass/Phenolic and Rayon carbon/Phenolic were carried out.

2. Fabrication of laminates was done on the metal plate.

3. Laminates were cured in Autoclave successfully.

4. Physical properties of Prepared laminated were studied.

5. Thermal properties of laminates were studies. There is no exothermic peak was observed. The laminates were fully cured.

6. Mechanical properties of prepared laminates were carried out.

FUTURE SCOPE:

This test method determines the short-beam strength of high-modulus fiber-reinforced composite materials. The specimen is a short beam machined from a curved or a flat laminate up to 6.00 mm [0.25 in.] thick. The beam is loaded in three-point bending.

1 Application of this test method is limited to continuous or discontinuous-fiber-reinforced polymer matrix composites, for which the elastic properties are balanced and symmetric with respect to the longitudinal axis of the beam.

2. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this Standard to establish appropriate safety and health practices and determine the applicable of regulatory limitations prior to use.

3. The value s stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the standard

REFERENCES:

1. Composite was published in 2001 as volume 21 of ASM Handbook Glossary of Terms, *Adhesives and Sealants*, Vol 3, *Engineered Materials Handbook*, ASM International, 1990, p 3–31

2. Glossary of Terms, *Engineered Plastics*, Vol 2, *Engineered Materials Handbook*, ASM International, 1988, p 2–47

3. Glossary of Terms, *Engineered Materials Handbook Desk Edition*, ASM International, 1995, p 3–72

4. "Standard Terminology for Composite Materials," ASTM D 3878, *Annual Book of ASTM Standards*, Vol 15.03

5. "Standard Terminology of Adhesives," ASTM D 907, *Annual Book of ASTM Standards*, Vol 15.06

6. "Standard Terminology of Advanced Ceramics," ASTM C 1145, *Annual Book of ASTM Standards*, Vol 15.01

7. "Standard Terminology of Structural Sandwich Constructions," ASTM C 274, *Annual Book of ASTM Standards*, Vol 15.03

8. "Standard Terminology Relating to Manufactured Carbon and Graphite," ASTM C 709, *Annual Book of ASTM Standards*, Vol 15.01

9. "Standard Terminology Relating to Plastics," ASTM D 883, *Annual Book of ASTM Standards*, Vol 08.01

10. "Standard Terminology Relating to Textiles," ASTM D 123, *Annual Book of ASTM Standards*, Vol 07.0

11. S.W. Horstman, "Composites and Metal Bonding Glossary," Aerospace Information Report (AIR) 4844, SAE International, 2000

12. The Composite Materials Handbook, MIL- HDBK-17, Department of Defense (DoD) release: Vol 1E,

13. Materials Sciences Corporation, University of Delaware, and Army Research Laboratory, 2000