AMT 2106 –AIRCRAFT MATERIALS CONSTRUCTION AND REPAIR II
(Composite)

PRELIM PERIOD

MODULE II

REINFORCING MATERIALS

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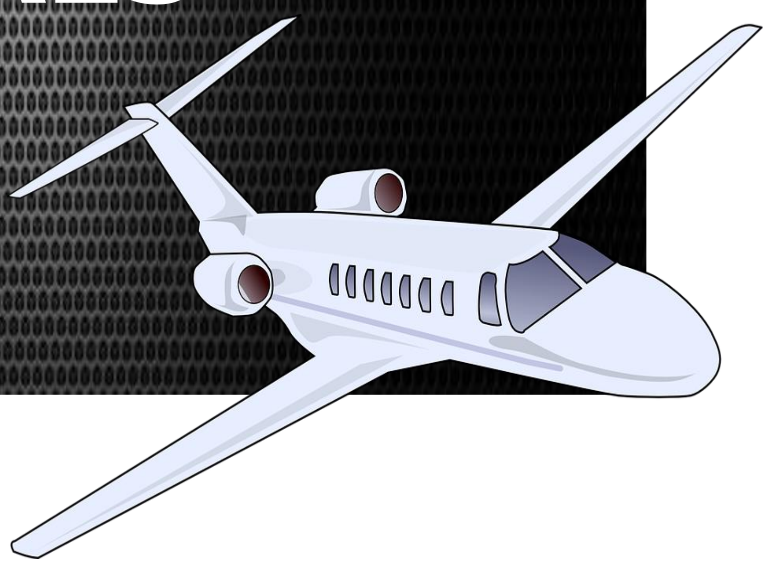

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Materials Science and Engineering introduction Chapter 15 Composites 7th ed.pdf retrieved to *https://in.bgu.ac.il/engn/mater/Documents/LaboratoryBriefings/4/Materials%20Science%20and%20Engineering%20introduction%20Chapter%2015%20Composites%207th%20ed.pdf*	**1**
A&P Technician Airframe Textbook - Jeppesen	**2**
FAA handbook CHAPTER 7 – ADVANCE COMPOSITE MATERIALS	**3**

This module briefly discusses, one of the element of the composite focuses in the reinforcing materials, descriptions and its corresponding advantages when apply to aircraft structure. This modules also addresses the construction and orientation of the fabric because all design, manufacturing, and repair work begins with the orientation of the fabric. This also discusses the different fiber design, style and hybrid of the fabric.

TIMEFRAME

You should be able to complete this module including all the self-assessments, research works, assignments, and other performance tasks within **6** hours**.**

LEARNING OUTCOMES

Course Learning Outcomes (CLO)

CLO 1. Understand the development of the composite structure and classify its element in terms of properties , advantages and characteristics of each elements.

CLO 3. Produce clearly written, thorough and concise reports with well-founded analysis and conclusions, that explains the operation, applications of the composite structures to the aircraft

CLO 4. Execute and apply the techniques/ methods applicable to understand the different materials in composite.

CLO 9. Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria, methods and techniques.

Module Learning Outcome (MLO)

MLO 1. Demonstrate understanding of facts and ideas by comparing, the different materials falls under reinforcing material, their properties and corresponding advantages and disadvantages.

MLO 2. Show and familiarized the parts and style of fabric used in composites

MLO 3. Define and explain the ff. types of hybrid in terms of aircraft composite and fiber placement

Topic Learning Outcomes(TLO)

TLO 3. Identify the different materials falls under reinforcing material, their properties and corresponding advantages and disadvantages.

TLO 4. Illustration and define the parts and style of fabric used in composites.

TLO 5. Illustrate and explain the different types of hybrid in terms of aircraft composite and fiber placement.

MODULE II: REINFORCING MATERIALS

Introduction

Many of our modern technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics, and polymeric materials. This is especially true for materials that are needed for aerospace, underwater, and transportation applications. For example, aircraft engineers are increasingly searching for structural materials that have low densities, are strong, stiff, and abrasion and impact resistant, and are not easily corroded. This is a rather formidable combination of characteristics. Frequently, strong materials are relatively dense; also, increasing the strength or stiffness generally results in a decrease in impact strength. Material property combinations and ranges have been, and are yet being, extended by the development of composite materials.

Generally speaking, a composite is considered to be any multiphase material that exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized. According to this principle of combined action, better property combinations are fashioned by the judicious combination of two or more distinct materials. Property trade-offs are also made for many composites. *(Materials Science and Engineering introduction Chapter 15 Composites 7th ed)*

REINFORCING MATERIALS

Reinforcing fibers provide the primary structural strength to the composite structure when combined with a matrix. Reinforcing fibers can be used in conjunction with one another (hybrids), woven into specific patterns (fiber science), combined with other materials such as rigid foams (sandwich structures), or simply used in combination with various matrix materials.

Each type of composite combination provides specific advantages. Following are the five most common types of reinforcing fibers used in aircraft composites.

Types of Reinforcing Materials

1. Fiberglass
2. Aramid
3. Carbon/Graphite
4. Boron
5. Ceramic

most common types of reinforcing fibers

1. FIBERGLASS

Fiberglass is made from small strands of molten silica glass that are spun together and woven into cloth. Many different weaves of fiberglass are available, depending on a particular application.

Advantage & Disadvantages

Widely available &low cost make fiber glass one of the most popular reinforcing fibers. One of the disadvantages of fiberglass is that it weighs more and has less strength than most other composite fibers. In the past, fiberglass was limited to nonstructural applications. The weave was heavy and polyester resins were used, which made the part brittle. However, with newly developed matrix formulas, fiberglass is an excellent reinforcing fiber currently used in advanced composite applications.

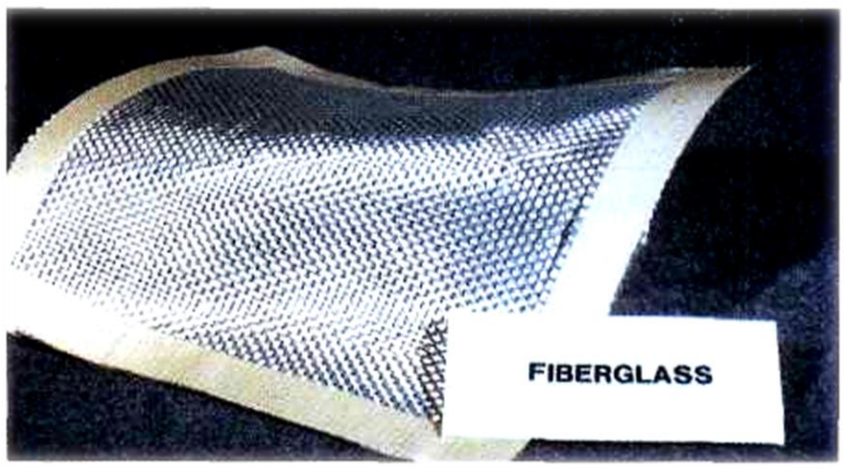


Figure 1.
Fiberglass is usually a white gleaming cloth. The widespread availability of fiberglass and its low cost make it one of the most common reinforcing fibers utilized in aircraft non-structural composites

3 Common Types of Fiberglass

The two most common types of fiberglass are S-glass and E-glass. E-glass, otherwise known as "electric glass" because of its high resistivity to current flow, is produced from borosilicate glass and is the most common type of fiberglass used for reinforcement. S-glass is produced from magnesia-alumina-silicate, and is used where a very high tensile strength fiberglass is needed.

1. **E – glass -** Is a borosilicate glass commonly used for reinforcement because of its low cost and good strength characteristics
2. **S –glass -** Is a magnesia-silicate glass that its up to 40 percent stronger than the e-glass and retains its strength characteristic at higher temperature**.**
3. **C-glass -** Is used in materials that require chemical resistance.

2. ARAMID

An aramid is usually characterized by its yellow color, light weight, tensile strength , and remarkable flexibility. In the early 1970s, DuPont introduced aramid, an organic aromatic-polymide polymer, commercially known as Kevlar . Aramid exhibits high tensile strength, exceptional flexibility, high tensile stiffness, low compressive properties, and excellent toughness. The tensile strength of Kevlar composite material is approximately four times greater than alloyed aluminum. Aramid fibers are non-conductive and produce no galvanic reaction with metals..

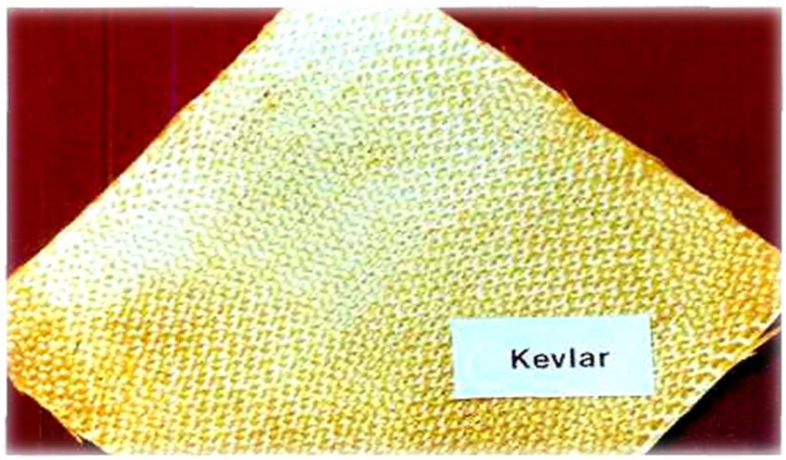


Figure 2.
Aramid fiber is usually characterized by its yellow color, and as with most reinforcing fibers, comes in various grades and weaves for different uses. Kevlar 49 is predominantly used in aircraft composite reinforced plastics; both in thermoplastic and thermosetting resin systems

Kevlar is a registered trademark of the El DuPont company and its most widely used Aramid. The tensile strength of aluminum is about 4 times that of Kevlar composite

Grade of a Kevlar fibers

1. Kevlar grade 49
2. Kevlar grade 29
3. Kevlar grade 129

Aramid is ideal for use in aircraft parts that are subject to high stress and vibration. Flexibility of the aramid fabric allows the blade to bend and twist in flight, absorbing much of the stress. In contrast, a blade made of metal develops fatigue and stress cracks more frequently under the same conditions.

Advantage

- Aramid is an ideal materials for use in aircraft parts that are subject to high stress and vibration.
  Note: Aramid-reinforced composites also demonstrate excellent vibration-damping characteristics in addition to a high degree of shatter and fatigue resistance

- Another important advantage is its strength-to-weight ratio; it is very light compared to other composite materials.
- Flexible

Disadvantages

- The high strength of this materials can cause a problem when Aramid structure are subjected to repair.

  Note: A disadvantage to aramid is that it stretches, which can cause problems when it is cut. Drilling aramid can also be a problem if the drill bit grabs a fiber and pulls until it stretches to its breaking point. When cutting aramid fabrics, the material will look fuzzy if inappropriate tools are used. Fuzzy material left around fastener holes or seams may act as a wick and absorb moisture or other liquid contaminants such as oil, fuel, or hydraulic fluid. Liquid contaminates may deteriorate the resin materials in the composite structure, producing delamination. It is important to cut aramid cloth correctly because even a slight amount of moisture will prevent aramid from bonding properly. Fuzz around the drilled hole may also prevent a fastener from seating properly, which may cause joint failure.

- Although it exhibits a great tensile strength , **it does not have as much compressive strength**.

3. <u>CARBON /GRAPHITE</u>

Carbon fibers are produced in an inert atmosphere by the pyrolysis of organic fibers such as rayon, poly-acrylonitrile, and pitch. The term **carbon** is often interchangeable with the term **graphite.** However, carbon fibers and graphite fibers differ in the temperature at which they are produced. Carbon fibers are typically carbonized at approximately 2400 F and composed of 93% to 95% carbon, while graphite fibers are produced at approximately 3450 to 5450 F and are more than 99% carbon.

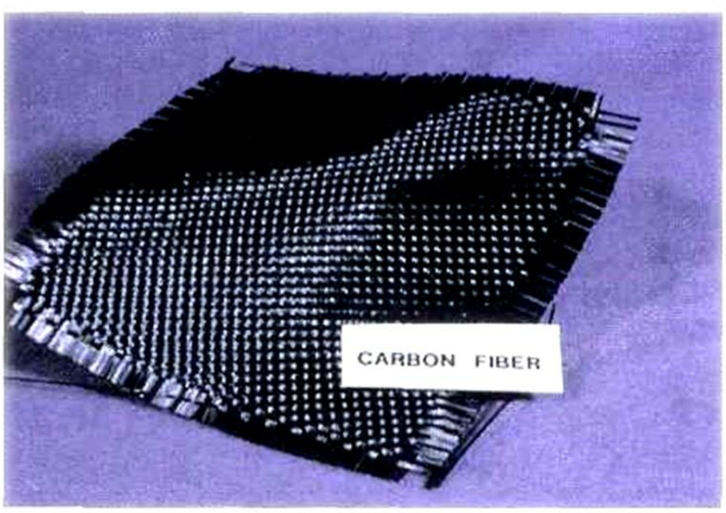


Figure 3.

In general, Americans refer to carbon fibers as "graphite" fiber, while Europeans refer to it as carbon fiber. Carbon actually describes the fiber more correctly, because it contains no graphite structure. Carbon/graphite is a black fiber that is very strong, stiff, and used primarily for its rigid strength characteristics. Fiber composites are used to fabricate primary structural components such as the ribs and skin surfaces of the wings

Advantage

- Carbon is a very strong, stiff reinforcement and used for its rigid strength characteristics. Are used to fabricate primary structural components such as ribs and wing skins. Is stronger in compressive strength than Kevlar. Electrically conductive, have low thermal expansion coefficients, and have high fatigue resistance.
- Advantages to carbon/graphite materials are in their high compressive strength and degree of stiffness.

Disadvantage

- Has a problem of being corrosive when bonded to aluminum.

  Note: However, carbon fiber is cathodic while aluminum and steel are anodic. Thus, carbon promotes galvanic corrosion when bonded to aluminum or steel, and special corrosion control techniques are needed to prevent this occurrence. Carbon/graphite materials are kept separate from aluminum components when sealants and corrosion barriers, such as fiberglass, are placed at the interfaces between composites and metals. To further resist galvanic corrosion, anodize, prime, and paint any aluminum surfaces prior to assembly with carbon/graphite material.

4. BORON

Boron fibers are made by depositing the element boron on a thin filament of tungsten. The resulting fiber is about .004 inch in diameter, has excellent compressive strength and stiffness, and is extremely hard. Have a very high strength and stiffness in tension, compression and bending stress.

Disadvantages

- Hazardous to work with its high expense
- Not common to used with civil aviation

  Note: In designing components that need both the strength and stiffness associated with boron, many civil aviation manufacturers are utilizing hybrid composite materials of aramid and carbon/graphite instead of boron.

CERAMICS

Ceramic fibers are used where a high-temperature application is needed. This form of composite will retain most of its strength and flexibility at temperatures up to 2,200 F. Tiles on the Space Shuttle are made of a special ceramic composite that dissipates heat quickly. Some firewalls are also made of ceramic-fiber composites. The most common use of ceramic fibers in civilian aviation is in combination with a metal matrix for high-temperature applications .Examples : firewalls and tiles on a space shuttle.

Mastery Check

Self-Assessment : Before we proceed with our discussion, let's check how well you have understood the discussion so far. Using the table below, try to identify which fiber are being describe, please answer with honestly. **Time frame: 10-15 mins**

Name of Fiber	DESCRIPTIONS
	1. A types of Reinforcing maetrials that are not common to civil aircrafts because it's too expensive.
	2. This referring to a fiber that exhibits high tensile strength, exceptional flexibility, high tensile stiffness, low compressive properties, and excellent toughness.
	3. This fiber is a white gleaming cloth and widely available to the markets .
	4. This referring to the reinforcing materials that exhibits its compressive strength when applied to aircraft structures .
	5. A fibers are used where a high-temperature application

FIBER ORIENTATION

When working with composite fibers, it is important to understand the construction and orientation of the fabric because all design, manufacturing, and repair work begins with the orientation of the fabric. Unlike metallic structures, the strength of a composite structure relies on the proper placement and use of the reinforcing fibers. Some of the terms used to describe fiber orientation are warp, weft, selvage edge and bias.

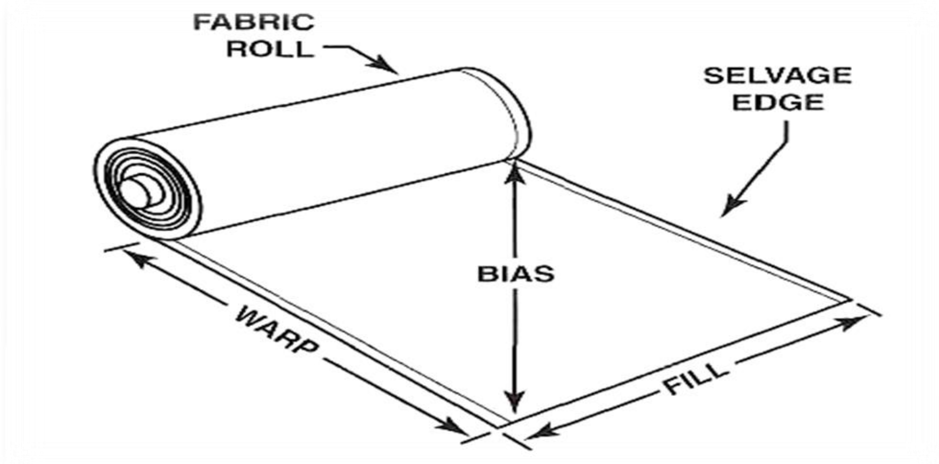


Figure 4.
All design, manufacturing, and repair work begins with the orientation of the fabric. Unlike metallic structures, the strength of a composite structure relies on the proper placement and use of the reinforcing fibers

SOME OF THE TERMS USED TO DESCRIBE TH FIBER ORIENTATIONS ARE THE FF:

1. **BIAS**- The bias is at 45 to a warp threads, and can be formed into contoured shapes .
   - The bias allows for manipulation of the fabric to form contoured shapes. Fabrics can often be stretched along the bias but seldom along the warp or fill.

2. **WARP**- The threads that run the length of the fabric as it comes off the bolt and designated at 0 , more threads and stronger than fill directions.
   - There are typically more threads woven into the warp direction than the fill direction, making it stronger in the warp direction. Because warp is critical in fabricating or repairing composites, insertion of another color or type of thread at periodic intervals identifies the warp direction. Marked plastic backings on the underside of **pre-impregnated** fabrics also identify the orientation of the warp threads. Pre-impregnated fabrics are pre-impregnated with resins by the manufacturer and later cured in the field.

3. **Weft (FILL)** -Are those that run perpendicular to the warp fibers, designated as 90 and weft are the threads that interweave with the warp threads.
   - The weft threads interweave with the warp threads to create the reinforcing cloth.

4. **SELVAGE EDGE**- It is parallel to the warp threads, and its been removed for all fabrication and repair works.
   - The bias allows for manipulation of the fabric to form contoured shapes. Fabrics can often be stretched along the bias but seldom along the warp or fill.
   -

FABRIC STYLES

Fabrics used in composite construction are manufactured in several different styles: unidirectional, bi-directional, multidirectional, and mat. Component designers can use any or all of these fabric styles, depending on the strength and flexibility requirements of the component part.

Materials used in aircraft constructions are commonly found in three styles:

1. Non-woven unidirectional fabric
2. Woven fabric
3. Mat

1. Unidirectional

This fiber orientation in which all of the major fibers run in one direction , giving strength in that direction is known as the unidirectional or the non woven fabric.

- This type of fabric is not woven together, meaning that there are no fill fibers. Occasionally, small cross threads are used to hold the major fiber bundles in place. However, the cross threads are not considered woven fibers.

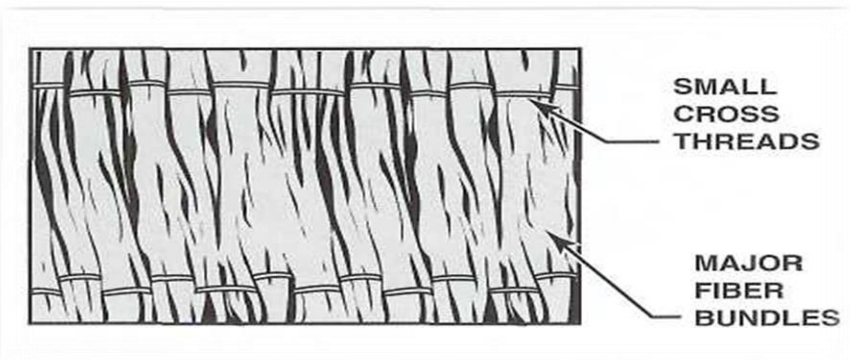


Figure 5.
Unidirectional fabrics are not woven together. Warp fibers run parallel to each other and are kept in place by small cross threads. The strength of this type of fabric lies in the warp direction, making it imperative to properly lay out the fabric.

2. Woven Fabric

This fabric are woven together in a number of weaves and weights and are more resistant to fiber breakout, delamination, and more damage tolerant than unidirectional materials

- Bi-directional fabrics are woven with the warp threads usually outnumbering the weft, so there is usually more strength in the warp direction than the fill. When using bi-directional fabrics, it is important to align the warp threads when performing a repair, due to the differences in the strength properties of the warp and weft directions.

- Another type of bi-directional material is the **intraply hybrid** fabric. This type of fabric is woven from different types of fibers. Intraply hybrid fabrics give composites specific strength, flexibility, and durability characteristics, depending on the combination and proportion of the fibers woven together. A particular structural design may call for different combinations of fibers. Carbon/fiberglass intraply-hybrid fabrics, for example, provide increased stiff-ness due to the carbon and increased heat resistance due to the fiberglass. Specific characteristics of the final fabric are dependent on the types and proportions of the fibers woven together

- Most common weaves used in advanced composite aircraft construction are the **plain and satin weaves**

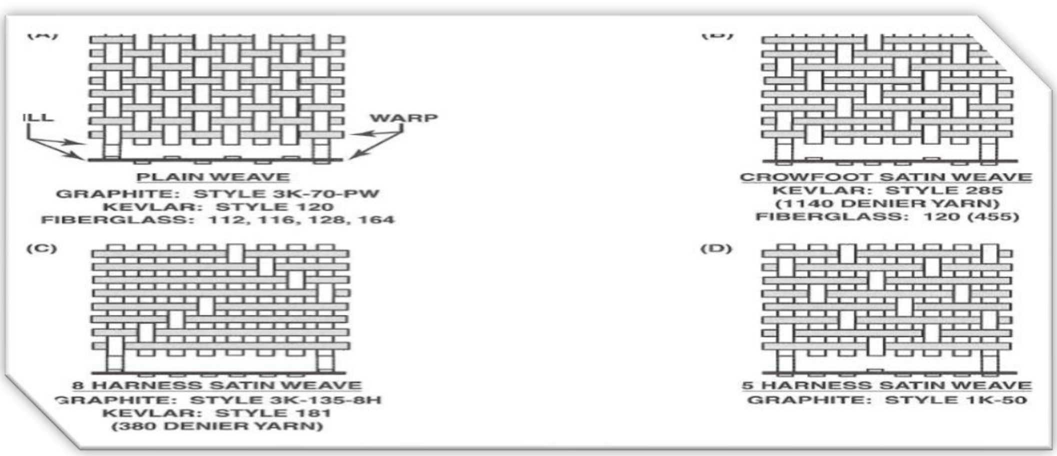


Figure 6.

The most common weave styles employed in aircraft applications are the plain, crowfoot satin, five-harness satin, and eight-harness satin weaves. While each type of fabric is not necessarily available in all weaves, each fabric that is produced with its own style number. For instance, Kevlar and carbon/graphite plain weaves utilize different style numbers for the same type weave.Therefore, make sure you use the correct type of material called for by the aircraft manufacturer's structural-repair manual.

3. MAT

A Mat is not as strong as a unidirectional or woven fabric , and therefore is not commonly used in a repair work.

- A mat is not as strong as a unidirectional or bi-directional fabric, and is therefore is not commonly used alone in repair work

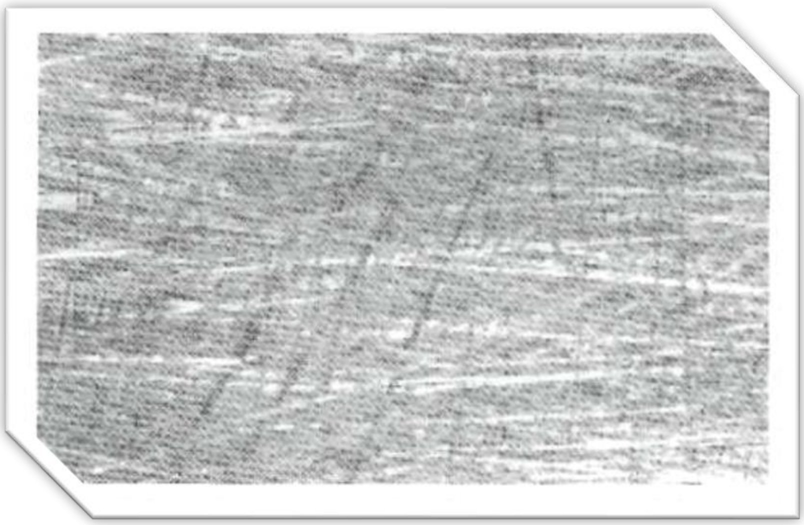


Figure 7.
A mat is not as strong as a unidirectional or bi-directional fabric, and is therefore is not commonly used alone in repair work

Fabric styles are characterized by the ff:

1. **Yarn construction**
2. **Count**
3. **Weight**
4. **Thickness**
5. **Weaves**

HYBRIDS

A manufacturer can design a part by using different types of fiber combination (hybrid) to tailor a part for strength or to reduce cost.

There are three common types of hybrid structures used in aviation today:

1. Intraply hybrid

- Intraply hybrids utilize reinforcing material that is woven from two or more different fibers.
- The strength of the final structure can be designed based on the proportions of each fiber used .

2. Interply hybrid

- An interply hybrid uses two or more layers of different reinforcing materials that are laminated together.
- Each layer in addition to being a different material, may be used in the form of unidirectional or bi-directional fabric

3. Selective Placement

FiBERrs may be selectively palce to give greater strength , flexibility or reduced cost.

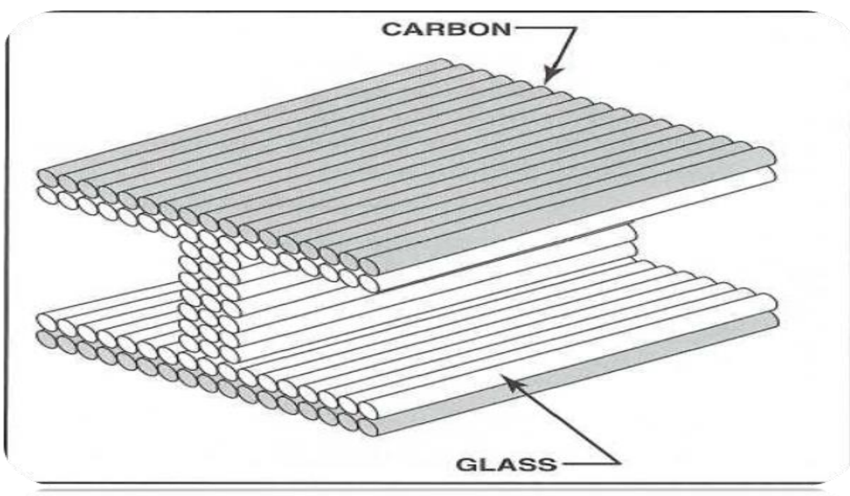


Figure 8.
Selectively placing different types of fibers in a composite structure may provide greater strength, flexibility, and overall reduced cost. An I-beam, for example, may use carbon/graphite fibers where stiffness is desired, and selectively blend in fiberglass to reduce the cost of the structure.

FIBER PLACEMENT

- The strength of a reinforcing material in a matrix is dependent on the weaves of the material, the wetting process, the filament tensile strength and the design of the part.

- To find the amount of strength in a laminate that is 50% fibers and a 50% resin add the tensile strength of the resin and divided by 2.

$$\frac{275{,}000 \text{ psi} + 20{,}000 \text{ psi}}{2}$$

$$\mathbf{= 147{,}500 \text{ psi}}$$

Mastery Check

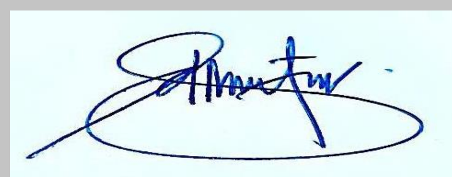
Self-Assessment: Before we proceed with our discussion, let's check how well you have understood the discussion so far. Using the table below, try to identify by analyzing whether the statement are being described is hybrid or style, please answer with honestly.

Time frame: 3-5 mins

Style or hybrid	
	1. Mr. Cabantan use aramid fibers where flexural remarkable, and mix with blend of fiberglass to reduce the cost of manufacturing his fairing in his car.
	2. I used plain satin to manufacture a composite for my exit doors, it have same number of horizontal and vertical fiber woven. I only used carbon for that.
	3. Mr. Adam manufacture a radome/nose, in which he needed an excess fiber to repair the contour shape, his fiber has different directions.
	4. I have two fibers, one is fiber glass and the other one is carbon. Upon manufacturing, the first fiber I place on mold was the fiber glass followed by the second layer of carbon and vice versa. And I made 3 layers of structure.

HONESTY CLAUSE

My signature below constitutes my pledge that all of my writing is my own work, with the exceptions of those portions which are properly documented



SHEILA MAY D. MOTOS,MEAM
Subject Instructor

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Student Signature

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Parent Signature