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## COMPOSITES MATERIALS FOR AVIATION INDUSTRY

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**Abstract:** *The paper presents the generality of the composite materials, in particular those used in the aviation industry. It is presented some aspects about their composition, properties, to their use by way their advantage and their manufacture.*

**Keywords:** *composite materials, fiber, matrix, composites manufacturing, recycling*

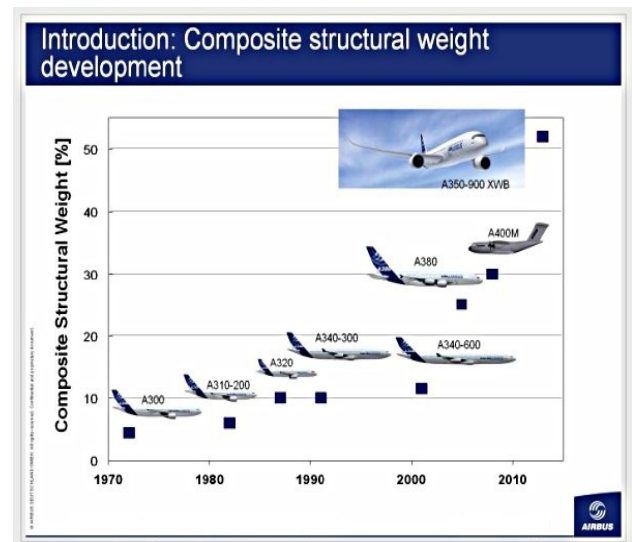
### 1. INTRODUCTION

Today there are over 50,000 different materials available to engineers to design and build everything around us. These materials can be classified into four major categories: metals, plastics, ceramics and composites. Each of these materials have characteristics that are their specific and their choice of application is based on these characteristic.

The industries of aeronautics have chosen to focus on a crucial point in the conception: design and manufacture of aircraft as light as possible while guaranteeing the safety of passages. Indeed over a plane is light it consumes less fuel, reduction of this consumption represents a major economic first order. He therefore had to find a material that combines light weight and high mechanical property capable of supporting the very high stresses which is subject aircraft during the flight.

Those thanks to this new way of designing that we could see appear in the 1960's from a composite material in new airliners. Representing only 5% of the total weight in that early day, it now represents about 53% of

the total weight of the Airbus A350 for example. The Figure 1 shows this evolution for the group Airbus Industry.



**Fig.1** Proportion of composite in Airbus Aircraft [4]

### 2. COMPOSITES STRUCTURE DESIGN

A composite material is made by combining two or more materials to give a unique combination of properties. The above

definition is more general and can include metals alloys, plastic co-polymers, minerals and wood.

The main concept of a composite is that it contains matrix materials. Typically, composite material is formed by reinforcing fibers in a matrix resin as shown in figure 2.

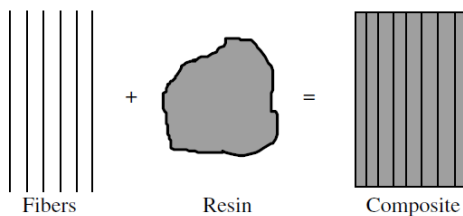


Fig. 2 Composite's components [3]

The reinforcements can be fibers, particulates, or whiskers, and the matrix materials can be metals, plastics or ceramics. The reinforcements can be made from polymers, ceramics and metals. The fiber can be continuous, long or short.

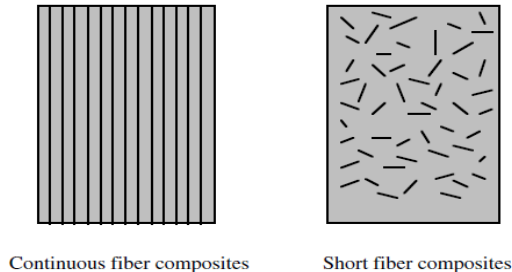


Fig. 3 Continuous or short fiber composite [3]

Composites made with a polymer matrix have become more common and are widely used in various industries. They can be thermoset or thermoplastic resins.

### 2.1 Fibers

The main functions of the fibers in a composite are:

- to carry the load. In a structural composite, 70 to 90% of the load is carried by fibers.
- to provide stiffness, strength, thermal stability, and other structural properties in the composites.

- to provide electrical conductivity or insulation (depending on the type of fiber used).

Table 1. Characteristics of fibers [5]

Reinforts	Filament diameter (µm)	Density (kg.m <sup>-3</sup> )	Longitudinal modulus of elasticity (MPa)	Shear modulus (MPa)	Poisson's ratio	Tensile strength (MPa)	Elongation at break (%)	Coefficient of thermal expansion (°C <sup>-1</sup> )
	d	Mv	E	G	k	C <sub>T</sub>	A	α
Glass E	16	2 600	74 000	30 000	0,25	2 500	3,5	0,5*10 <sup>-3</sup>
Glass R	10	2 500	86 000		0,2	3 200	4	0,3*10 <sup>-3</sup>
Carbon HM	6,5	1 800	390 000	20 000	0,35	2 500	0,6	0,08*10 <sup>-3</sup>
Carbon HR	7	1 750	230 000	50 000	0,3	3 200	1,3	0,02*10 <sup>-3</sup>
Kevlar 46	12	1 450	130 000	12 000	0,4	2 900	2,3	-0,2*10 <sup>-3</sup>
Boron	100	2 600	400 000			3 400	0,8	0,4*10 <sup>-3</sup>
Alumina silicate	10	2 600	200 000			3 000	1,5	
Polyethylene		960	100 000			3 000		

### 2.2 Matrix

The important functions of a matrix material include following:

- the matrix material binds the fibers together and transfers the load to the fibers.
- the matrix isolates the fibers so that individual fibers can act separately. This stops or slows the propagation of a crack.
- the matrix provides protection to reinforcing fibers against chemical attack and mechanical damage.
- the matrix provides a good surface finish quality and aids in the production of net-shape or near-net-shape parts.

## 3. SPECIAL FEATURES OF COMPOSITES

Composites have been routinely designed and manufactured for applications in which high performance and light weight are needed.

They offer several advantages as we can see below:

- Composite materials provide capabilities for part integration. Several metallic components can be replaced by a single composite component.
- Composite materials have a high specific stiffness (stiffness-to-density ratio). Composite offer the stiffness of steel at one fifth the weight and equal

the stiffness of aluminum at one half the weight.

- The specific strength is much higher for composite materials. Steel and aluminum alloys exhibit good fatigue strength up to about 50% of their static strength. Unidirectional carbon/epoxy composites have good fatigue strength up to almost 90% of their static strength.
- Composite materials offer high corrosion resistance.
- Composite materials offer increased amounts of design flexibility.
- Complex parts, appearance, and special contours, which are sometimes not possible with metals, can be fabricated using composite materials without welding or riveting the separate. It offers greater manufacturing feasibility.

#### **4. COMPOSITES MANUFACTURING PROCESS**

There are four basic steps involved in composites part fabrication. All composites manufacturing processes involve the same four steps, although they are accomplished in different ways.

##### **4.1. Impregnation**

In this step, fibers and resins are mixed together to form a lamina. In a hand lay-up process, prepregs that are already impregnated by the material supplier in a controlled environment are used. In a wet lay-up process, each fabric layer is wetted with resin using a squeezing roller for proper impregnation.

The purpose of this step is to make sure that the resin flows entirely around all fibers. Viscosity, surface tension and capillary action are the main parameters affecting the impregnation process.

##### **4.2. Lay-up**

In this step, composite laminates are formed by placing fiber resin mixture or prepregs at desired angles and at places where

they are needed. The desired composite thickness is built up by placing various layers of the fiber and resin mixture. In a prepreg lay-up process, prepregs are laid at a specific fiber orientation, either manually or by machine.

The purpose of this step is to achieve the desired fiber architecture as dictated by the design. Performance of a composite structure relies heavily on fiber orientation and lay-up.

##### **4.3. Consolidation**

This step involves creating intimate contact between each layer of prepreg or lamina. This step ensures that all the entrapped air is removed between layers during processing. Consolidation of continuous fiber composites involves two important processes: resin flow through porous media and elastic fiber deformation.

##### **4.4. Solidification**

The last step is solidification, which may take less than a minute for thermoplastics or may take up to 120min for thermosets. Vacuum or pressure is maintained during this period. In thermoplastics, there is no chemical change during solidification and therefore solidification requires the least amount of time. In thermoplastics processing, the rate of solidification depends on the cooling rate of the process.

The above four steps are common in thermoset as well as thermoplastics composites processing. The methods of applying heat and pressure, as well as creating a desired fiber distribution, are different for different manufacturing methods.

#### **5. FABRICS**

There are two major types of fabrics available in composites industry: woven fabrics and nonwoven (noncrimp) fabrics.

##### **5.1. Woven fabrics**

These fabrics are woven yarns, roving or tows in mat form in a single layer. Common weave styles are shown in following figures.

The amount of fiber in different directions is controlled by the weave pattern.

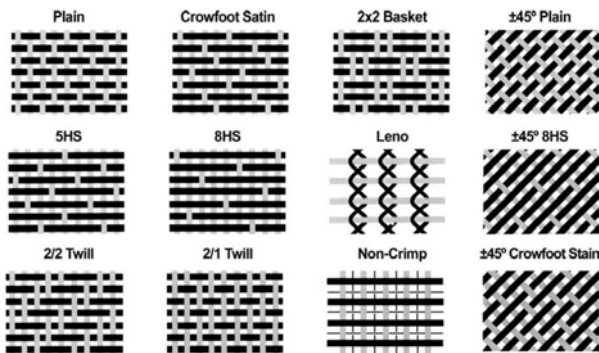


Fig. 4 Main woven fabrics [3]

### 5.2. Noncrimp fabrics

In noncrimp fabrics, yarns are placed parallel to each and then stitched together using polyester thread. Warp unidirectional fabric is used when fibers are needed in one direction only for instance, in stiffness-critical applications such as water ski applications where the fabric is laid along the length of the ski to improve resistance to bending.

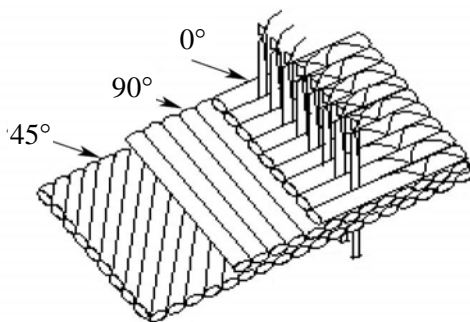


Fig. 5 Schematic of noncrimp fabrics [3]

## 6. MACHINING OF COMPOSITES

Composite materials offer the benefits of part integration and thus minimize the requirement for machining operations. However, machining operations cannot be completely avoided and most of the components have some degree of machining. Machining operations are extensively used in

the aerospace industry.

Machining of metals is very common and is easily performed. However, the machining of composites poses many difficult very specific:

- Machining of composite creates discontinuity in the fiber and thus affects the performance of the part.
- The temperature during cutting should not exceed the cure temperature of the resin for thermoset composites to avoid material disintegration. Glass and Kevlar fibers have poor thermal conductivity and such high temperature may lead to localized heating and degradation.
- Machining exposes fibers to chemicals and moisture.

The tool used for the composite machining are the same who the tool used in metal machining.

## 7. JOINING OF COMPOSITE MATERIALS

In any product, there are generally several parts or components joined together to make the complete assembly. Parts are connected with each other to make the final product. The purpose of the joint is to transfer loads from one member to another, or to create relative motion between two members. Joints are usually avoided in a structure as good design policy. In any structure, a joint is the weaker area and most failures emanate from joints.

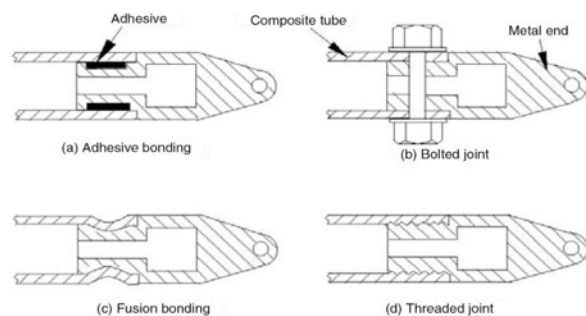


Fig. 6 Various types of joints for joining a metal end with a composite tube [3]

In adhesive bonding, two substrate materials are joined by some type of adhesive (epoxy, polyurethane or methyl acrylate). The parts

that are joined are called substrates or adherents. The most common type of joint is a single lap joint wherein the load is transferred from one substrate to another by shear stresses in the adhesive.

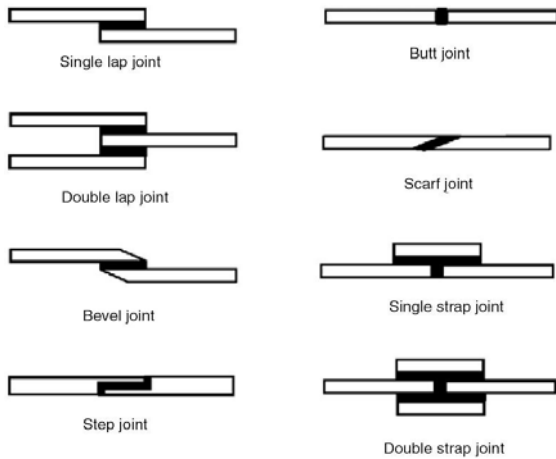


Fig. 7 Adhesive bonding [3]

### 8. RECYCLING OF COMPOSITE

With the increase in the use of composite materials in various industrial sectors, the scrap materials and composite waste parts cannot just be landfilled; instead, these need to be recycled for a better environment. Currently in many business sectors, composite wastes are landfilled with little regard for recovering fibers and plastics for future use. Governments and customers are becoming aware of the environmental pollution created by these materials and passing strict regulations for recycling of plastics and composites waste. Germany, England, France, Italy and other European countries have mandated that plastics and composites waste must be recycled.

There are several Categories of Dealing with Wastes of Composite materials as landfilling or burying, incineration and recycling.

#### 8.1. Aerospace recycling infrastructure

At present, the most common method of scrap disposal is landfilling. Landfilling has been the most common way of handling waste. In this process, the waste is carried to a

specific place and unloaded there. Because plastics and composites are not biodegradable, they cause environmental pollution. This method is becoming increasingly restricted by governments.

Several programs have started to enhance the recycling activities in aerospace industries. In France, TARMAC Aerospace is the first aircraft recycling company around the world. This firm is developing the PAMELA’s project (Process for Advanced Management of End-of-Life Aircraft).

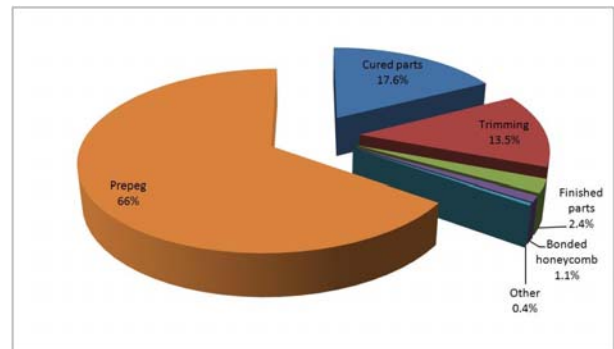


Fig. 8 Average distribution of composite wastes in aerospace industries [7]

### 9. CONCLUSIONS

There are many reasons for the growth in composite applications, but the primary impetus is that the products fabricated by composites are stronger and lighter. Today, the largest user of composite materials is the transportation industry.

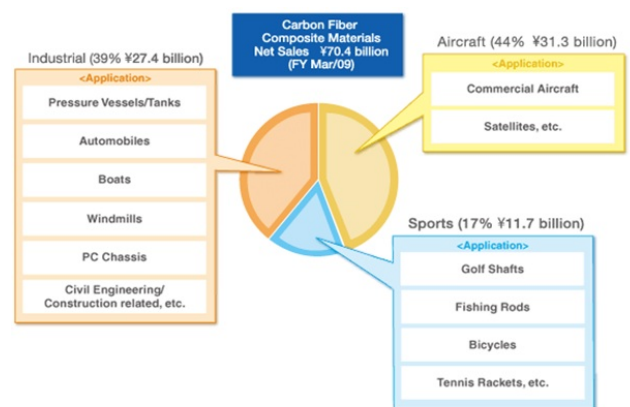


Fig. 9 Carbon fiber composite material’s distribution all around the world according to Net Sales [6]

The aerospace industry was among the first to realize the benefits of composite materials. Airplanes, rockets and missiles all fly higher, faster and farther with the help of composite.

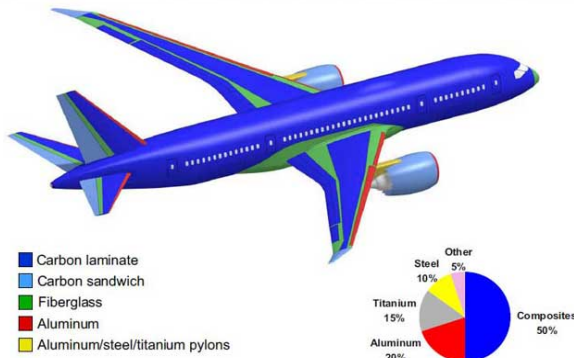


Fig. 10 Materials in the Boeing 787 [8]

Military aircrafts use composite materials to lower the weight of the structure. The composite components used are horizontal and vertical stabilizers, wing skins, fin boxes, flaps and various other structural components.

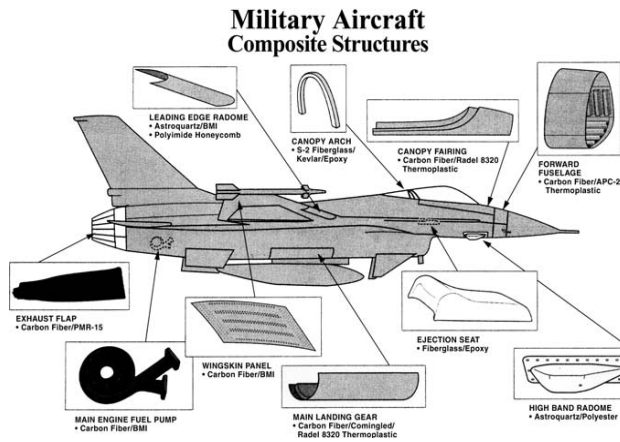


Fig. 11 Typical composite structures used in military aircraft [3]

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