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TEXTILE STRUCTURES FOR AERONAUTICS (PART I)

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Abstract: *Three-dimensional (3D) textile structures with better delamination resistance and damage impact tolerance to be applied in composites for structural components is one of the main goals of the aeronautical industry. Textile Research Centre in Canet de Mar has been working since 2008 in this field. Our staff has been designing, developing and producing different textile structures using different production methods and machinery to improve three-dimensional textile structures as fibre reinforcement for composites. This paper describes different tests done in our textile labs from unidirectional structures to woven, knitted or braided 3 D textile structures. Advantages and disadvantages of each textile structure are summarized.*
The first part of this paper deals with the introduction of our Textile Research Centre in the field of composites and carbon fibre as a main material to produce three – dimensional textile structures. The use of composite materials in aerospace structures has increased over the past decades. Our contribution related to this field consists of the development of three- dimensional textile structures and even the adaptation and improvement of machinery to do it possible. Carbon fibre provides advantages as volumetric fraction and minimum fault occurrence. However carbon fibre has also disadvantages as uncomfortable handling delamination and high cost of material and processing.

Key words: *3D, composites, carbon fibre, fabric, aeronautics*

1. INTRODUCTION

Three-dimensional (3D) textile structures with better delamination resistance and damage impact tolerance to be applied in composites for structural components is one of the main goals of the aeronautical industry.

This paper aims to describe the different conventional fabrics making processes and evaluate advantages and disadvantages of each one related to aeronautical industry.

The first time the Textile Research Centre in Canet de Mar got in touch the field of composites for aeronautical industry it was six years ago when a company asked us to produce a cross-shaped 3D textile structure. The challenge was brought to the Research Staff, telling them the structure was a fitting or beam for aeronautics. Next morning, several 3D textile structures were on the table to be assessed. Figure 1 was the closest one to the requirements expressed by the aeronautical company. Our quick and right reply showed that company our capability to think, design and produce textile structures as well as new answers that fit the needs of aeronautical sector.

However, after this first contact we studied the requirements the textile structures have to fulfil and then we realized the complexity and difficulty it has this field [1]. It was the starting point of our collaboration in the field of textile structures for aeronautical sector as a part of composite structures.

Fig. 1. *Cross-shaped 3D fabric*
Source: CRTTT – Escola de Teixits

2. PURPOSE OF COMPOSITES

Cost increases and the reduction of fossil fuel reserves leads to design more efficient and lighter aircrafts. New designs have also in mind the simplification of the production process as well as the requirements of reliability and safety of aircrafts. The main goal is to achieve lighter weight structural components (carbon fibre or other fibres) to replace metal elements with complex geometry as fittings or frames.

Fig. 2 *Redesigning of aircrafts*

3. WHAT A COMPOSITE MATERIAL IS

Composite material is a material made from two or more constituent materials with improved characteristics from the individual components. The individual components remain separate and distinct within the finished structure. Composite materials are made up of two constituent materials: matrix (resin) and fibres /reinforcement (textile structures) [2]. From two constituent materials composite materials for aeronautical can be designed.

It can be generally thought composite materials have been recently invented. However, as shown in table 1 [3], composite materials were used from the beginning of world. Composites can be found either in the nature or in the human body. Besides, from the early times to present days composites have also been invented by humans. However, the fundamental principle of all of them is the same.

Table 1. *Compound materials [3]*

SOURCE	MATERIAL		MATRIX	FIBRES/REINFORCMENT
Nature	Wood		Natural resins	Cellulose fibres
Human Body	Bones		Bone calcium	Collagen fibres
Human Invention	Ancient Times	Adobe	Mud	Straw
		Reinforced plaster	Plaster	Horsehair
	Modernity	Reinforced concrete	Concrete	Reinforced steel
		Asbestos cement	Cement's mortar	Asbestos
		Fibrous mortars and concretes	Mortar	Steel, glass, polymeric, carbon, vegetable fibres
			Concrete	
		Reinforced plaster	Plaster	Glass, polymeric, vegetable fibres
		Polymeric mortars	Resin	Sand
		Composites	**Resin**	Glass, polymeric, carbon, aramid

Looking at the table it can be observed the main innovations in the field of composites are related to building industry in order to design and build more resilient and secure structures. First references to a different industry are related to marine industry, Glasspar, a boat-building company started in 1947 when it began building small fibreglass boat hulls in his fibreglass shop in Costa Mesa, California.

4. WHY CARBON FIBRE?

Carbon Fibre [4] is used because its strength is almost three times higher than steel, and its density 4.5 times lower. Other Carbon Fibre properties include corrosion and fire resistance, chemical inertness and electrical conductivity. It keeps its shape to temperature changes. The above properties make Carbon Fiber perfectly suitable to needs and requirements of aeronautical industry

Table 2 shows the main features of Carbon Fibres and comparison with other fibres

Table 2. *Textile Fibres*

Material	Density [g/cm^3]	Elongation at break[%]	Tensile stress [MPa]
GLASS FIBRE			
E-Glass S-Glass	2,54 2,49	4,8 5,0	3.450 4.300
CARBON FIBRE			
HS HM	1,74-1,76 1,78-1,96	1.8 1,9	4.500 6.000
BORON FIBRE	2,70	0,8	3.100
ARAMID FIBRE			
Kevlar 49 Kevlar 149	1,45 1,47	2,8 1,9	3.620 3.450

5. PROPERTIES OF CARBON FIRE USED IN OUR TESTS AND PREFORMS

Carbon Fibre classification is related to the number of filaments it has each type of yarn. Table 3 shows classification of different types of Carbon Fibre according to the number (k) it has each bobbin.

The relationship is as follows, 1k corresponds to 1,000 filaments of Carbon Fibre. The most common type of fibre used in our tests is 12k, that is to say, 12,000 filaments in laminar form. The use of a type of fibre is a matter of price. 1k, 2k and 3k Carbon Fibre prices are higher than other types. Therefore, the use of them will have an extra cost.

Carbon Fibre is not compatible with resin. This means the fibre has to be prepared previously in order not to reject the resin. There is a sizing process consisting in coating the fibre to make it compatible with the type of resin to be used. We have used epoxi resin for our essays.

The best condition when handling Carbon Fibre is completely flat and stretched as the main drawback is corrugation.

Table 3. *Technical properties of the main Carbon Fibre filament yarns [5]*

Number of filaments 1k=1,000	Nominal linear density	Twist	Tensile Strength [MPa]	Tensile Modulus [GPa]	Elongation at break [%]	Ø [µm] Filament diameter	Density [g/cm^3] Z	Sizing	% Size level
1k	67 tex	15 S	3.950	238	1,7	7,0	1,76	EPOXI	2,5
2k	140 tex	2 de 15 S 300 Z	3.700				0,14 g/m		
3k	200 tex		3.950	238	1,7	7,0	1,76	EPOXI	1,3
6k	400 tex		3.950	238	1,7	7,0	1,76	EPOXI	1,3
12k	800 tex		4.500	240	1,8	7.0	1,77	EPOXI	1,3
12k	1.420 tex		2.750	215	1,2	7,5[1]	2,70	PU[2]	1,3

6. LAMINAR CARBON FIBRE STRUCTURES FROM UNDIRECTIONAL TOW

Design and fabrication of multilayered laminar structures [6] obtained from unidirectional tows and then cured in an autoclave are the reference material for any structural analysis. It consists of obtaining an isotropic carbon fibre structure able to resist strength from different angles along the axis of coordinates.

Figure 3 shows the distribution of different layers of Carbon Fibre according to the right orientation of each layer in order to obtain an isotropic design of the interlaminar structure. It can be seen it is a 7 layers structure following the configuration 0º, +45º, -45º, 90º, -45º, +45º, 0º

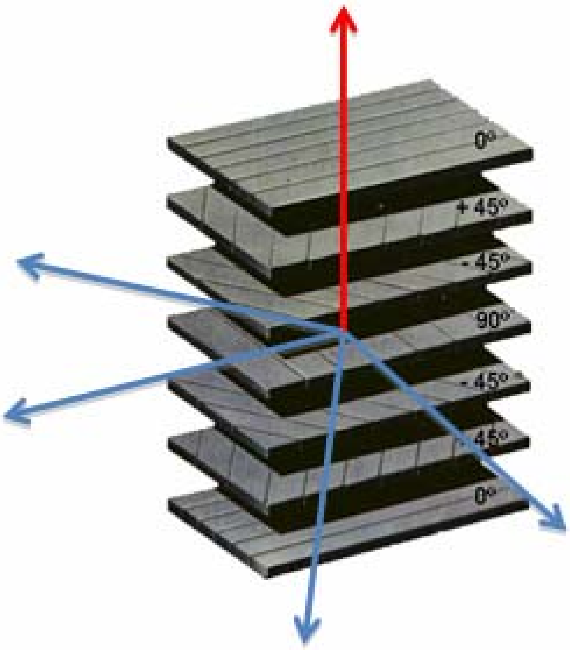

Fig. 3. *Carbon fibre 7 laminar layered structure and fibre orientation of each layer*

6.1. Advantages

- Maximum volumetric fraction
- Minimum fault occurrence: holes or fibre misalignment.

6.2. Disadvantages

- Uncomfortable handling. When placing unidirectional carbon fibre tows according to the structural design, crimps and wrinkles easily happen to appear. This drawback is known as low drapeability.
- Delamination happens when Z strength is applied on the structures. A structure as shown in figure 3 has a high resistance except when this is applied following Z direction. Therefore, it ha a low cross or transversal resistance. When delamination occurs, the fibre would break down as the pages of a book open.
- High cost of material and processing

7. CONCLUSIONS

The manufacture of complex three dimensional textile structures it is still in its starting stage with a high cost due to the amount of labour involved in the process.

Composites are the nowadays solution in the redesign process of aircraft in order to make them more efficient and with a lower consumption.

Carbon fibre is the most suitable material in the manufacturing of composites for the aeronautical sector. It has got higher tensile strength than other fibres.

Delamination is a disadvantage for carbon fibre laminar structures.

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