TEXTILE STRUCTURES FOR AERONAUTICS (PART II)

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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 second part of this paper deals with our know-how in the manufacturing and assessing of three-dimensional textile structures during this last five years in the field of textile structures for composites but also in the development of structures for other applications. In the field of composites for aeronautic sector we have developed textile structures using the main methods of textile production, that is to say, weaving, warp knitting, weft knitting and braiding. Comparing the advantages and disadvantages it could be said that braided fabrics, with a structure in the three space axes (+θº, 0º, - θº) *are the most suitable for fittings and frames.*

Key words: *3D, carbon fibre, fabric, woven, knitted, braided, stitching, tufting*

1. CARBON FIBRE STRUCTURES FROM A FABRIC [1], [2]

An objective of this paper is to examine different manufacturing processes of textile structures or fabrics in order to assess advantages and disadvantages of each manufacturing process. According to the technology used, figure 1 shows the different manufacturing processes.

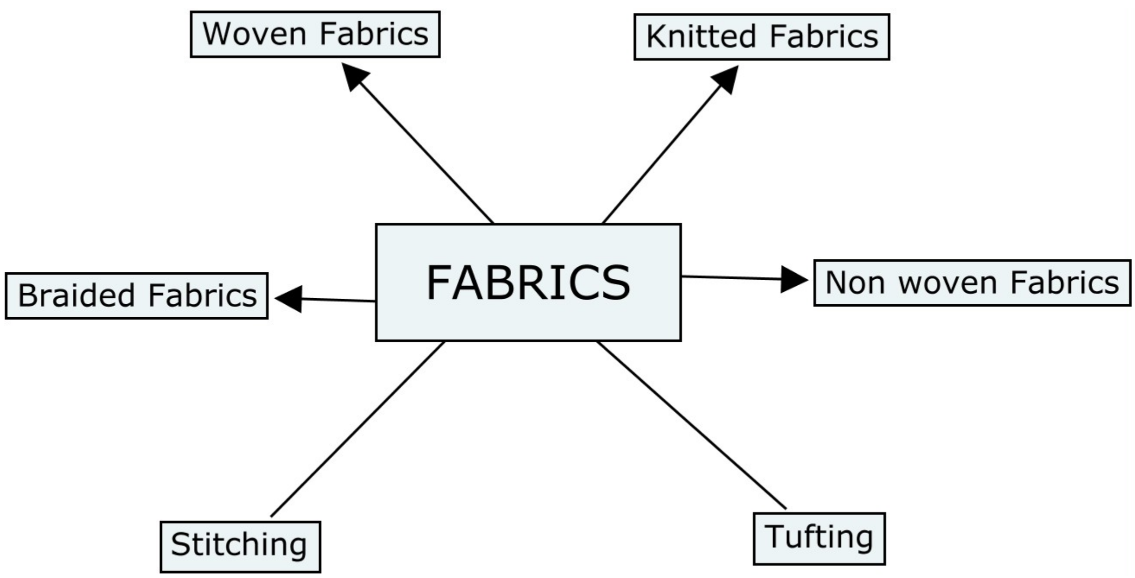


Fig.1. *Classification of textile structures*

Generally speaking fabrics [3] have advantages and disadvantages regarding to reference multilayered laminar structures.

Advantages:

- Easy handling.
- Some of fabrics avoid wrinkles and have good "drapeability".
- Hybrid fabrics can be designed.
- Possibility of combining fibre and matrix in the same fabric: Twintex® (fibreglass + polypropylene)

Disadvantages:

- The manufacturing process of a textile structure or a fabric implies the bending of carbon fibres (fig. 2). This can cause a large reduction of stiffness and tensile strength. They are less stiffness and strength than reference unidirectional laminar structures.
- Textile structures have got resin-rich areas (matrix) that automatically become weak areas. This is a type of defect with less strength of fatigue failure than reference unidirectional laminar structures.

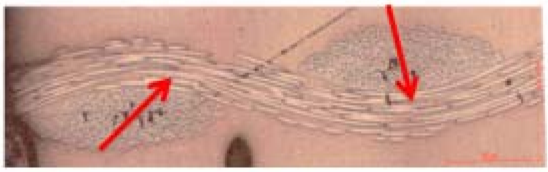


Fig. 2. *Fabric crimping*

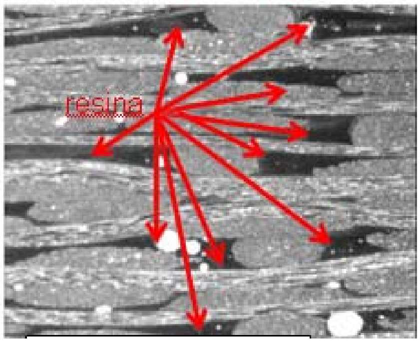


Fig. 3. *Resin-rich zone*

1.1. Woven fabrics [4]

Nowadays weaving is the most widely fabric manufacturing process to obtain carbon fibre textile structures usually through a plain weave fabric or satin weave fabric.

The construction technique consists of overlapping layers of woven fabric having different orientations according to spatial axes setting up a 2,5 D structure.

Advantages:

- Excellent tensile strength.

Disadvantages:

- Delamination when z direction force is applied.
- Low resistance to impact.

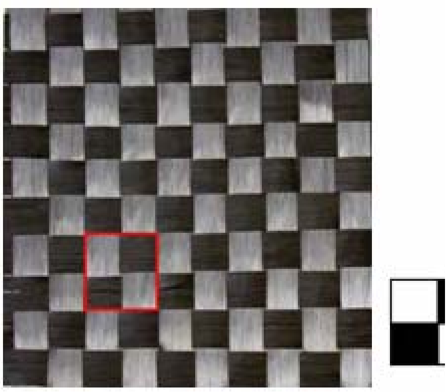


Fig.4. *Plain weave*

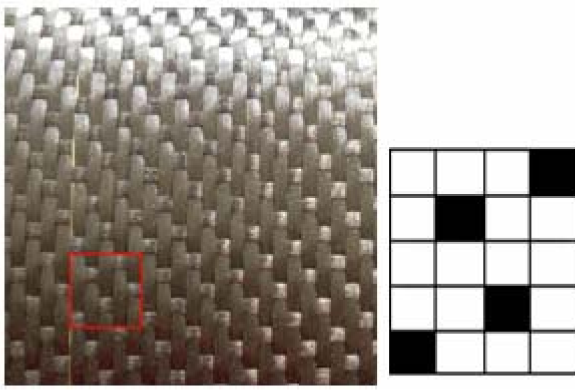


Fig. 5. *Satin*

1.2 Knitted Fabrics [5]

Knitted fabrics can be broadly classified into two groups: weft and warp knitted fabrics. Both of them are fibrous structures characterized by a basic structure called loop. Weft-knitted fabrics are obtained in courses from at least one yarn, while warp-knitted fabrics are produced in wales using a number of yarns identical to the wales to be formed.

As I told above, the bending of carbon fibre is a shortcoming for textile structures. When loop formation is produced carbon fibre bends, so that the use of knitted fabric structures to produce composites with carbon fibre is a disadvantage.

1.2.1 Weft-knitted fabrics

Weft-knitted fabrics are usually used to protect woven or reference fabrics against impact because weft-knitted fabrics have elastic structures suitable for impact attenuation.

Advantages:

- Higher impact damage tolerance.

Disadvantages:

- When loops are formed a high percentage of carbon fibre filaments breaks or fails.
- The outer layer appearance does not show impact. However structural breakages and damages can be observed in inside layers.

a) b)

Fig. 6. *Weft-knitted structure a) and carbon fibre weft-knitted fabric b)*

1.2.2 Warp-knitted fabrics

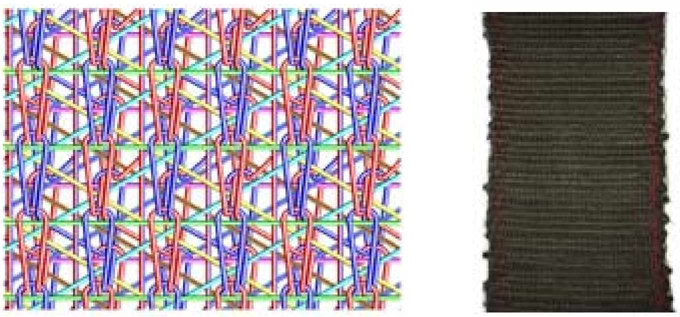
2,5 D fabrics can be obtained trough warp-knitting technique as yarn orientation at 0º, 90º, +45º and -45º.can be inserted.

Advantages:

- Multilayer structure interlocked by stitches can be produced.

Disadvantages:

- When loops are formed a high percentage of carbon fibre filaments breaks or fails.
- Warp-knitted mechanical properties are quite lower when compared to multi-ply reference fabric.



a) b)

Fig. 7. *Warp-knitted structure a) and carbon fibre warp-knitted fabric b)*

1.3 Stitched bonded fabrics

Production technique used to obtain 2,5 D fabrics with yarn insertion at 0º, 90º, +45º and -45º and then fabric layers are bonded by tricot stitching.

Advantages:

- Multilayer structure interlocked by stitches or seams can be produced.

Disadvantages:

- When loops are formed a high percentage of carbon fibre filaments breaks or fails.
- Resin rich areas where interlaminar breakages are produced.

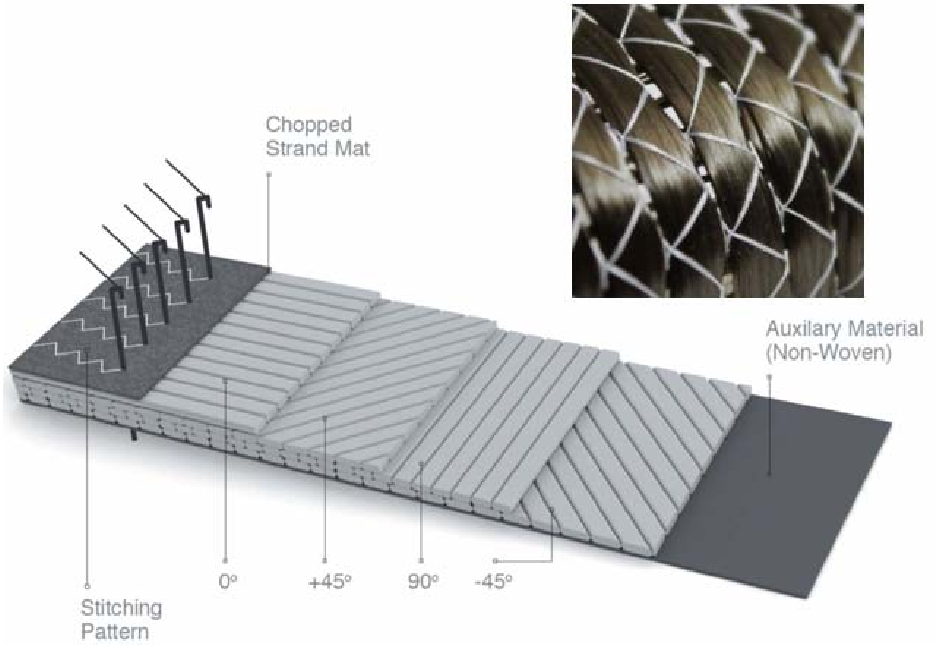


Fig. 8. *Stitched bonded fabric and stitching pattern*

1.4. Tufting Fabrics [6]

Manufacturing process completely excluded when producing carbon fibre composite fabrics, as tufting is used for the production of pile structures or artificial grass green applications.

Fig. 9. *Tufting machine and production system of tufting fabric (left). Tufting fabric for artificial turf.*

1.5 Non-woven fabrics + embroidering.

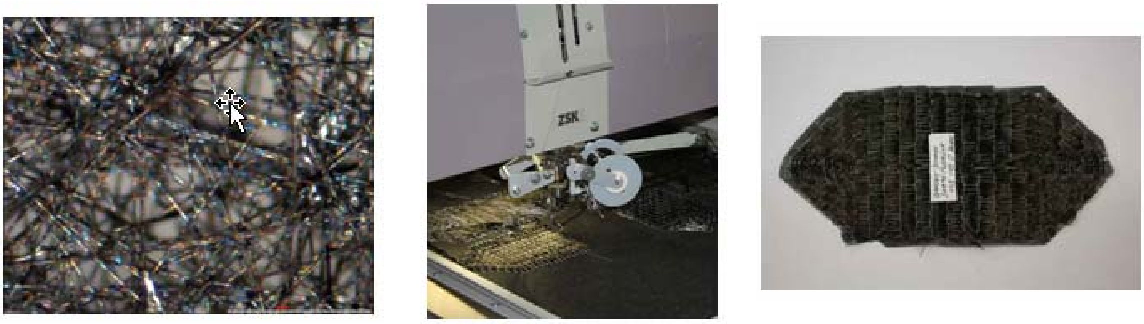
A non-woven fabric would not be a preferred structure for the production of composite material for aeronautics. However, when a non-woven carbon fibre structure is used as a ground base of an embroidered carbon fibre structure conditions change.

Advantages:

- Multilayer structure interlocked by seams can be produced.

- From the beginning to the end the embroidered structure is made using the same carbon fibre yarn.

Disadvantages:
- High percentage of carbon fibre yarn breakage when making a multilayer structure.
- Carbon fibre can not be used as a sewing thread.



a) ***b)*** ***c)***

Fig. 10. *Non-woven carbon fibre fabric a). Embroidery machine head embroidering carbon fibre b). Carbon fibre embroidered multilayer fabric piece c)*

1.6. Braided fabrics [7]
Triaxial braided structures suit perfectly to the needs of aeronautic sector.

Advantages:
- Triaxial compact structures (+θº, 0º, - θº)
- Production of coated structures (core) through triaxial fabrics.

Disadvantages:
- With a regular core, the angle remains at position. However when core diameter varies, carbon fibre angles change so critical points occur as triaxiality (+45º,0º,-45º) can not be maintained.
- Carbon fibre yarn width is not regular through the braided structure.

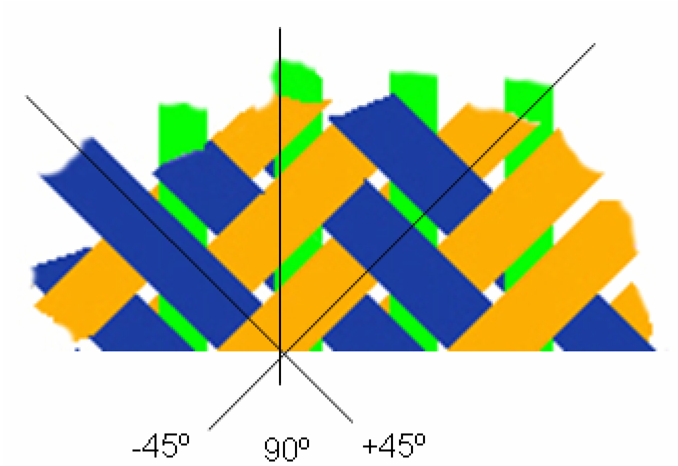
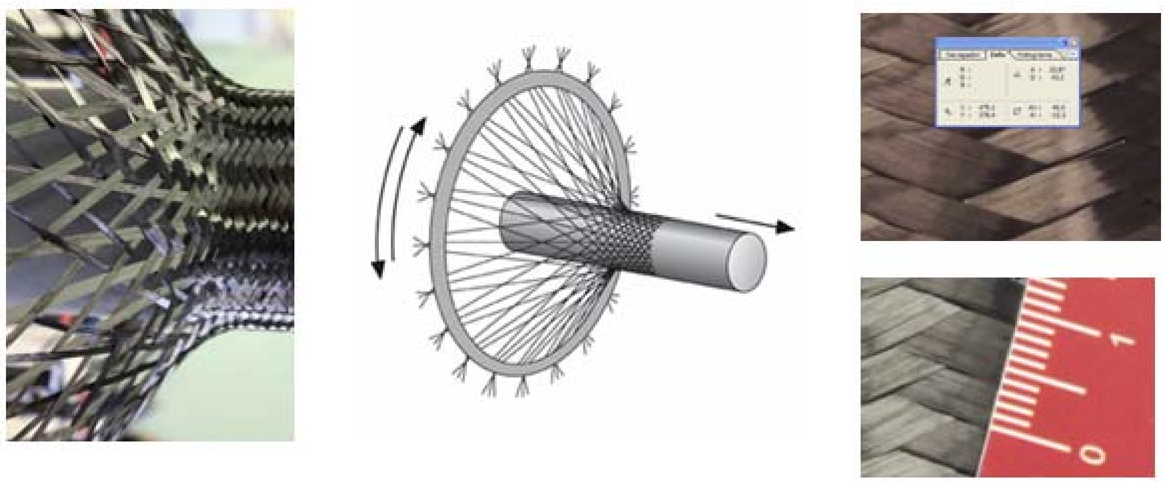


Fig.11. *Triaxial braided structure graphic display*



a) ***b)*** ***c)***

Fig. 12. *Carbon fibre braided structure a). Braider outline with core b). Carbon fibre angle variation and width variation in a braided structure c)*

2. CONCLUSIONS

Our Research Textile Centre has manufactured and assessed three-dimensional textile structures within several projects using the main methods of textile production, i.e. weaving, warp knitting, weft knitting and braiding.

Braided Fabrics are the most suitable fabrics for the manufacturing of frames and fittings. Braided fabrics can be triaxial, and this three-dimensional structure suits perfectly to the needs of aeronautic sector. Triaxial fabrics grow its structure in the three space axes (+θº, 0º, - θº). However this structuture has also the shortcoming of delamination.

Textile industry should continue to investigate and improve models in order to offer new and better solutions to aeronautics sector. The main challenge is overcome delamination.

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