New developments in the field of NCF technology – Current status and their use in new applications

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ABSTRACT

An analysis of the possibilities of near net-shape NCF preforms shows the potential of offering a vast variety of constructions and tailored reinforcements, but also a way for cost savings and production efficiency. With the goal to produce fabrics of highest quality to the specifications and design of its customers, SAERTEX provides an important step in an innovative solution for advanced composite structures with improved mechanical and stiffness properties. The end result is a light-weight solution with significantly reduced manufacturing cost.

SAERTEX has realized a number of innovative developments exclusively or with partners. One specific example is the SAERtow technology, which has enabled access to new markets and product applications. Using this advanced process to increase product quality when spreading and processing large tow yarns; SAERTEX was able to qualify Carbon-NCF within the automotive industry for highly stressed parts. This market penetration was achieved due to this breakthrough technology, as well as a steady improvement of machine and process technologies and an optimization of the productivity of the machines and processes for high volume production.

Supplementary value adding processes developed for a variety of markets include cutting of tapes or kits, coating of NCF products and the development of image processing for quality assurance purposes.

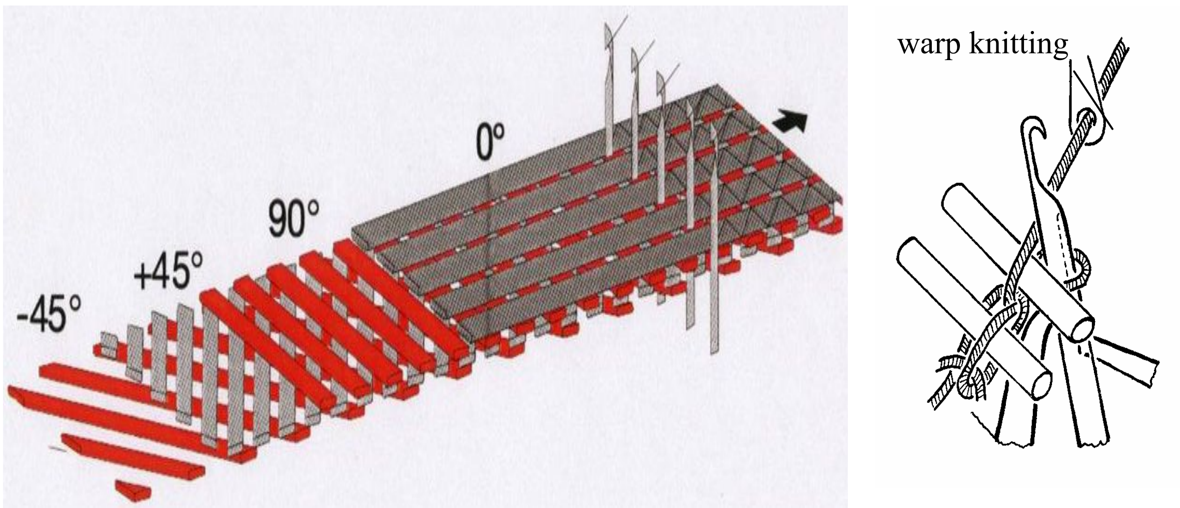
1. INTRODUCTION

Multi-axial, multi-ply fabrics, better known as Non-Crimp Fabrics (NCF) have been used successfully in a wide variety of fiber reinforced plastics for approximately two decades now. The biggest markets are the wind energy, marine and sports industries, as well as transportation and infrastructural applications. The use of NCF in the aircraft industry is also steadily growing.

The market share of these fabrics has increased significantly during the last years compared to other textile reinforcement structures. Nevertheless, there are numerous applications and potential markets where NCF are not used yet, which is – apart from other reasons – due to the lack of knowledge about the specific properties of these fabrics and their impact on design, production and possible financial benefits for the end-producer.

2. Non Crimp Fabrics – Standard and State of the Art

The principle of the NCF technology is shown in figure 1. Typically multi-axial fabrics consist of one up to 5 plies of straight and parallel yarn layers. Each yarn layer can be individually oriented according to the calculated mechanical load. Most common are the angles 0°, 90° and –45° respectively +45° in correlation to the production direction. The whole stack of layers is fixed by warp knitting yarns.



(source: LIBA, Naila) (source: Karl Mayer, Obertshausen)

Figure 1: NCF-technology

The advantages of the multi-axial fabrics over other types of textiles like woven fabrics can be summarised as follows:

- Straight yarn orientation without the typical crimp of woven fabrics. The mechanical properties are superior as a result of that.
- Numbers of plies and orientations can be chosen by the designer. In civil engineering UD-fabrics (just 0°-orientation), bidirectional (90°/0°), bidiagonal (-45°/+45°), triaxial (-45°/0°/+45°) and quadraxial (-45°/90°/+45°/0°) will be the most common styles.
- The grid size down to a closed surface can be chosen very free.
- The fixation of the yarns can be chosen by use of different warp knitting styles without any kind of chemical binder as necessary with woven fabrics for grids. The drapeability can be designed from low to high as a result of that.

Modern SAERTEX processing technology allows the angles of the single layers to each other to be varied between 90° and 22°, with an additional 0°-ply. At the same time one is free to choose the material or a combination of different materials for every individual layer, as well as their amounts. This freedom of textile design makes it possible to introduce the right amount of reinforcement material exactly in the direction where it is needed which can considerably reduce the weight of the end part as no unnecessary material is added.
Comparing the tensile strength of multiaxial non crimp fabrics with woven fabrics shows a 20 – 30% increase in tensile strength. Similar results of about 20% higher values are approachable for the tensile modulus (see figure 2).

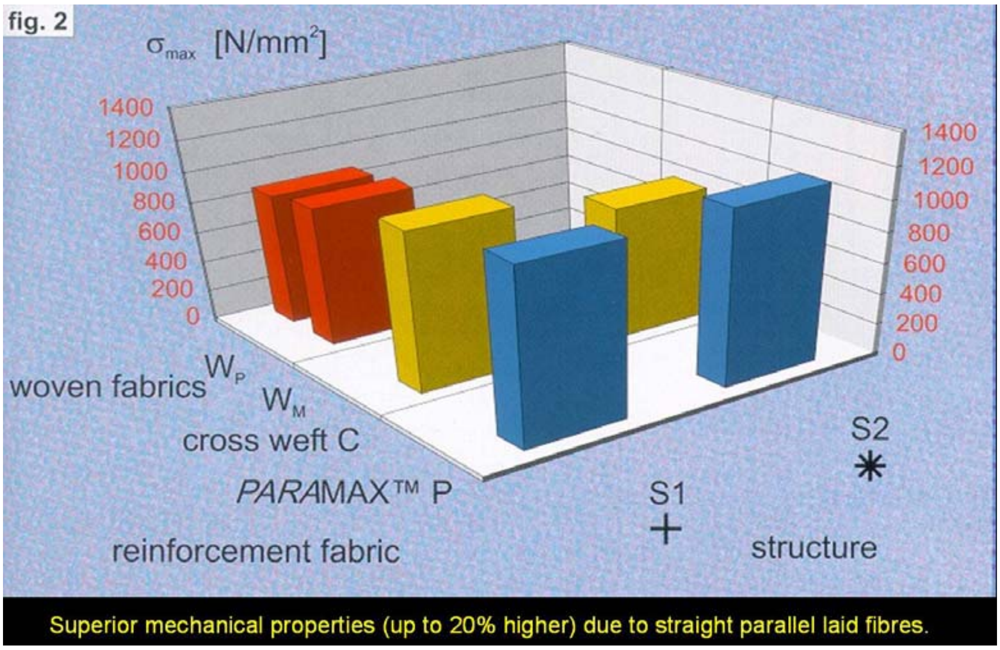


Figure 2: Comparison of the mechanical properties of wowen (red), cross weft (yellow) and multiaxial non-crimp fabrics (blue) [Lit. 2]

Reason for this result is the crimp induced by the weaving reinforced yarn. The tested NCF-materials are produced on a LIBA machine as shown in figure 2.
The relative orientation of the single fibre layers to each other can be precisely defined.
The freedom of design that comes with this state-of-the art manufacturing technique offers the possibility to produce a multitude of different reinforcements, as e.g. unidirectional fabrics (1 ply,), bidirectional fabrics (2 plies), quadraxial fabrics (4 plies,, and even pentaxial fabrics (5 plies,).
The number of axis used is determined by the application and it´s requirement for reinforcement in any one direction. For example a wing skin requires a four axis quadraxial material containing predominantly 0° and ± 45° fibres and some 90° to provide chordwise stiffness primarily where a structure must withstand bolt bearing loads [Lit. 3]

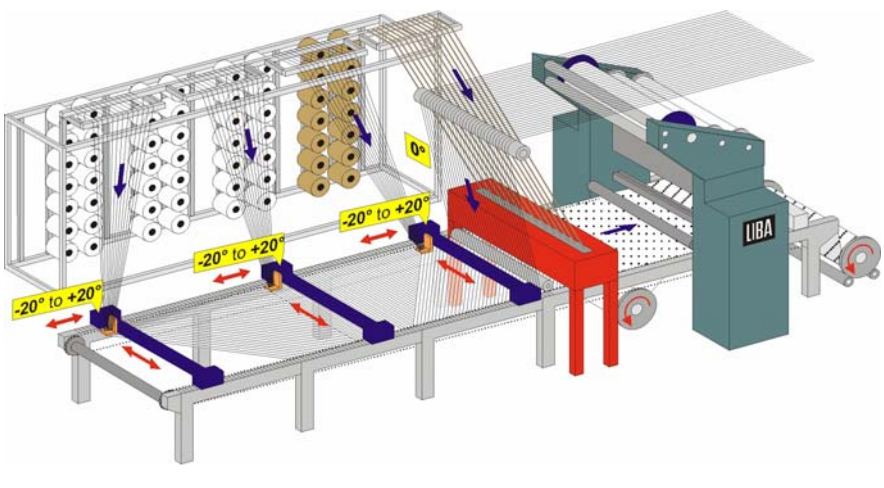


Figure 3: Typical computer controlled LIBA NCF machine

Another advantage of multi-axial fabrics is that the lay-up sequence is shortened significantly, as several reinforcement layers are positioned into the mould in one step. This saves time, enhances productivity and reduces costs. The unbent threads of non-crimp fabrics shows a higher fibre density, as the threads are lying flat on top of each other and are not interlaced as in woven fabrics. The minimized space between the fibres reduces the resin consumption. The consequences are reduced resin costs, reduced part weight and a higher fibre volume fraction which means better mechanical properties of the laminate.

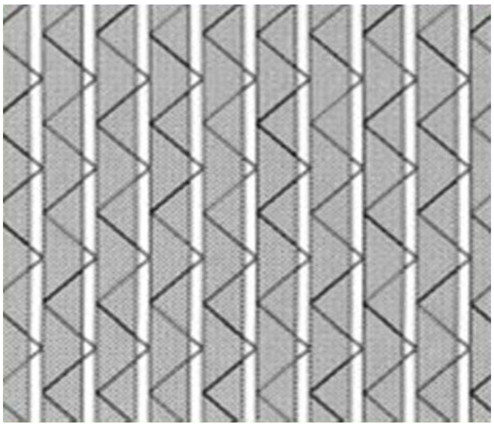


Figure 4: Unidirectional fabric

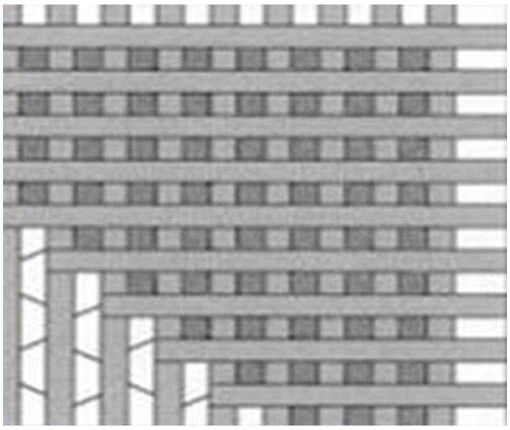


Figure 5: Bi-directional fabric

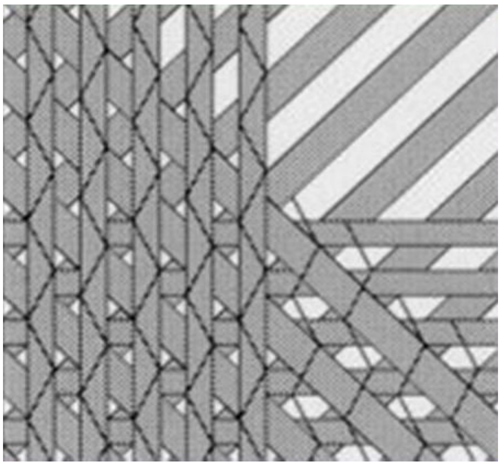


Figure 6: Quadraxial fabric

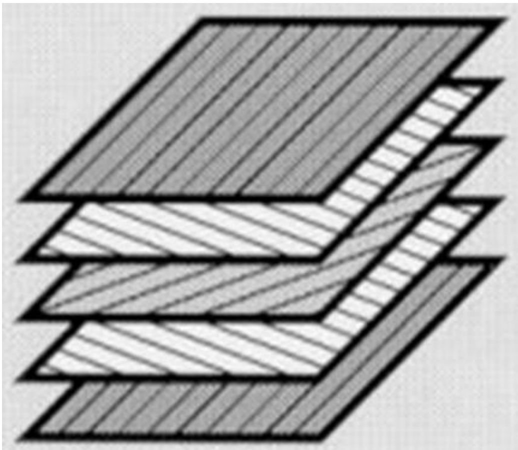


Figure 7: Pentaxial fabric

Furthermore, it is possible to control the drape of a multiaxial fabric, its ability to adapt to complex geometries, by varying the tension of the stitching thread and stitching pattern.

In addition to that, modern fabrication technology allows for combination of other materials with multiaxial NCFs, like a veil, a self-adhesive binder to keep a fabric in position or a thermoplastic binder to manufacture preforms.

3. SAERtow Technology

The reasons why the use of NCFs and their combination with other materials (e.g. a core) has been permanently growing are their outstanding properties and the possibility to customise them to the needs of individual applications where high strength and low weight are required.
But to produce a material with better mechanical properties is not enough. It is necessary to improve the general properties of the material, the production process and the economic basis for the customer. For the realization, SAERTEX developed the SAERtow product with the objective of offering end users (automotive and aerospace sector) high quality fabrics with no compromise. SAERtow (**t**ow **o**ptimized **w**eight) is a new product family. This material is the output of a new, innovative SAERTEX production technology.

The SAERtow technology is able to improve all named points as follows:

- <u>Improvement of the material</u>
  - the ply areal weight can be reduced down to 75 g/m² (HT-carbon fibres) and 100 g/m² (IM-carbon fibre)
  - with these reduced areal weights it is possible to realize closed surfaces
  - the fibre placement and fibre alignment is more accurate (see fig 7a and 7b)

Fig. 8a: Conventional NCF with 6K / 12 K

Fig 8b: SAERtow NCF with 12K/24K

- <u>Improvement of the production process</u>
  - for the realization large tow fibres (≥ 24K) can be used in the SAERtow process

- <u>Improvement of the economic basis for the customer</u>
  - with the spreading of the fibres there is a very efficient way for the usage of the material possible
  - large tow fibres are generally more cost efficient
  - production of tailored material is possible in a range of 50” to 100” (1,27 m to 2,54 m) and every width in-between

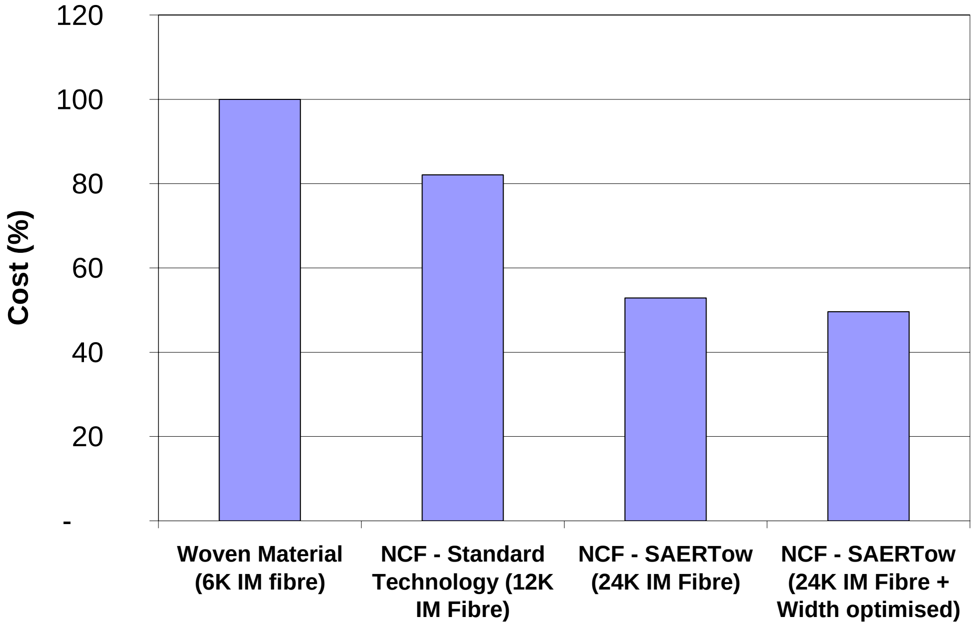


Figure 9: Cost Comparism between Standard technology and SAERtow

With this new technology, it is possible to offer the end user a cost advantage compared to the standard process. In figure 9 a standard woven fabric on basis of 6K-IMS-fibre is compared with a standard NCF based on 12K-IMS. With this fiber a cost reduction of about 20% is possible. If the same style will be produced with a 24K-IMS fiber under optimized conditions with the SAERtow process, the price of the material can be reduced up to 50% (compared with the woven carbon fabric).

The development of the SAERtow machine technology and the resulting material is a good example where requirements at the beginning of a project were viewed as unattainable and in close coordination with the customer solutions for all problems were found. The process and the material are qualified in accordance to the general requirements of the automotive industry. The approval for the aerospace industry is actually in progress.

4. Further work to accelerate insertion of NCF materials in Aerospace

For a further opening of the market for NCF-materials it is not sufficient to realize the described improvements of the properties of the material and the production process. There are different options, where the manufacturer and the end user will get significant simplifications and improvements. As example in the following two subject areas are listed in which SAERTEX currently works:

- <u>Automated / in-line NCF material quality inspection methods</u>
  In the aerospace market defects in the fabric (gaps, fuzzballs, etc.) could be a security risk. From there it is not only for the safety very important to detect these defects in the production process of the fabric. The difficulty at this is to develop the stated new technology (with reduced areal weight) taking into

consideration that it will be more and more sophisticated to fulfil the established defect criteria.
An automated / in line quality inspection of NCF material during the production process would be very helpful for the producer and the end-customer. First tests for the analysis of the surface regarding fibre orientation, gaps or fuzz balls are done (see fig. 10). The results are published [Lit. 4]. Target for SAERTEX is to realize an automated quality control system in the production process.

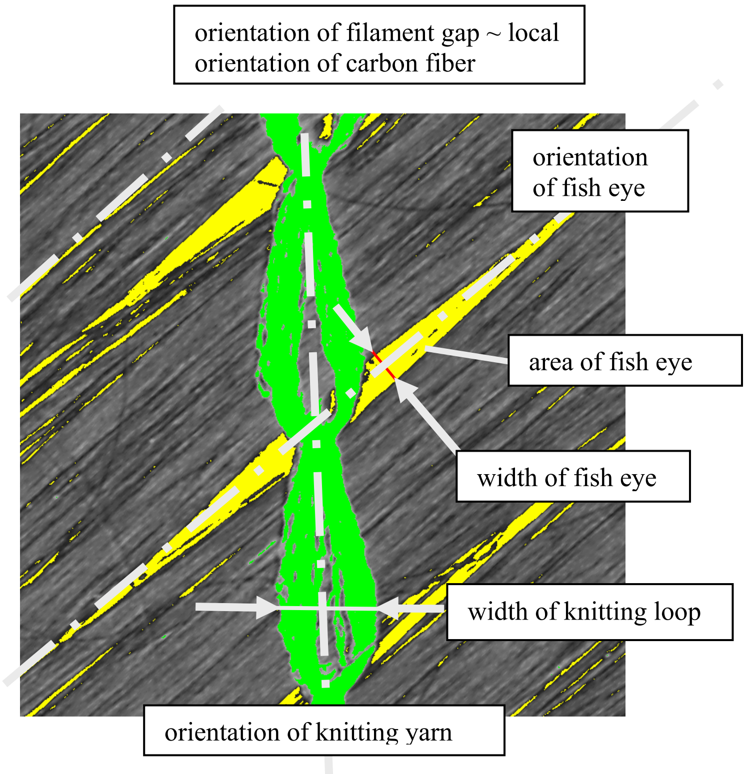


Figure 10: Detailed picture of an analysed NCF

- <u>Powdering of NCF / development of a tape production process</u>
  Powder binder will be used on the surface of fabrics. For preform production it is necessary to use the powder as a fixation. This fixation can also be used for the production of small tapes down to 20 mm. Stabilized tapes with small width are necessary for automated production of profiles.
  First it is for SAERTEX important to develop a series process for the production of small tapes with different widths in one step based on a master roll. Second step will be an automated generation of a defect report for every individual roll.

SAERTEX is involved in several projects and is in direct contact to customers of the aerospace and automotive industry to support such developments with the target to use the obtained know how in the future.

REFERENCES

1- Horsting K., Wulhorst B., Franzke G., Offermann P., New Types of Textile Fabrics for Fibre Composites, SAMPE Journal, Volume 29, Number 1, January / February 1993.
2- PARAMAX committee (www.iparamaxc.com)
3- Backhouse R.; Multiaxial Non Crimp Fabrics: characterisation of manufacturing capability for composite aircraft structure applications, *Eng. D. Thesis*, Cranfield University, School of Industrial and Manufacturing Science
4- M. Schneider, K. Edelmann, U. Tiltmann, Quality Analysis of Reinforcement Structures for Composites by Digital Image Processing. SAMPE 2004