MULTIWEAVE, MULTIDIRECTIONAL WEAVING FOR TECHNICAL APPLICATIONS

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Abstract

Technical textiles are products for applications where mechanical performance is the more important factor, namely in the reinforcement of composite materials for technical applications. The possibility of reinforcing along more than the two conventional directions is of paramount importance in a large number of applications, namely aircraft fuselages, boat hulls, etc. A multidirectional fabric is particularly suitable for situations requiring shape stability when submitted to simultaneous loads in multiple directions. The objective has been a 2D woven structure obtained by the interlaced insertion of yarns along bias directions at approximately 45° between the warp and weft. A multidirectional weaving system has been investigated, designed and developed comprising the following systems: warp feeding, bias yarns feeding and criss-cross insertion, shedding, incorporating one heddle, weft feeding and insertion, beating-up, incorporating the reed, taking-up and winding. The final solution incorporates the use of conventional weaving elements as well as completely new mechanisms or modifications of existing ones. The main result is the Multiweave development prototype whose working principal will be explained in the paper and is being used to produce different types of Directionally Oriented Structures, using various types of fibres (HT polyester, aramid, carbon and glass) and yarn counts.

Keywords: Technical textiles, Multidirectional weaving, MULTIWEAVE

Resumo

Têxteis técnicos são produtos para aplicações onde o desempenho mecânico é o factor mais importante, nomeadamente no reforço de materiais compósitos. A possibilidade de entrelaçar segundo mais que as duas direcções convencionais é de importância decisiva num grande número de aplicações, nomeadamente fuselagens de aviões, cascos de barcos, etc. Um tecido multidireccional é particularmente apropriado para aplicações que requerem estabilidade de forma quando submetido a solicitações simultâneas em múltiplas direcções. O objectivo foi uma estrutura de tecido 2D obtida pela inserção de fios entrelaçados segundo direcções a aproximadamente 45° entre a teia e a trama. Um sistema de tecelagem multidireccional foi projectado e desenvolvido, constituído pelos seguinte sistemas: alimentação de fios de teia, alimentação, inserção e entrelaçamento de fios diagonais, formação da cala, incorporando um liço, alimentação e inserção da trama, mecanismo de batimento, incorporando o pente, extracção e enrolamento do tecido. A solução final incorpora o uso de elementos convencionais da tecnologia de tecelagem mas também mecanismos completamente novos ou versões modificadas de sistemas existentes. O principal resultado é o protótipo Multiweave cujo princípio de funcionamento será explicado e que está a ser utilisado para produzir diferentes tipos de Estruturas Direccionalmente Orientadas, usando vários tipos de fibras (Poliéster de alta tenacidade, aramida, carbono e vidro) e de fios.

Palavras-chave: Têxteis técnicos, Tecelagem multidireccional, MULTIWEAVE

1. Introduction

Several efforts to produce multidirectional interlaced fabrics have been made in the past. A number of European patents have described the tetraxial [1-3] and multiaxial [4-5] structures and machines for their production. Those patents propose different solutions for the problem of bias yarns feeding and criss-crossing, but none has proved to be sufficiently good for the construction of either a reliable neither a commercial multidirectional weaving machine. Following some earlier work [6], a new multidirectional woven structure and the respective manufacturing process have been developed. This kind of fabric is designed to boost the reinforcement in bias directions by the insertion of interlaced yarns between the weft and the warp.

One of the most important characteristics of technical textiles is the possibility of providing specific strength in multiple directions. This necessitated the development of multidirectional and tetraxial fabrics. The use and impact of the multidirectional fabric may be found in two different types of products, namely:

- Technical textiles, such as composites for car and aircraft industry, conveyor belts, inflatable boats, sails, boat hulls, air inflated houses, geotextiles, wall coverings, sport devices, tarpaulins, tents, grinding and lapping disks and for many other applications on products that still use traditional technology of gluing together several layers of fabrics, differently oriented; and
- Garments designed to be tear resistant, with an original texture, easily conformable and dimensionally stable. They can be used for very different articles, such as military and protective clothing. Although the application on conventional clothing looks considerably out of the way, the possible applications on tennis and other sports shoes and some sportswear need to be further explored.

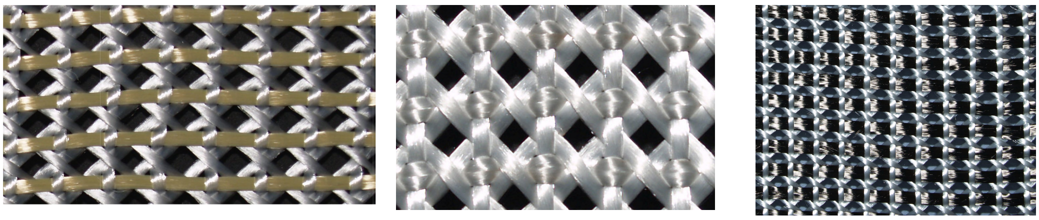
2. Materials and methods

2.1 Materials

Fabric samples of different fibres were prepared using the Multiweave prototype. The fabric details are given in Table 1 and the respective samples are represented in figure 1.

Sample №	Warp	Bias	Weft
1	PES 1100/2 dtex	PES 1100/2 dtex	Aramid 2200 dtex
2	PES 1100/4 dtex	PES 1100/4 dtex	PES 1100/4 dtex
3	PES 1100/2 dtex	PES 1100/2 dtex	Carbon 800 Tex

Table 1. Composition of Multiweave fabric samples.



Sample 1 Sample 2 Sample 3

Figure 1. Multiweave fabric samples.

2.2 Methodology

2.2.1 The model

A multidirectional woven fabric can be obtained by interlacing 4 sets of yarns, the warps (blue), the wefts (green) and other two sets of bias yarns at +45° and -45° (red) as is represented in the model of figure 2.

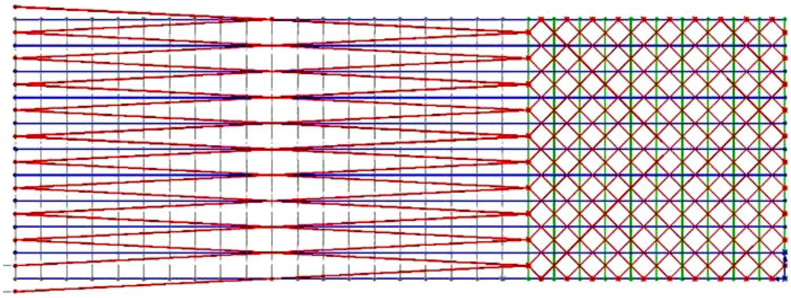
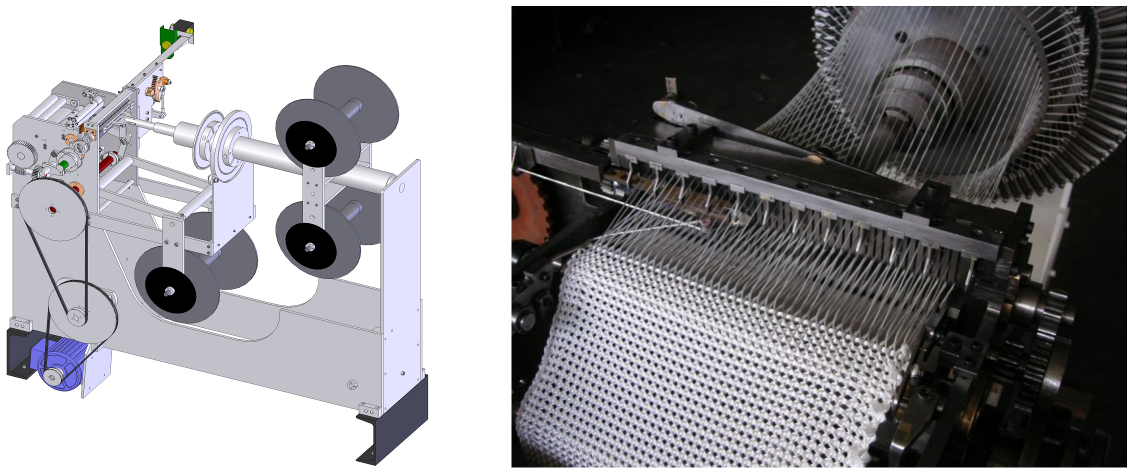


Figure 2. Geometric model of a multidirectional woven fabric.

2.2.2 The development prototype

The main specifications for the design of the limited scale multiweave development prototype were established according to the available technical capabilities. The resulting multiweave machine, whose assembly design is shown in Fig. 3 (a), comprises elements such as bias yarns feeding system, mechanism for the criss-cross insertion of the bias yarns, warping system, shedding system incorporating the heddle, weft insertion system, beating-up mechanism incorporating the reed and fabric taking-up system. A detail of the fabric formation area is shown in figure 3 (b), where the shed, the weft insertion needle, the special heddle at the upper position and part of the bias yarns feeding system are shown.



(a) (b)

Figure 3. (a) Multiweave assembly design and (b) multiweave prototype showing the fabric formation area

2.2.3 Working Principle

The bias yarns are inserted from the bias beams through a tension compensation device with a step wise movement in two very close parallel layers in opposite directions by means of an appropriate mechanism. The heddle and the reed are in their lower and backward positions, out of the plane of the bias yarns, allowing their free criss-crossing. The heddle rises forming the shed and the warps interlace with the bias. The shed is formed between the warp and the two very close parallel layers of the bias yarns. A first (false) beating takes place to clear the shed; this is found necessary due to the reason that when the warp yarns are raised by the heddle, they are partially held up by the criss-crossing effect of the bias, preventing from obtaining a clear shed. The weft yarn is then inserted, interlaced with the warps and the bias yarns as shown in Fig. 4; a second (real) beating operation takes place which compacts the fabric at the same time when the heddle moves down to its rest position closing the shed and holding the weft. The taking-up mechanism advances one step and the fabric is wound-up.

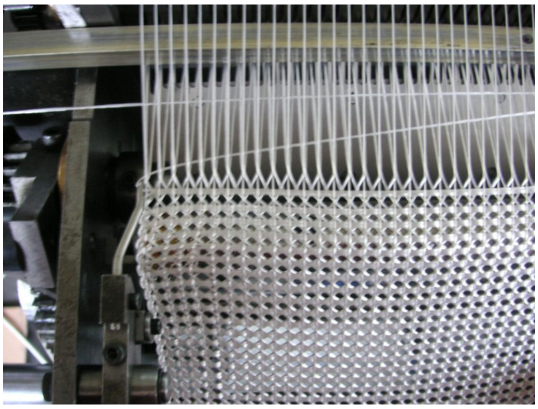


Figure 4. Multiweave – detail of shed and weft insertion.

During the development process, all synchronization has been achieved mechanically to help getting a working prototype faster. Therefore, all movements are mechanically driven from a main shaft with the help of cam and intermittent mechanisms. With all the mechanical systems sufficiently developed, the required torque in the main shaft could be measured. Consequently the most important decisions, such as choosing the driving motor and the frequency inverter, were made. The control system is based on an ARM MCU microcontroller board with embedded software designed to control the motor, detect emergency stops using sensors and interface with users. The main functionalities of the control system include broken weft, warp, bias yarns detection; strained weft detection and speed regulation. The main user interface options includes: Total fabric produced, fabric produced since the machine was turned on or the last counter reset, average speed (mm/s) since the machine was turned on since the last counter reset, motor's main shaft speed in rpm, number of emergency stops, total emergency's down-time and programming a certain amount of fabric production.

2.2.4 Testing

As there are no standards available for multidirectional fabric testing, a new procedure needs to be developed in order to test the mechanical properties of the Multiweave fabrics. Therefore, conventional strip and grab tensile tests were carried out.

3. Results and Discussion

Figure 5 shows the typical tensile behaviour for 1100/2 HT polyester Multiweave fabric (sample No. 2). This multiweave sample shows a quite anisotropic behaviour once the mechanical parameters vary according to the tested direction. As expected, due to the double weft insertion, the sample gives higher tensile strength in the weft direction. Grab tests or force-elongation tests for Multiweave sample comprise the following observations:

(i) Weft, bias and warp yarns show a similar behaviour, which is typical for a woven structure;

(ii) (ii) Differences in the graphs are mainly due to the “double weft” or the different materials used, and (iii) the weft always seems to be less crimped than the warp or bias.

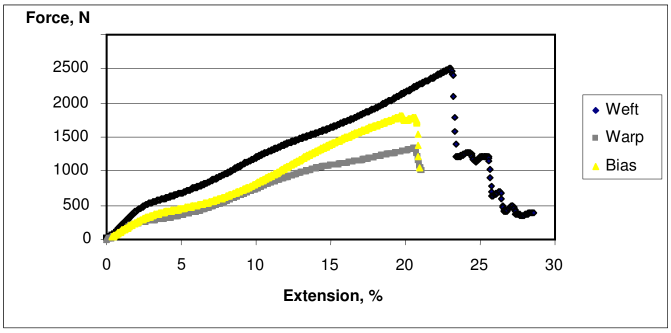


Figure 5.Typical tensile grab test on sample No. 2.

Figure 6 compares the tensile behaviour in the weft direction for different materials, such as carbon, aramid (Kevlar®) and polyester. As expected, the carbon exhibits the higher tensile strength, followed by aramid, and then polyester. On the other hand, polyester exhibits the higher elongation, while aramid the lower one.

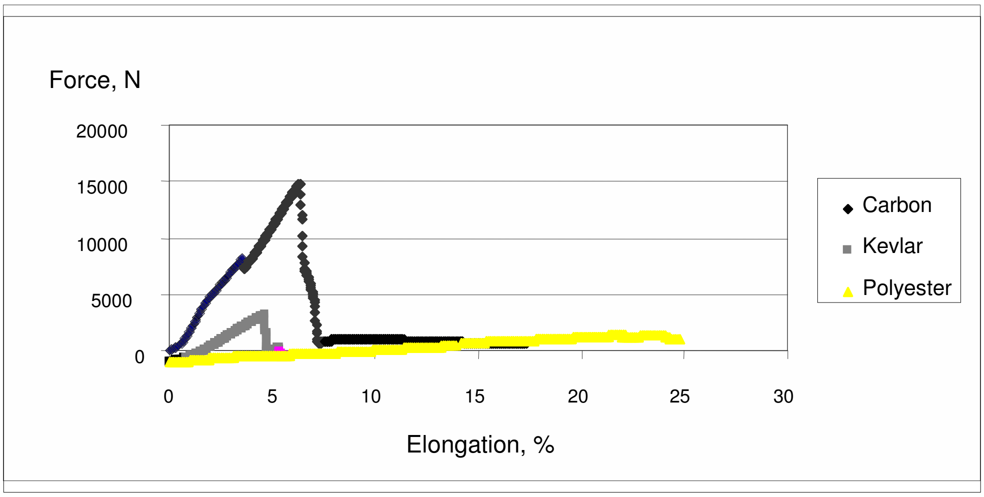


Figure 6. Typical tensile behaviour in the weft direction for different materials.

To keep the multidirectional structure fixed and to produce a first multidirectional composite, a Multiweave fabric has been laminated in a polyester resin. It is observed that if both fabric and resin are made of the same material the fabric structure does not change.

Figure 7 compares the tensile behaviour of laminated and non-laminated Multiweave 1100/2 HT polyester fabric. As it can be observed the maximum applicable force is approximately ten times higher for the laminated sample than that for the non-laminated one. While the resin can only compensate shear stress, tensile stress is compensated by the fabric structure.

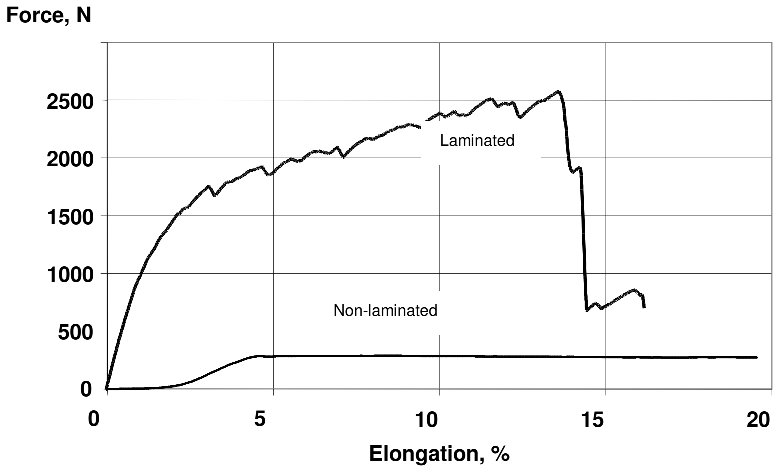


Figure 7. Typical tensile behaviour for 1100/2 HT polyester, laminated and non-laminated.

4 Conclusions

The Multiweave concept was embodied in a development prototype which proved its feasibility. The design of newly developed multidirectional weaving system is concerned with the characteristics of the fabric structure, where there is criss-crossing between all sets of yarns, which increases the capability for supporting more severe mechanical loads without failure, namely without delaminating. Simultaneously, the strength-weight ratio is expected to increase, which can be very advantageous for applications such as in the aircraft and car industries. Other important application areas are marine textiles, such as composites for boat and ship building, which are the products having severe stressing conditions. The main result is the multiweave prototype which is being used to produce different types of DOS, directionally oriented structures, using various types of fibres (HT polyester, aramid, carbon and glass) and yarn counts.

The present limited scale development prototype is observed as a learning tool from which much know-how be acquired. Some mechanisms and details need reviewing and optimisation. However, some aspects need to be identified, e.g. while moving to a larger fabric width (500 mm or 1000 mm), extra problems will be raised by the extra complexity of the bias yarns feeding system and the fabric being produced presents a structure which is not yet very dense, mainly due to the limitations imposed by the relatively high bias pitch, hence more research and development is required to find out the appropriate solutions. The industrial importance of this study is expected to be exploited by the technical textiles sector, mainly in textile reinforced composites for high technological applications, replacing, with advantages, the existing technique of using several layers of fabrics, differently oriented, to achieve a higher isotropic behaviour.

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