IMPROVED WARP KNITTING MACHINE FOR SYMMETRIC MULTI-PLIES

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Keywords: *stitch bonding, warp knitting, multiaxial multi-ply*

Abstract

Stitch bonded multi-plies are broadly used in the technical textiles sector. One of the main fields of application is the reinforcement of composite materials. For this they offer versatile properties and several advantages compared to other technical textiles, for example high productivity of the manufacturing process and the possibility to combine different layers, such as threads, nonwovens or glass mats, in one multi-ply. Focus of the research described in this paper is on further improving the usability of the stitch bonding process by adding new functions and abolishing existing restrictions.

These improvements are exemplified through the warp offset and the needle shift techniques, both aimed at broadening the range of applications of stitch bonded multi-plies by offering the customer free choosing of the make-up of the fabric.

1 Introduction

Since the beginning of the 1980s, the Institute of Textile and Clothing Technology (ITB) at Technische Universität (TU) Dresden has been developing load-adapted reinforcement textiles for composites. In the center of this development has been the stitch bonding technology, also called “Malimo” technology after the company that first produced such machinery in the 1950s.

Stitch bonded fabrics are produced on special warp knitting machines (see example in Figure 1). These stitch bonding machines use the stitching thread of the warp knitting process to combine layers of threads, nonwovens or films to multi-plies. Stitch bonded fabrics are used in various fields of application, of which composites is an important part. In this sector they compete against products from several other textile and non-textile manufacturing processes.

Fig. 1. Stitch bonding machine 14024 Karl Mayer Malimo

Comparing the variety of 2-dimensional reinforcements for composites it becomes obvious that the potential fields of application of these structures partly complement each other, but partly also overlap. Chemically bonded multi-plies offer the advantage of good activation of the strength of single filaments within the fabric. Only warp knitting machines can combine layers of threads with load-adapted fiber orientation and scores of other layer materials. Weaving may be more cost-effective for the production of biaxial structures, but that depends on the application and the production volume.

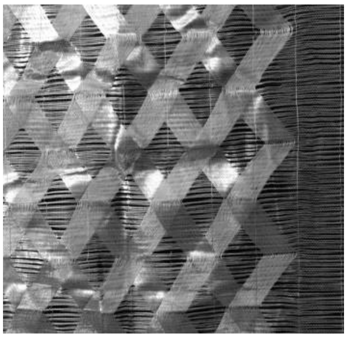
One of the main aspects of research at the ITB is therefore the improvement of stitch bonding machinery for the production of high-value technical textiles. This research is based on machines by Karl Mayer Malimo company, Germany, which have been constantly enhanced in order to develop ever new applications.

2 Improving the thread arrangement

All textile manufacturing techniques for processing of systems of reinforcing threads (warp and weft threads) arrange the threads in every layer parallel to each other due to the standardized gauge of the work elements. The individual layers can be arranged in either one or more orientations. However, the adjustment of the threads to the lines of force in the component is limited. To manufacture reinforcing textiles according to the requirements of the composite a method has been developed to arrange the threads of one layer into groups, which are then separately controlled [1].

With this warp offset device it is possible to position the warp threads variably between 0° and 82° to the work direction. The offset device consists of at least two slide rails on which movable yarn guides are mounted. These yarn guides are driven by stepping motors and are individually controlled.

By turning away from defined spaces between the threads and the thread groups, respectively, the difference between target and actual position of the threads in the component is drastically reduced. The modified process is suitable for all types of stitch bonding machines in which free positioning of the threads is made possible by the design of the work elements. Figure 2 shows examples for the arrangement of warp threads in the textile using the warp offset device.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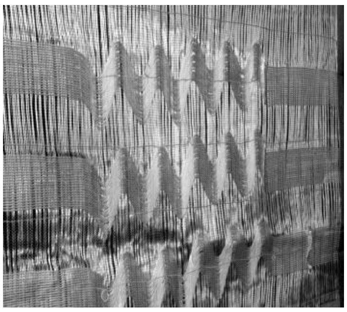
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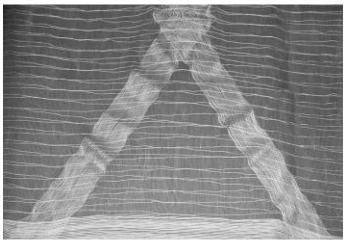
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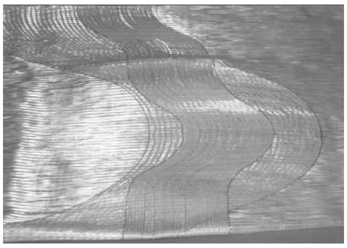
d)

Fig. 2. Examples for stitch bonded multi-plies made using the warp offset device
a) two warp layers crossing
b) threads with reserve length
c) reinforcement for triangular preform
d) segment of a circle

The warp offset device was integrated into a stitch bonding machine that is used to produce a variety of load-adapted reinforcing textiles for many purposes with different fibre material. One example, a hollow girder exposed to thrust loads, is shown in Figure 3. The reinforcing textile is wrapped around a foam core and impregnated with a mineral or polymer matrix, thus creating light-weight girders with high torsional and flexural strength.

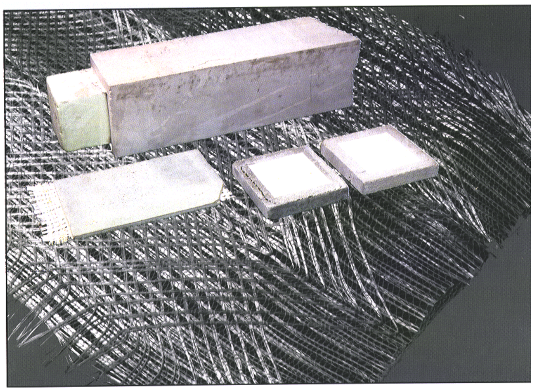

Fig. 3. Concrete girder with foam core

This method can also be used for the production of load-adapted, disc-shaped preforms. The warp offset produces curved patterns of the reinforcing threads. However, for technological reasons, these tangential reinforcements can span only angles up to 120° (Figure 4). This means the disc preform needs to be assembled from several segments (Figure 5). The radial reinforcement can be achieved by several layers of biaxial or multiaxial multi-plies or by manipulating weft or warp yarns during the manufacturing process.

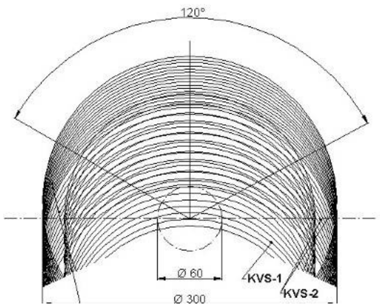

Fig. 4. schematic of segment of a circle produced with the warp offset device

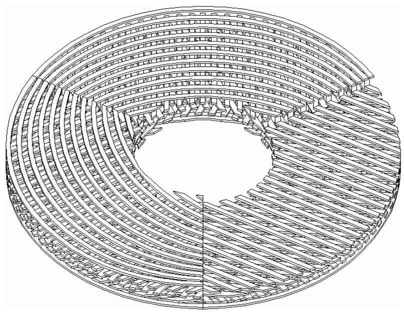

Fig. 5. Schematic annulus made of 120° segments

The manufacturing process provides reproducible results of high quality. One advantage compared with competing textile manufacturing processes can be found in the fact that the threads are positioned straight without any crimp. However, the formation of circular preforms from the 120° segments is connected with an increased manufacturing effort, which is at least partially compensated for by the high productivity of the stitch bonding process.

3 Improving the layer arrangement

One disadvantage of stitch bonding machines sometimes arises from their operating principle. Basically, the guide bars by their movement determine the course of the stitching thread in the multi-ply. The crosswise course of the stitching thread in the fabric is created by the movement of the guide bar across the grain of the fabric in the machine. In thread processing stitch bonding machines, this cross-connection of the stitching thread fixes the warp threads. But there must be at least one layer of weft threads behind the warp threads in order to clamp the warp threads. This means that it is impossible to realize a symmetric arrangement of the layers or to bind a single warp layer.

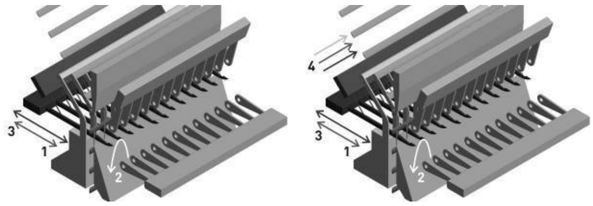

Fig. 6. Operating cycle without (left) and with (right) needle shift

With a new development by the Institute of Textile and Clothing Technology, which has been implemented by Karl Mayer Malimo, the needle bar is shifted sidewise (Figure 6), thus creating cross-connections of the stitching threads on the back side of the fabric as well (Figures 7 and 8). Both the needle and the wire tongue bar are equipped with an additional guide track rectangular to the stroke back and forth. Stroke and shift can be superposed.

With this additional work step in the knitting cycle it is not only possible to produce fabrics consisting of a single warp layer, but also to create a symmetric arrangement of the layers in the multi-ply (Figure 9) [2].

Fig. 7. Needle loops without (left) and with (right) needle shift

A mock-up machine (Figure 10) has been developed in order to demonstrate the previously named possibilities provided by the improved warp knitting process. It features two guide bars and a shiftable needle bar as well as all other working elements of a stitch bonding machine. Since the patterning is based on manually driven slides instead of cam discs, the pattern repeat and width of the needle and guide bar movements are unrestricted.

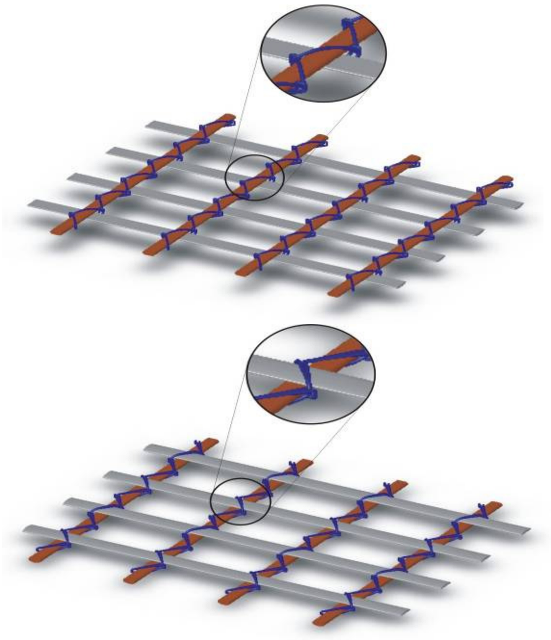

Fig. 8. Stitch bonded multi-ply
brown: warp thread, grey: weft thread,
blue: stitching thread

This machine is used to produce sample structures with all kinds of regular or irregular pattern repeats to evaluate their usability in composites and to assess the possibilities to fabricate them on a full-scale prototype machine.

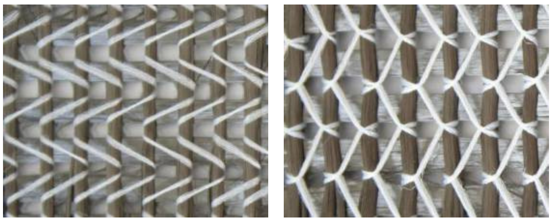

Fig. 9. Symmetric carbon fibre multi-ply
(face and reverse side)

A biaxial stitch bonding machine (Figure 11) was chosen as basis for the first prototype machine with the extended warp knitting cycle. The additional shifting movement of the needle bar is realized by a third cam disc, complementing the cam discs for the two guide bars. Furthermore, yarn guides for the second warp layer are integrated into the machine to completely implement the needle shift idea.

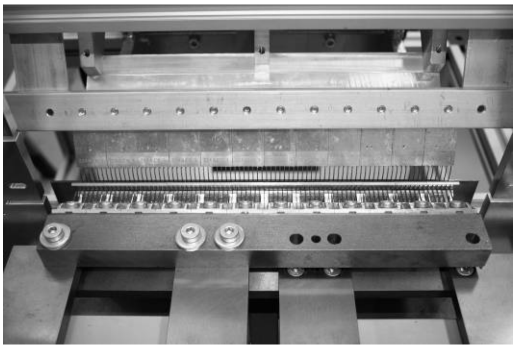

Fig. 10. Mock-up machine

First sample structures produced on the prototype machine show the possibilities offered by the extended warp knitting process, especially for the use in fibre reinforced composites. But the use in other types of stitch bonding processes, such as web processing “Maliwatt” or “Malivlies” machines, is also thinkable. In Malivlies machines for example, where the web is mechanically fixed by forming stitches from the fibres in the web, it is now possible to fix warp threads on one surface of the web by the stitches formed with needle shift. That is relevant for example in interior components for automobiles to withstand forces in deep drawing processes often used there.

Fig. 11. Prototype machine during conversion

3 Acknowledgements

We thank Karl Mayer Malimo Textilmaschinenfabrik of Chemnitz, Germany, for the construction of the prototype and the German Research Foundation (DFG) for the financial support of this project in the framework of the Collaborative Research Center SFB 528 “Textile reinforcements for structural strengthening and repair”.

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