NC STATE UNIVERSITY

JTATM

JOURNAL OF TEXTILE AND APPAREL, TECHNOLOGY AND MANAGEMENT

Volume 2, Issue 1, Fall 2001

RECENT DEVELOPMENT IN THE ROBOTIC STITCHING TECHNOLOGY FOR TEXTILE STRUCTURAL COMPOSITES

Dr.-Ing. Jürgen Wittig
ALTIN Nähtechnik GmbH
Berlin, Germany

ABSTRACT

Dry preform production is gaining increasing importance due to the widespread availability of modern resin infusion techniques. This requires reproducible structural preforms of high accuracy which have to be manufactured on automated systems at low costs. Shaping of the structure, fixation of patches or layers and reinforcement of the parts in z – direction are the main tasks for this process step. Stitching is therefore the ideal solution. ALTIN Naehtechnik has developed a stitching process, where 3–dimensional preforms can be produced by the application of unique stitching technologies. For the achievement of high accuracy numeric controlled industrial robots are used to carry special designed stitching heads along the seam path. The exchangeable heads are designed to operate with all modern high performance yarns including carbon. The patented One Side Stitching- and the Tufting – heads allow to stitch and to reinforce special structures with access from only one side. The paper gives an overview of major developments and achievements in preform stitching.

KEY WORDS: One Side Stitching, Robotics/Automation, Three Dimensional Stitching

1. INTRODUCTION

The stitching of several textile partial structures whose fiber alignment is optimized according to the stress lines in the non-impregnated state is gaining increasingly attraction in the composite industry. An additional essential part of this strategy is the direct reinforcement of the FRP components for the improvement of their mechanical characteristics by inserting reinforcement of fibers in Z-direction.

Although stitching as a technology for connecting two or several individual textile parts together has been well known for a long time, the previously known stitching techniques are not efficient or cannot be applied in the majority of the cases, mostly due to the large dimensions and the three-dimensional structure of the FRP components.

To overcome stitching technique limitations the ALTIN Nähtechnik has developed a technology where stitching heads, which have been especially designed for the processing of FRP performs, are continuously carried along the seam line of a resting work piece by a robot.

During stitching the work piece is fastened onto special fixation devices.

The limitations of the access to the preforms due to the necessary fixtures has been overcome in the majority of the applications by the availability of one side stitching techniques. Since the work piece has to be accessed from one side only, stitching of complicated structures is no longer limited by the design or the size of the stitching machine. The possibility to mount the manipulator arm to a rail or a gantry system has also eliminated the limitations in the stitching area. Besides the conventional double lock stitch two different techniques for one side stitching are available. The two needle one side simple chain stitch head produces a double line seam, the work piece is penetrated by the stitching thread at different inserting angles. Especially for the local reinforcement of FRP a tufting head can be used which allows to insert the stitching thread under various angles and at lowest possible thread tensions.

To make optimal use of the well known advantages of NC-operated robot systems, a wide range of control features is available including an offline programming systems which aside from generating the robot program is also capable of conducting feasibility analyses and simulations.

2. THE STITCHING ROBOT

The robot-supported three-dimensional stitching system described here is based on the principle of a continuous relative motion between the stitching head fastened to a robotic arm and the stationary work piece held by a work piece fixation device. This system (see fig. 1) can be applied to all stitching types, which are used for the processing of FRP preforms. A major advantage is that the stitching machine does not need work piece feed items known from conventional stitching machines. Thus, careful handling of the work piece is ensured and structural damage caused by the transport system can be prevented. A precondition for the continuous relative motion between the stitching head and the work piece is that the needles have no sideward movement in seam direction while they are in contact with the material to be stitched.

This is guaranteed by a mechanical differential gear, the so called transverse slide drive. The vertical upward and downward movements of needles occur concurrently to a back and forth movement in seam direction. For this purpose the moving axles of both stitching tools are integrated in a common framework. This framework is moved against the positive seam direction as long as at least one needle is in contact with the work piece. The velocity of this movement corresponds to the seam building velocity. When neither of the two stitching tools is in contact with the work piece, the transverse slide movement in seam direction takes place.

3. DOUBLE LOCK STITCH

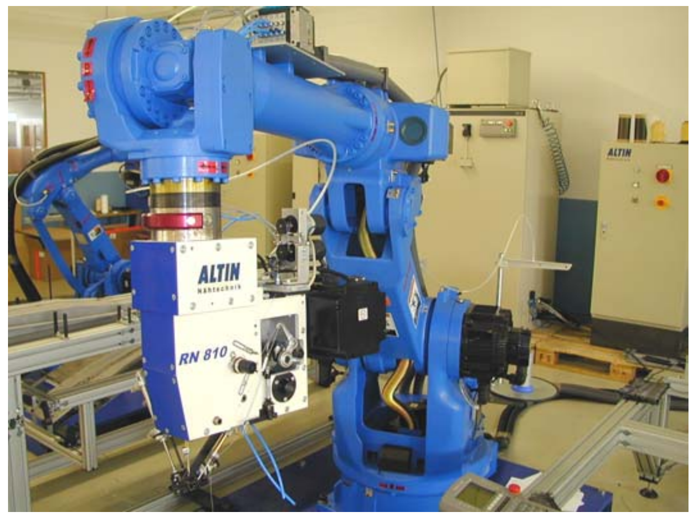

Fig.1 Robotic Stitching System

The main aspect to be considered when stitching FRP semi-finished material is the handling of geometrically more complicated, usually three-dimensional structures with simultaneous large spatial expansion. Technically the stitching of these types of structures is difficult if conventional stitch types are applied. For instance the two thread lockstitch requires access to the work piece from both sides. A double lock stitch head and a typical application for a double lock stitch are shown in figures 2 and 3.

The existing limits of the well-known stitching techniques can be overcome by a technology where access to the work piece is only necessary from one side. The ALTIN Nähtechnik has developed two separate stitching technologies, the one side stitching system, known as the OSS system and a tufting system.

Fig. 2 Double Lock Stitch Head

Fig.3 Double Lock Stitch Head in Operation

4. ONE SIDE STITCHING (OSS)

The core of this system is a robot-guided special stitching head (see fig. 1). Its stitch formation mechanism is based on the principle of the simple chain stitch. This stitch is produced by two stitching tools. Both tools are manipulated from the top side of the work piece, so that it is not necessary to arrange any stitch formation element underneath the work piece. Only free space for penetration of the needles has to be taken into consideration.

The inserting angles of the stitching tools are 45° and 90°. Although the operational principle permits a variation of these angles within certain limits, these angles were determined to be optimal. The reason is that the stitching angle determines the final position of the stitching thread in the FRP structure.

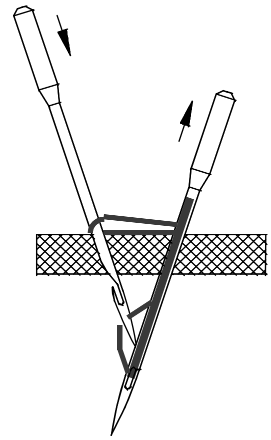

Fig. 4 Stitch Formation

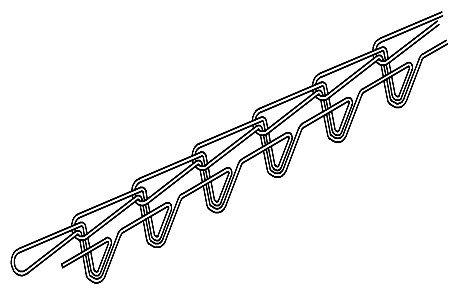

Fig. 5 Seam Pattern

The principle of the OSS system is the manipulation of a stitching thread by two stitching tools, a conventional needle and a catcher. Both stitching tools are driven translatorically, their moving axes form a point of intersection below the stitching material.

The catcher-needle takes over the loop of the stitching thread produced by the needle and pulls it back through the work piece to the top side through the loop of the previously formed stitch which is located on the shaft of the catcher-needle. In this way the interlocking of the stitching thread is formed. The principle of the stitch formation is represented in fig. 4.

Unlike other known stitching methods the interlocking of the sewing thread on the work piece takes place on the top side, so that a stitch picture in accordance with fig. 5 occurs.

The implementation of the 45° stitching angle enables the optimum position of the stitching thread as a reinforcing element in the structure. By this action the one side stitching system is not only capable of connecting several semi-finished materials, but also achieves the second major task in the stitching of FRP components, the reinforcement in the Z-direction. A typical stitch design and a prepared test panel are shown in figures 6 and 7.

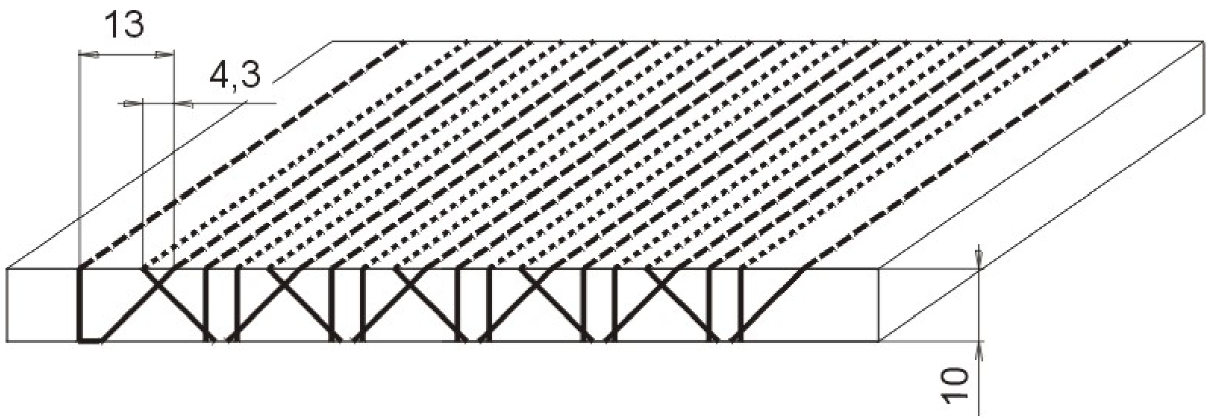

Fig. 6   Stitch Design for a Flat Sample

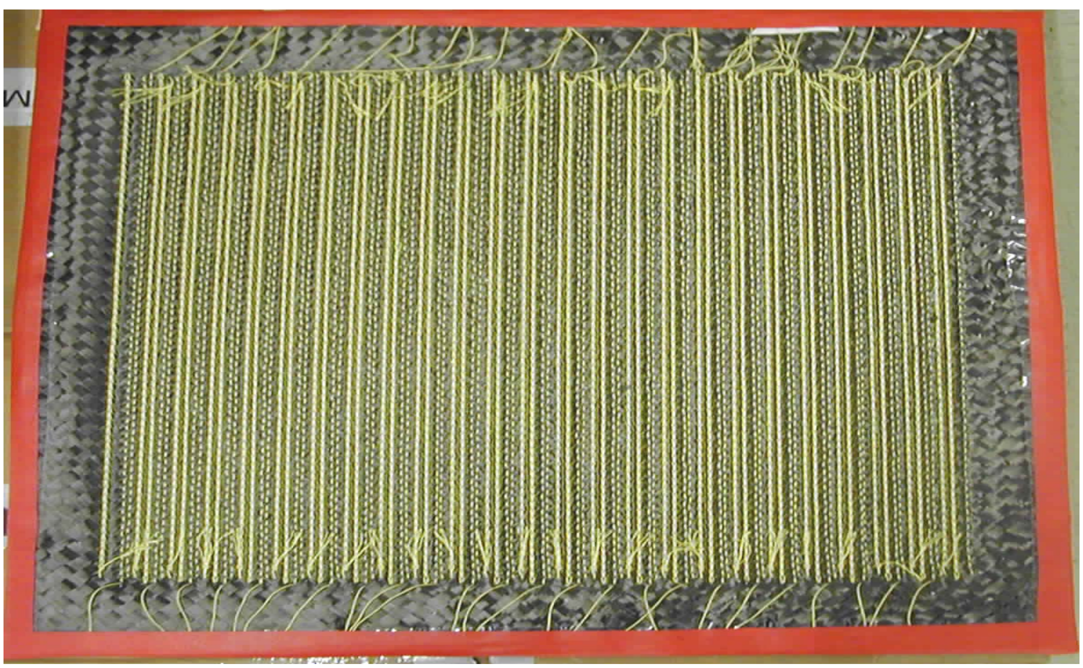

Fig. 7   Stitched Flat Panel

5. TUFTING

Different from the above described two-needle system, the tufting system represents a stitching technology which is mainly designed for the reinforcement of FRP preforms. The major target of this technology is the insertion of load taking threads in Z-direction, which can be executed also under various angles. The advantage of tufting is the low tension under which the thread is inserted. This results in a reduction of the stitching effect on the in-plane properties of FRP and is achieved by not interlocking the stitches of the seam which would require a tightening of each single stitch. The possible stitch pattern and a sample are shown in the figures 8 and 9.

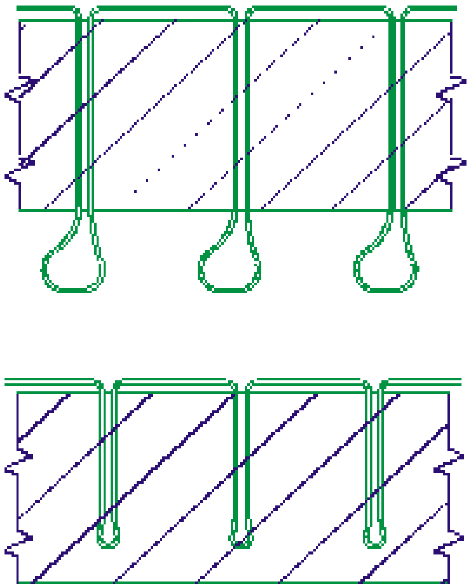

Fig. 8 Possible Tufting Stitches

Fig. 9 Reverse Side of Tufted Structure

The process is applicable for preforms up to 40 mm of thickness. The tufting head as shown in figure 10 is variable regarding its stitch length, insertion angle and the length of the loops. Also negative values for the loop length can be achieved resulting in a partial reinforcement of the preform. Since for such a reinforcement it is not required to penetrate the work piece completely it is possible to reinforce the preform directly in the RTM tool.

The wide range for the parameters for stitch distance, needle insertion and loop length is adjusted by electro-mechanical means and can therefore be modified via the robot control

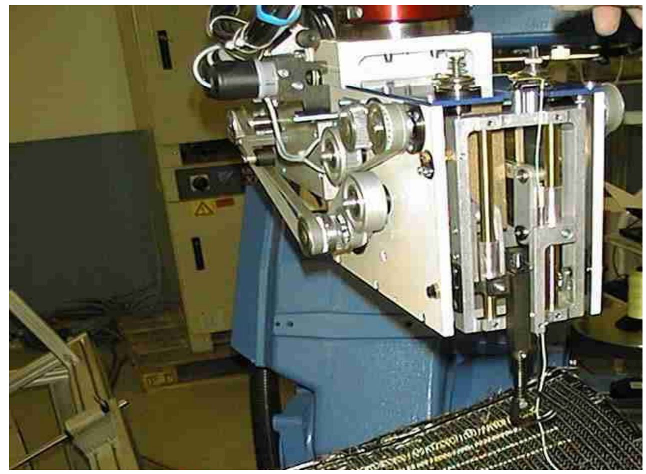

Fig. 10 Tufting Head

system while performing a stitching job.

6. ROBOT CONTROL AND SIMULATION

The industrial robot carrying the stitching head is operated via a system which allows the control of up to 27 servo axis's. By this feature the six servo drives of the robot arm, the servo of the stitching head, servo drives of an x-y gatry system plus additional servo drives of for a controlled movement of the fixation device can be coordinated. The size of the stitching area is therefore only limited by the size of the gantry which is used, as it is known form modern automatic tape laying systems.

The conception of the three-dimensional stitching system took into consideration both, the economic and the practical applicability. The implementation of the stitching heads at a robot, offers the possibility of being able to arrange the courses of motion in the three-dimensional space almost without limitations. For the realization of the respective stitching function, when different stitch types are used, the stitching head can be changed quickly by means of a tool-free coupling system.

In the total machine concept all necessary and meaningful mechanization devices for the

effective and reproducible operation of the three-dimensional stitching system are considered. For example a thread cutting and thread clamping mechanism, a thread tension release, a device for the active thread feeding and a system for the detection of thread breakages are available.
The programming of a robot system can take place by teach-in procedures. However this programming technique is often ineffective and has approached the limit of its efficiency at high precision demands. For such tasks the application of a simulation system is available. The tools (stitching heads), work piece fixation devices and the seam courses originating from CAD-projects are used as input data for a robot simulation. With this robot simulation, apart from the investigation of collision freeness and cycle time investigations, the seam path of the stitching head can be defined accurately according to the constructional specifications and the necessary robot program can be prepared completely in off-line mode.

The resulting robot program is transferred to the robot control and tested on the real object. For the transfer of the data between the CAD workstation, robot simulation and robot control a Ethernet with TCP/IP log is used. It offers the highest flexibility for future developments and improvements particularly regarding quality assurance and service with systems under production conditions.

7. FIXATION DEVICES

Since the stitching technique itself is far developed and reliable in its performance, the major questions are related nowadays to the development of fixation devices for the preform production. The task is to drape and to fix the separate layers in such a way, that no or minimal new-positioning has to be undertaken while the seams are applied in their exact positions.

Fig. 11 Design of a Fixture for an Aircraft Structure

Altin has achieved a vast amount of experience in fixture design over the past years, whereby the newly developed One Side Stitching techniques have greatly improved the application of stitching to the preform production. Figure 11 shows the fixture design for the production of a curved stringer for an aircraft part.

8. STITCHED STRUCTURES

With the available stitching heads almost every shape of preform can be produced by stitching nowadays. One of the typical applications however remain the production of T-shaped preforms with the OSS technique. Here the specific nature of the stitch with its one thread applied under an angle of 45° in the fabric allows to reinforce the structures directly in its weakest position. Figure 12 shows a sketch for such an application, the parts produced in this way can be seen in figure 13 and 14.

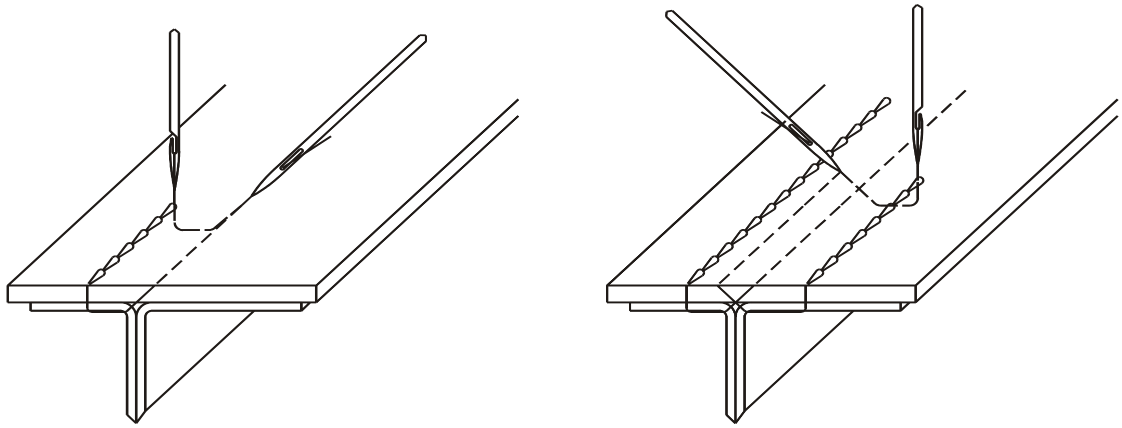

Fig. 12 T-Shape Structure stitched by OSS Technology

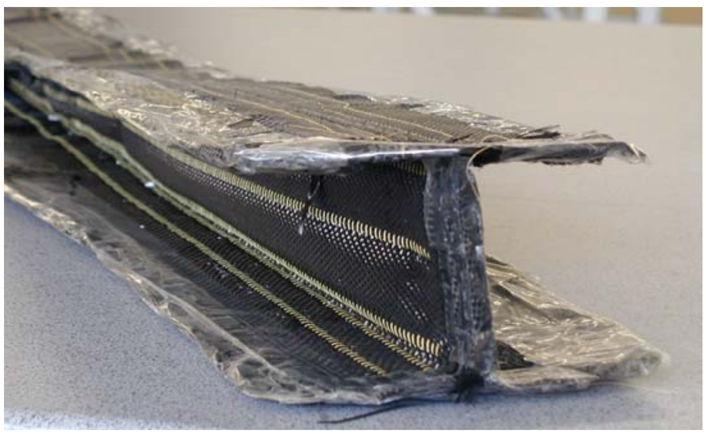

Fig. 13 Double Cone Shaped Stringer for Aircraft Application

Fig. 14 Stitched T-Profiles

9. CONCLUSION

With the development of the three-dimensional stitching system the step was made by which a structural stitching technique went from laboratory to industrial production. Major American and European and also Asian aircraft parts manufacturers have ordered such systems or have them already in operation. For almost every application stitching heads are available up to material thickness of 40 mm. The tool free coupling system allows the interchanging of the different stitching heads on same the handling system ensuring maximum universality. Aramide and Carbon threads can be applied allowing the production of preform structures previously unthinkable to be produced by stitching. Utilization of the OSS and tufting technology makes it possible to stitch complicated three-dimensional FRP structures in an effective way. Stitching in the mould has become possible. The size of the structures is only limited by the size of the gantry system used. Further developments will increase the application range for this technique.

AUTHOR’S INFORMATION:

Dr.-Ing. Jürgen Wittig
ALTIN Nähtechnik GmbH
Staakener Feldstr. 39-41, D-13591 Berlin, Germany
E-Mail: sales@altin-naehtechnik.de