# SPACER FABRICS FROM HYBRID YARN WITH FABRIC STRUCTURES AS SPACER

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## *Abstract*

*Within the scope of Collaborative Research Centre SFB 639 "Textile-reinforced composite components for function-integrating multi-material design in complex lightweight applications", woven and flat-knitted spacer fabrics from commingled hybrid yarns are developed, pressed and the characteristics of the formed composite structures are tested. The developed spacer fabric structures have U- shaped and V- shaped connections with woven or knitted crosslinks which yield good performance under complex stresses especially under bending strength in comparison with conventional spacer fabrics. Various modifications on flat knitting and weaving machines are executed to enable hybrid yarn processing into 3D textile preform structures. These new developments extend the performance and the application areas of cost-effective textile reinforced thermoplastic composites. Integration of functional components and further near-net-shape structures are the main emphasis of future work.*


## 1 Introduction

The woven, warp-knitted, weft-knitted, braided and stitch-bonded textile preforms, which can be produced from glass, carbon and aramid yarns, are on a large scale used for the production of composite materials. Spacer fabrics can be developed with weaving, warp knitting and weft knitting techniques. These conventional spacer fabrics have two outer layers which are connected through pile yarns. If the spacer fabrics are to be used as preforms for the thermoplastic composite materials with high flexural rigidity, then it is advantageous to connect the two outer layers with woven or knitted crosslinks instead of pile yarns. The woven or knitted crosslinks, which create the space between two outer layers, can also be easily pressed in order to produce thermoplastic composite components. However, the pressing of the spacer part is mostly not possible for the conventional spacer fabrics, which are produced through pile yarn connections. The woven or knitted crosslinks, in comparison with pile yarn connections, yield significantly higher strength against tensile, compressive and especially bending forces. Therefore, the development of spacer fabrics with woven or knitted crosslinks is necessary [1, 2].

Woven and knitted spacer fabric preforms from hybrid yarns are developed for the lightweight applications of thermoplastic matrix composites. Possible connection variations for the woven and knitted crosslinks are analyzed. After considering the reproducibility and press ability of the various structures, U- and V-shaped crosslinks (Fig. 1) are selected for further developments. The used hybrid yarns consist of one high-strength and one thermoplastic matrix components. In particular, PP/GF hybrid yarns are produced with 0.5 fiber volume fraction through air-texturizing process [3]. An over-delivery of the matrix component of hybrid yarn in comparison with the high-strength component is necessary, which to some extent prevents damage and strength reduction of textile structures during production. Simultaneous investigations are going on about the online spinning of GF/PP hybrid yarns.

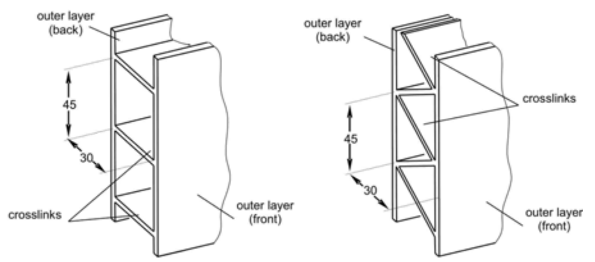


Fig. 1. Schematic of U-shaped (left) and V-shaped (right) spacer fabrics with fabric structures as spacer

## 2 Development of Spacer Fabrics

### 2.1 Woven Spacer Fabrics

#### *3.3.1 Preliminary Developments on Narrow Weaving Machine*

The preliminary trials of the spacer fabric development are accomplished on the narrow weaving machine. Figure 2 illustrates the production technique of the developed U-shaped spacer fabrics, which is realized in three steps. In the first step (Fig. 2A) upper and lower surfaces are produced. In the second step (Fig. 2B) half of the warp yarns make floatings while the remaining warp yarns produce the woven crosslinks. In order to create the sandwich structure, the floating warp yarns are pulled back in the third step (Fig. 2C) [4].

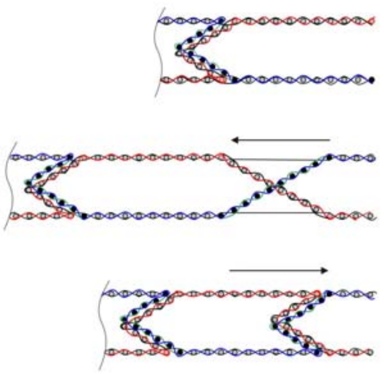


Fig. 2. Production steps of the U-shaped spacer fabrics; A: weaving of the outer layers, B: weaving of crosslinks and floatings, C: pulling back

Essentially, a terry weaving mechanism is developed to enable the transformation of flat woven structure into sandwich structure. The preliminary trials of the spacer fabric development are accomplished on the narrow weaving machine. Main elements of the modified narrow weaving machine are illustrated in figure 3 [5].

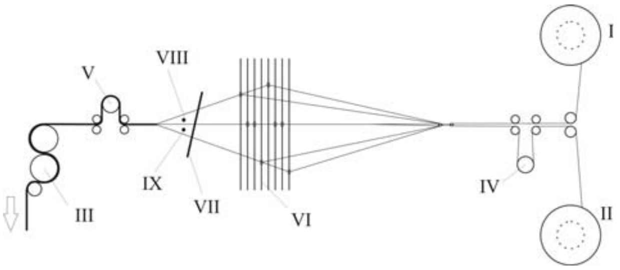


Fig. 3. Main elements of the modified narrow weaving machine

I: warp beam for crosslinks
II: warp beam for floatings
III: fabric take-up
IV: pulling-back mechanism
V: terry weaving (fabric storing) mechanism
VI: shafts
VII: reed
VIII: upper weft insertion
IX: lower weft insertion

Figure 4 and 5 demonstrate the modifications on the narrow weaving machine, which enable the fabric storing during the weaving of crosslinks (Fig 2B) and the pulling back of the floatings (Fig 2C).

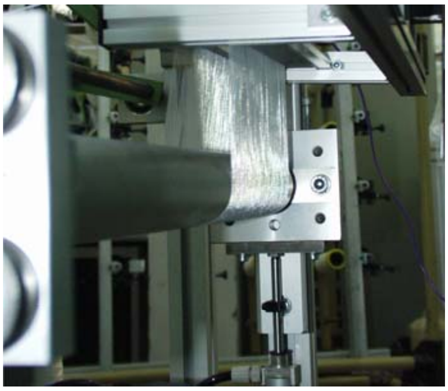

Fig. 4. Pulling-back mechanism for warp yarn floatings (Fig. 3 IV)

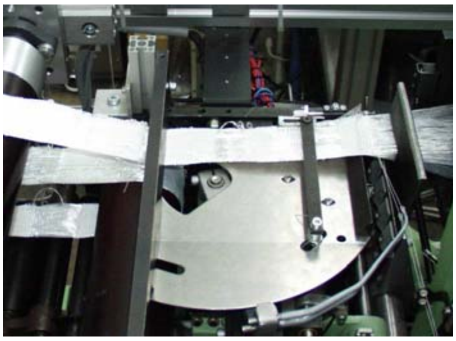

Fig. 5. Terry weaving (fabric storing) mechanism (Fig. 3 V)

In addition to the developed terry weaving mechanism, a new fabric take-up system is developed. Aim of the system is to ensure a uniform take-up of the fabric layers and to avoid buckling which causes damage on the reinforcement material. Straight-line arranged roller pairs characterize this system, one of which can be engaged to the other roller with a defined contact force. In front of the take-up system a gripper inserts supporting bars into the hollow space of the woven fabrics. A second gripper extricates the bars from the fabrics at the back side of the system. Figure 7 shows the modified narrow weaving machine with new take-up system [6].

A controlling system is developed for the synchronization of the mechanisms of the modified narrow weaving machine and good results are achieved in flexibility concerning the dimensions of the fabrics as well as the defined movements of the mechanisms and precise actuating.

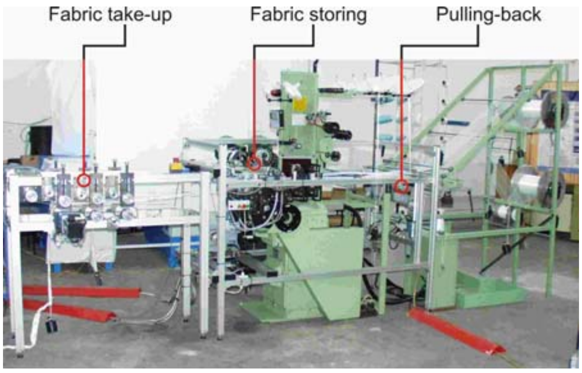


Fig. 7. Modified narrow weaving machine

The narrow woven spacer fabrics (Fig. 8) are produced with PES high strength yarns. During weaving, although the behavior of the flat multi-filament PES yarns are different than the commingled hybrid yarns, valuable experiences are gathered concerning the weaving patterns. These experiences open the possibility of functional component insertion into the fabric structures and extent the application field of narrow weaving in technical textiles.

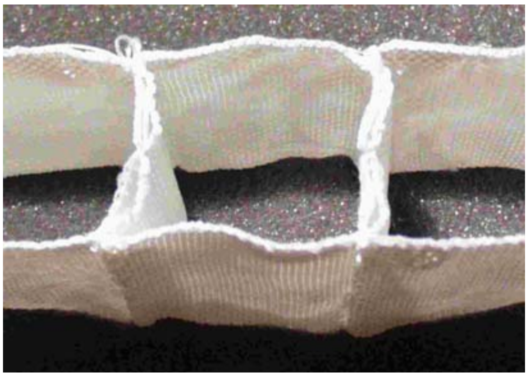

Fig. 8. U-shaped narrow woven spacer fabrics

### *3.3.1 Developments on Double Rapier Weaving Machine*

Based on the experiences of spacer fabric production on narrow weaving machine, the production of spacer fabrics on a double rapier velvet weaving machine is being carried out. The low elasticity of the produced commingled hybrid yarns requires a precise adjustment of the weaving geometry and reduces the feasible machine performance.

Fig. 9. U-shaped narrow woven spacer fabrics

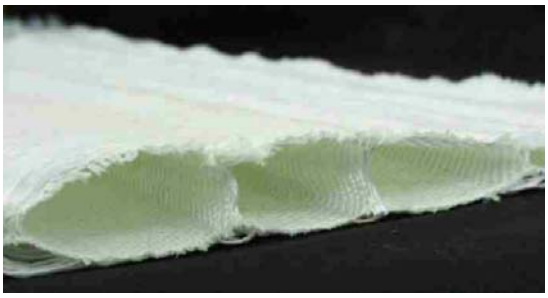

Fig. 10. U-shaped narrow woven spacer fabrics

## 2.1 Flat-knitted Spacer Fabrics

For the development of flat-knitted spacer fabrics, the yarn guiding elements of the conventional flat knitting machine is modified. Due to the high flexibility of flat knitting, production of spacer fabrics with knitted crosslinks is possible both in vertical and horizontal directions. Furthermore, integration of weft and warp yarn reinforcements as well as connection of more than two flat layers can be realized. Up to now spacer fabrics with two outer layers through U- and V-shaped crosslinks are developed [7]. Production method of U-shaped flat-knitted spacer fabrics is illustrated in figure 11.

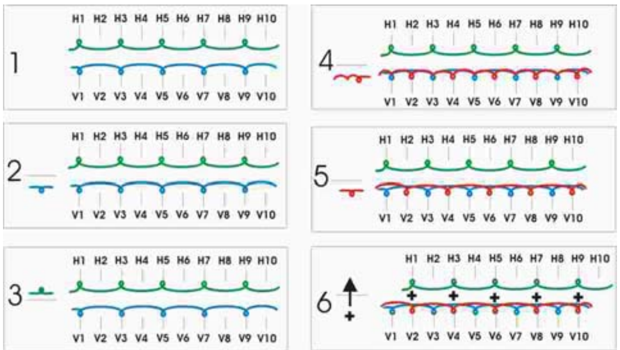


Fig. 11. Production method of U-shaped flat-knitted spacer fabrics

The production of the U-shaped flat-knitted spacer fabrics consists of 6 main steps which are:

1. Start phase, both needle beds have single jersey
2. Blue yarn carrier knits with the uneven numbered needles of the front needle bed (V1, V3, V5…)
3. Green yarn carrier knits with the uneven numbered needles of the back needle bed (H1, H3, H5…). Step 2 and 3 can be repeated to adjust the length between two crosslinks, which is 45 mm for the basic structure illustrated in figure 1.
4. Red yarn carrier knits with even needles (V2, V4, V6…) and tucks with the uneven needles (V1, V3, V5…) of the front needle bed. This is the first course of the crosslink. Tucks with the front needle connects the crosslink with front outer layer.
5. Red yarn carrier continues to knit only with the even needles of the front needle bed. Step 5 is repeated until the aimed length of the crosslink is produced. This length is 30mm for the basic structure illustrated in figure 1.
6. Last course of the stitches from step 5 is transferred to the back needle bed. In order to connect the last row of the crosslink with the stitches of back outer layer, back needle bed is racked. Thereafter, the stitches on the even numbered needles of the front needle bed (V2, V4, V6…) will be transferred to the uneven numbered needles (H1, H3, H5…) of the back needle bed. After stitch transfer, the needles of the back needle bed are racked to their original position and the rapport is completed.

Above explained main principle can be applied to further geometric connections like V-shaped spacer fabrics. Developed U-shaped and V-shaped flat-knitted spacer fabric structures are demonstrated in figure 12.

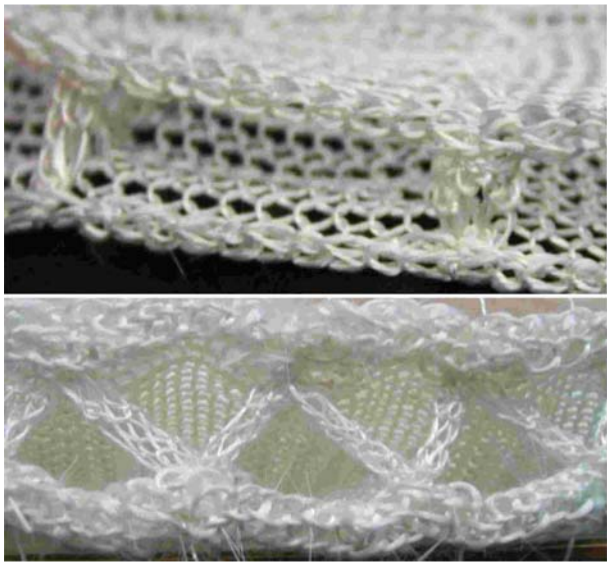

Fig. 12. U-shaped (top) and V-shaped flat-knitted spacer fabrics

Weft yarn reinforcements are integrated to the above mentioned structures. After thermo-pressing 1600 g/m² and a component thickness of 1mm is reached.

## 3 Conclusions

Within the scope of Collaborative Research Centre SFB 639 "Textile-reinforced composite components for function-integrating multi-material design in complex lightweight applications", woven and flat-knitted spacer fabrics are developed, pressed and the characteristics of the formed composite structures are tested. Spacer fabric structures with woven or knitted crosslinks yield good performance under complex stresses especially under bending strength in comparison with conventional spacer fabrics. These new developments extend the performance and the application areas of textile reinforced thermoplastic composites. Integration of functional components and further near-net-shape structures are the main emphasis of future work.

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