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# Useage of Dry Fiber Placement Fiber Semifinished Products for the Production of Board Sports Equipment Using the Example of a Splitboard

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## Keywords

Board Sports Equiment, Dry Fiber Placment, Snowboard, Splitboard

## Abstract

In the state of the art, sandwich structures are predominantly used for the production of board sports equipment such as snowboards, skateboards and wakeboards, which usually consist of a wood core with cover layers of fiber-reinforced plastic (FRP). These almost exclusively thermoset FRP in the top and bottom booms are mainly manufactured by means of hand lay-up processes and subsequent hot pressing and joined in situ to the wood core. In the state of the art, multiaxial knitted fabrics with a fiber orientation of 0/90 or 0/+45/-45 are often used as semi-finished fiber products. These semi-finished fiber products manufactured on classic textile lines have a width of several inches after production. The most common width is 1.27 m or 50 inches, which leads to a very high waste of up to 30 % in production. By using the dry fiber placement process to manufacture preforms for a so-called splitboard, which is a subgroup of snowboards, it was possible to reduce the waste of carbon fibers during the fiber semifinished product production by approx. 60 % and significantly increase the economic efficiency. In addition, the variable tape placement of the dry fiber placement technology makes it possible to produce complex layer structures automatically, which can currently only be produced manually.

## 1 Introduction

In the state of the art, sandwich structures are mainly used for the production of board sports equipment such as snowboards, skateboards and wakeboards, which usually consist of a wooden core with cover layers made of fiber-reinforced plastic (FRP) composites [1]. These almost exclusively thermoset FRP in the upper and lower belt are mainly manufactured by means of hand lay-up and subsequent hot pressing and joined in-situ to the wood core. In the state of the art, multiaxial knitted fabrics with a fiber orientation of [0/90], [+/-45] or [0/+45/-45] are often used as semi-finished fiber products. These semi-finished fiber products, produced on traditional textile lines, usually have a width in inches, with common commercial widths being 50 inches (or 1.27 m). In the production of semi-finished fiber products, these standardized widths often lead to very high waste, for example in the production of preforms for snowboards with waste rates of 30-80 %. By using the Dry Fiber Placement (DFP) process to manufacture preforms for a so-called splitboard, which is a subgroup of snowboards, it was possible to reduce the waste of carbon fibers during the fiber semi-finished product production by approx. 74 % and to significantly increase the economic efficiency. In addition, the variable sliver deposition of the DFP technology makes it possible to manufacture complex layer structures, which can currently only be produced manually, in an automated process.

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## 2 Value chain in the manufacture of board sports equipment

According to current literature, the value chain for the manufacture of continuous fiber-reinforced boardsports equipment can be divided into two main processes: semi-finished product manufacture and component manufacture [2,3,4,5] (see Fig. 1). Semi-finished product manufacture is in turn subdivided into two processes: fiber semifinished product manufacture and matrix manufacture, the output of which is combined in the main process of component manufacture. Three process variants for the production of FRP components are currently dominant on the market: [6]

(1) A flat textile semi-finished product is manufactured from continuous reinforcing fibers, usually made of glass, carbon or basalt, which are directly impregnated into the component by means of a thermosetting matrix system. Textile technologies used include winding [7], braiding [8], tailored fiber placement (TFP) [9] and dry fiber placement (DFP) [10].
(2) A textile flat semi-finished product is produced from reinforcing fibers, which is further processed into a preform by cutting and stacking. The combination with the matrix in a mold results in the blank component. Woven fabrics [11], knitted fabrics [12] and knitted fabrics [13] are used as semi-finished textile products.
(3) A textile semi-finished product is produced from the reinforcing fibers, whereby the processes from 1. and 2. can be applied. Combination with a thermosetting or thermoplastic matrix produces a thermosetting or thermoplastic prepreg [2], which is contoured and stacked in the next process step and then consolidated under temperature and pressure.

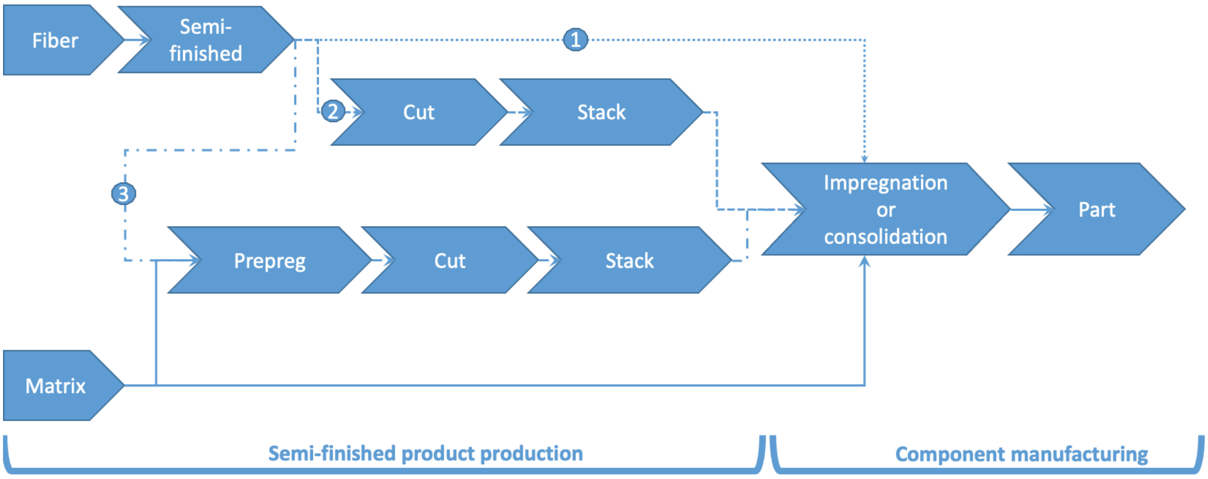


*Fig.1: Value chain of continuous fiber-reinforced composites based on [2].*

In addition to these basic technologies, other manufacturing processes exist for the production of FRP components, so that a heterogeneous set of manufacturing options with different advantages and disadvantages is available. Board sports equipment is currently manufactured almost exclusively using the $2^{nd}$ method, with thermoset resin systems being used in most cases. The impregnation of the cut-to-size fiber semi-finished products is carried out by means of a wet hand laminate and subsequent pressing [14]. For small series, pressing is carried out either by means of evacuation or in open press molds, in which case cold-curing resin systems are usually used. For larger series, i.e. from approx. 50 pieces per model and length, closed molds and thermosetting resin systems are usually used, so that the cycle time is reduced from several hours to approx. 12-20 minutes due to the faster consolidation of the resin.

These short pressing times make it necessary to impregnate the fiber semi-finished product with resin in a short time, which in the state of the art is usually done by manual application and spreading with a doctor blade. In this process step, high forces act on the preform and it must be ensured that no fibers or fiber bundles are detached or displaced from the textile semi-finished product. Therefore, in the state of the art, woven or knitted fabrics made of glass, carbon, basalt or flax fibers are mostly used, which have an excellent fixation of the fibers.

## 3 Fiber semi-finished products for board sports equipment

Due to the low consumption of textile semi-finished products compared to other industries, standardized reinforcement textiles are mostly used in the production of board sports equipment. Multiaxial fabrics made of glass fibers [15] in [0/90], [+/-45°] or [0/+45/-45] are mainly used here. These semi-finished products are manufactured on highly productive production lines and are used by a large number of producers in the industry to manufacture large series. Due to the enormous setup effort of the knitting machines required for the production of multi-axial fabrics, such semi-finished products can only be produced in large quantities. For this reason, different manufacturers in the snowboard industry often use identical semi-finished fiber products from one production batch.

For niche applications that require special semi-finished fiber products either because of customer requirements or because of the special design (such as splitboards), the final preforms must be manufactured either from various semi-finished textile products available on the market. This results in a very high rate of waste and, in addition, requires a high level of manpower for the predominantly manual production steps. For these reasons, highly flexible and automatable manufacturing processes such as TFP and DFP with a material output adapted to these applications have recently been increasingly used. Due to the lower productivity, these processes are currently used almost exclusively for the production of high-performance semifinished carbon fiber products.

However, carbon fibers are currently used in the boardsports industry only in special applications and then usually only partially. Products whose semi-finished fiber products consist of almost 100 % carbon fiber are very rare, which is due to the high cost of the semi-finished fiber products, the lack of availability in small quantities, and the reduced elongation at break of standard carbon fibers compared to glass fibers.

## 4 Splitboard application example

Splitboards [16] are a comparatively new subspecies of snowboards [14] in which the board can be divided into two halves along the longitudinal axis for ascent. With these components, which are similar to snowshoes or touring skis and can be joined to form a snowboard for the descent, the athlete can climb mountains without using lift facilities. The division of the snowboard into two components results in different stiffness and strength requirements for the sandwich composite of the component, so that existing semi-finished fiber products for snowboards cannot be transferred directly to splitboards.

For further consideration, a snowboard with [+45/-45°] fiber orientation is assumed for the textile fiber semi-finished products made of carbon fiber with a basis weight of 400 g/mm$^2$. The semi-finished fiber products compared are woven fabrics, scrims and DFP semi-finished products. The length of the splitboard is 1,590 mm with a maximum width of 325 mm, resulting in a rectangle of 1,640 mm x 365 mm as the preform from a production engineering point of view.

For the determination of the material costs, selected semi-finished fiber products as well as the corresponding basis weight and geometric data of an established distributor for fiber composites are used (see Table 1).

V1 is a standard carbon fiber fabric in plain weave, which has to be twisted by 45 % to cut the preform components, so that four parts (parts 2 and 3 with 1,000 mm x 365 mm, parts 1 and 4 with 640 mm x 365 mm) of 200 g/m$^2$ each are required for the splitboard preform (see Fig. 2, left). The material input per belt is therefore 2.3 m$^2$ at a material cost of EUR 51.43 and a waste of approx. 74 %.

*Table 1: Variants of carbon fiber semi-finished products V1-V4*

| | Type | Grammage | Note | Width | Fiber | Cost |
|---|---|---|---|---|---|---|
| V1 [17] | Carbon fabric | 200 g/m² | Style 450-5 Aero, Plain weave | 1,000 mm | Tenax® HTA40 or Torayca® T300 / 200 tex (3k) | 22.36 EUR/m² |
| V2 [18] | TeXtreme® Carbon fabric | 200 g/m² | Plain weave | 1,000 mm | Pyrofil™ TRS50 15k, Width of the fiber tapes 20 mm | 40.99 EUR/m² |
| V3 [19] | Carbon fiber scrim ST | 50 g/m² | UD | 500 mm | ZOLTEK™ PX35 50k | 6.59 EUR/m² |
| V3* | Carbon fiber scrim ST | 50 g/m² | UD | 1.000 mm | ZOLTEK™ PX35 50k | 6.59 EUR/m² |
| V4 [20] | Carbon roving | 384 g/m² | DFP | 365 mm | Tenax HTS40 F13 / 12k / 800 tex | 58.16 EUR/m² |

V2 consists of spread rovings with a width of 20 mm and has better mechanical properties due to the low layer thickness and the lack of ondulation. In addition, it has a very attractive appearance in the visible carbon area. Both properties are replicated by variant V4, which is produced on the DFP line. The material costs for Preform V2 are 94.28 EUR for a cut identical to V1 and are thus approx. 46 % more expensive than fabric V1.

V3 is a UD scrim made of carbon fiber and is included in the analysis because an ondulation-free design of the preform is intended to improve the mechanical properties and preforms can also be produced with no ondulation or, if required, with only very low ondulation using DFP equipment. Due to the available width of 500 mm, however, it is not possible to cut preform parts with a fiber orientation of +45° or -45°, which is why variant V3* (see Fig. 2, right) with an assumed width of 1,000 mm and identical costs per m² is introduced. Due to the lower weight per unit area, however, 8 layers are required per sandwich belt, so that the material requirement is approx. 9.2 m² and the material costs are EUR 60.63 per preform. Analogous to V1 and V2, the waste is also approx. 74 %.

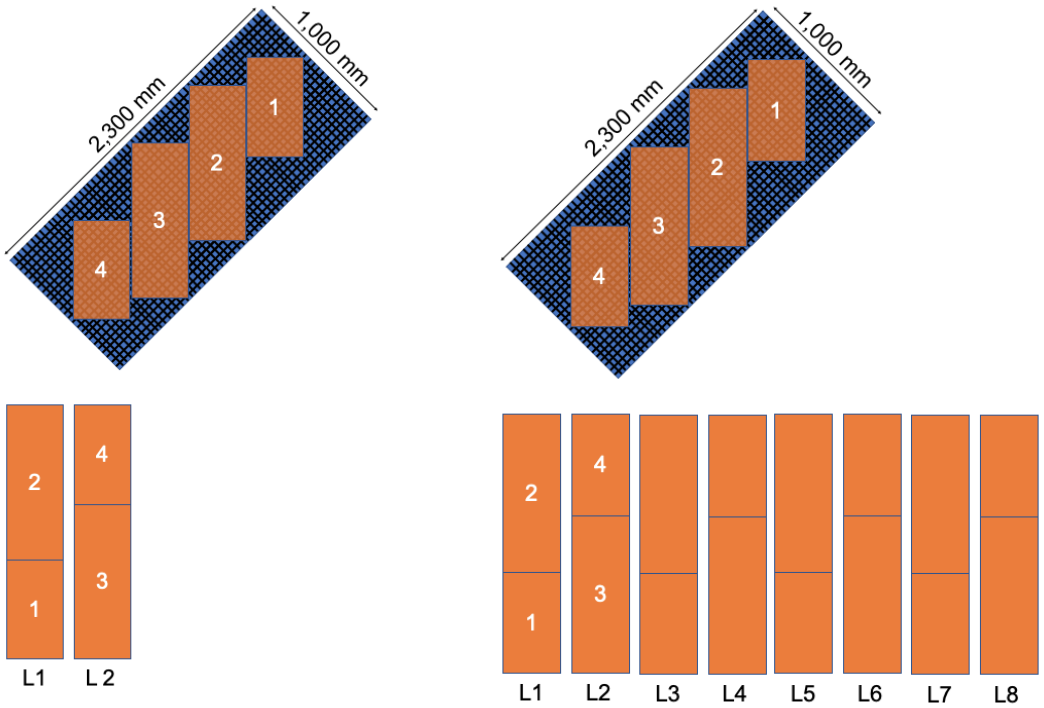


*Fig. 2: Pattern and layer structure V1 and V2 (left) and V3* (right)*

V4 is produced by dry fiber placement [10] directly from the roving spool, using six 12k rovings. These are spread to a strip width of 25 mm and placed directly in the final contour of the preform with an angular orientation of +45° or -45° (see Fig. 3). To produce a "quasi" fabric, one tape per layer is left out, which is then laid in the next but one layer. The waste per layer, in the trivial preform case of the rectangle, is the triangular projection of the respective tape end over the target contour. In the trivial case of the 45° angle, the waste per belt is described by the area of two isosceles triangles with a cathetus length corresponding to the belt width or a square with the side lengths of the belt width.

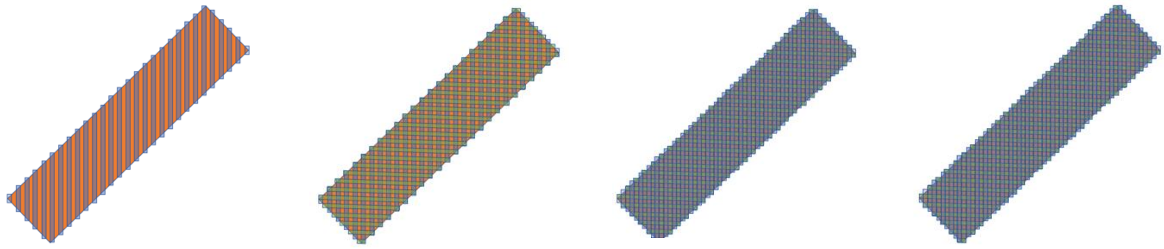

*Fig. 3: Layers 1-4 of the DFP-Preform V4*

The circumference of the preform considered here is 4,010 mm (1,640 mm x 365 mm) with 25 belts per layer, so that there is only a waste of 0.062 $m^2$ (25*(0.025 m)$^2$ with 4 layers) or approx. 10 %. This reduces the waste of the V1, V2 and V3* output variants by approx. 94 %, thus making an essential contribution to saving resources and also helping to reduce product-specific $CO_2$ emissions.

To determine the material costs of the preform from roving V4, the basis weight must be determined. The roving V4 has 800 tex, i.e. 800 g/km fiber, and is spread to 25 mm in the DFP process, resulting in a basis weight of 32 g/$m^2$ per 12k roving. In order to approximate the desired basis weight of 400 g/$m^2$, 6 bobbins have to enter the DFP process simultaneously, resulting in a final basis weight of 384 g/$m^2$ (6 rovings at 32 g/$m^2$, 50 % coverage per layer and 4 layers). The weight deviation of 4 % to the variants V1, V2 and V3* is neglected for the considerations made here.

The material requirement for a preform in the DPF process is 0.661 $m^2$ (0.599 $m^2$ plus 0.062 $m^2$ waste) and costs EUR 14.76 at the price of EUR 58.16/kg assumed for V4 and a basis weight of 384 g/$m^2$. This represents an enormous material cost saving compared to V1, V2 and V3 of 71 %, 84 % and 76 %, respectively, and can make a significant contribution to increasing the use of carbon fibers in board sports equipment.

## 5 Summary and outlook

It was shown that for the application example of a splitboard, the waste cuttings in preform production can be reduced from currently 74 % to 10 % and thus by 94 %. At the same time, material costs can be reduced by between 71 % and 84 % under the assumptions made here. It should be noted, however, that this cost reduction relates to the pure material costs when purchased from an established dealer in Germany and requires further analysis in future work. On the one hand, the price for roving V4 is not comparable with the purchase prices for carbon fibers when purchased directly from the manufacturer. Here, even with smaller purchase quantities, prices in the range of 15-20 EUR/kg can be achieved, so that the material costs drop into the range of 3.75-5.00 EUR. Similar price jumps can be expected for the materials V1, V2 and V3*.

Also, only the material costs were analyzed. A consideration of other influencing factors such as process times and other cost-relevant components such as labor costs, depreciation, energy and space requirements is absolutely essential in subsequent studies in order to develop a sound basis for decision-making.

The resulting different material properties of the V1, V2, V3* and V4 variants are also worth investigating, as the semi-finished products consist of different fiber types. Analyses of the influence of the processing technique between classic woven, scrim and knitted fabrics and the DFP semi-finished products using the identical carbon fiber type are also necessary.

However, due to the enormous potential savings in waste and material costs, it can already be assumed on the basis of the available data that DFP technology can help to reduce the costs of high-performance board sports equipment made of carbon fiber-reinforced plastic.

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