LOW-DAMAGE PROCESSING OF RECYCLED CARBON FIBERS

For the gentle processing of recycled carbon fibers (rCF) in the yarn formation process an industrially suitable coating process for achieving a defined surface profiling of drafting system rollers was developed and industrially tested. Based on this, technologies, in particular stretching technology in the drafting system, with high process stability for high-quality fibre structures (sliver, yarn, tape and composite materials) for technical applications are realized.

In the context of the program initiated by the European Union to promote the circular economy, the development of efficient recycling methods for carbon fiber reinforced plastics (CFRP) on a commercial and industrial scale is becoming the focus of research. The current production of nonwovens and injection molding materials from recycled fibers could only be carried out with random fiber orientation. These approaches led to significantly reduced mechanical properties of the composite materials compared to those based on primary carbon filament yarns due to severe fiber shortening and low fiber orientation levels. Compared to nonwoven formation and injection molding processes, the spinning of rCF into yarn constructions offers considerable potential for significantly improved characteristic values. The composite materials based on the yarn structure with increased fiber orientation can now be processed for higher quality products.

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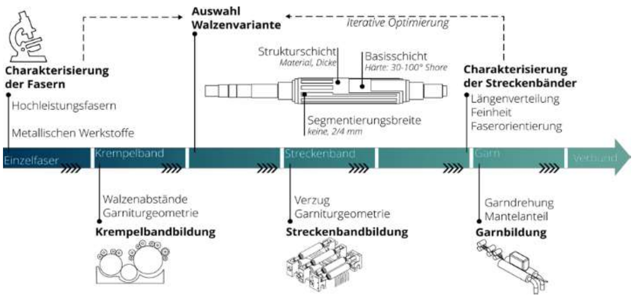
Challenges

Yarn production itself involves critical drafting processes in the draw frames of the draw frame as well as in the Spinning and taping machines. Since conventional drafting systems were primarily developed for processing natural fibers and traditional man-made fibers and not for the cross-force sensitive rCF, there are considerable challenges. These include uncontrolled fiber damage during the drawing process and the resulting variations in fiber length distribution, which lead to undefined adhesion-slip mechanisms of the high-performance fibers between the rollers. These problems lead to considerable disruptions in the drawing process.

Fig. 1: Schematic representation of the integration of coated drafting rollers into the processing procedure for recycled carbon fibers developed at the ITM.



process and result in inhomogeneous sliver, yarn and composite structures. In order to meet these challenges and optimize process stability, productivity and the quality of the end products, the Institute of Textile Machinery and High Performance Materials Technology (ITM) at the Technical University of Dresden, in collaboration with Topocrom GmbH, has driven forward the development of an innovative roller system (Fig. 1).

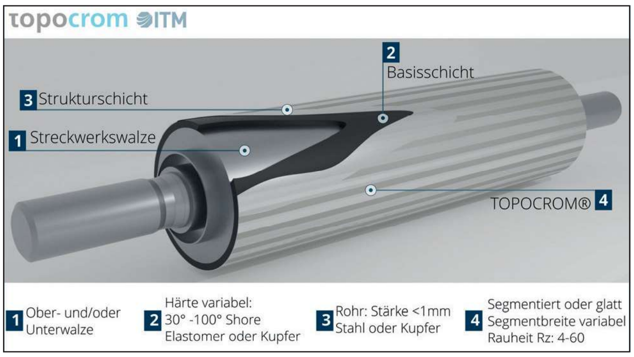
Movement progression in the warping process

The movement of the fibers in the drafting field is directly related to the forces acting on the fibers. The circumferential speed of the roller pairs in the drafting system in conjunction with the applied contact pressure and the coefficient of friction of the roller surfaces are the primary variables in the drafting process. The coefficient of friction is a function of the surface quality, the material of the roller surfaces and the size of the contact area between the fiber and the roller. In order to ensure optimum fibre orientation in the sliver and at the same time avoid misalignment and winding, roller systems have been developed that are characterized by a coating and elasticity of the rollers that is adapted to the specific properties of the carbon fibres (Fig. 2). This system makes it possible to adapt the surface elasticity and profiling to the material-specific requirements.

Coating process for the drafting rollers

Specific coatings are applied to roller systems using a process that comprises the application of a base layer, a structural layer and a final top layer. These layers, which are characterized by hemispherical structural elements, allow for variations in hardness and optional

Fig. 2: Exemplary illustration of a drafting roller with detailed structure and variable parameters.



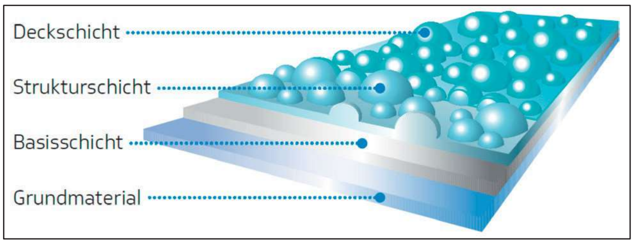


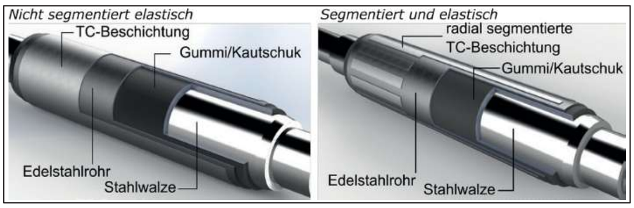
Fig. 3: Structural, layer-by-layer composition of the Topocrom layer structure.

open or closed structures (Fig. 3). The coating process takes place in a closed reactor with continuous rotation of the workpiece. This process enables the layers to be produced in one continuous operation, which ensures that the desired layer structure can be reproduced exactly. The process is also characterized by its environmental compatibility, which meets current ecological requirements thanks to the closed system. The process technology allows targeted definition of the layer thicknesses, surface roughness and profiling depending on the specific material properties.

Segmentation of the drafting system rollers

A new process has been developed that enables the axial segmentation of roller surfaces in order to reduce distortion and winding (Fig. 4). This technique is based on a segmented pro filing of the roller surface, whereby specific areas without coating are provided in order to minimize the adhesion between the roller surface and the fibres. This effectively prevents the fibers from sticking to the roller and thus the formation of roller windings. A special process is used to achieve this segmentation: Prior to the coating process, selected areas are covered with special masks, which, by shielding the parts of the roller surface that are not to be coated, prevent the defined

Fig. 4: Exemplary illustration of the developed drafting rollers with detailed structure in two variants: non-segmented elastic and segmented elastic.



segments are formed. After the coating process, coated areas are created on the exposed surfaces, while the areas protected by the special masks remain uncoated and retain the topology of the base material.

The adhesion between the drafting system rollers and the fibers can be precisely adjusted by specifically setting the elasticity and the segmented profiling of the roller surfaces. This leads to an optimized drafting process, which significantly reduces irregularities in the fibre structure and fibre damage and prevents the formation of roller windings. In addition, excessively long fibers that are clamped between the rollers are guided by a defined sliding mechanism and are not necessarily torn, which further reduces fiber damage.

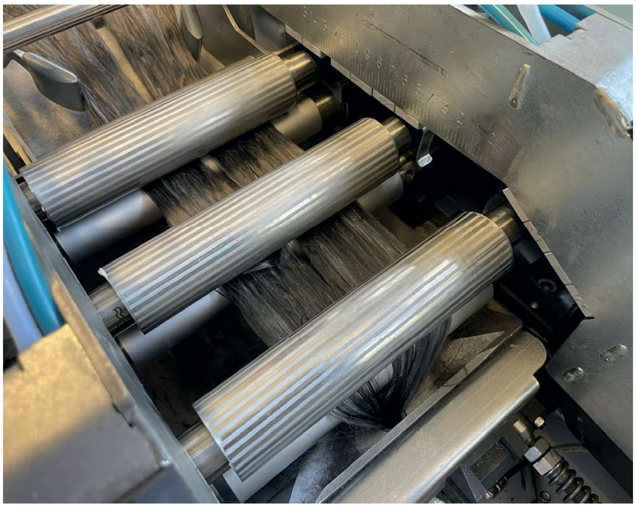


Fig. 5: Illustration of coated drafting system rollers integrated into the drafting system with elastic base layer and segmented surface, used for
the processing of a hybrid carding tape made from recycled carbon fibers and thermoplastic fibers.

Analysis method for determining the course of movement of the fibers

In order to determine the warping behavior and roll winding formation as well as the safe fiber guidance in the warping fields in the warping process, a new type of analysis was carried out using a newly developed measurement setup and a specially developed algorithm. This analysis was based on optical motion measurement using video data recorded by industrial cameras in the distortion area of the draw frame. The need for reference markers arose due to the specific surface properties of the rCF, which cause uneven reflections and therefore make it difficult to continuously record the fibers. For this reason, optical reference markers were applied to the fiber tape at the beginning of the test. The applied markers were then recognized using the developed algorithm. The course of the fibers was described indirectly based on the movement of the markers and displayed visually as well as evaluated numerically. By varying the surface profiling and the elasticity of the coated rollers, the field width and loading pressure could be comprehensively investigated and analyzed. From this, specific preferred parameters for the new roller surface could be determined.

Results

The implemented adjustments to the drafting system rollers (Fig. 5) enabled a significant minimization of fibre damage and an effective elimination of winding and distortion faults. The analysis of the movement curve shows that the elastic, segmented

Compared to the uncoated variants, the coated rollers exhibit a more uniform speed profile in the drawing field in both the longitudinal and transverse fiber directions. This shows a uniform stretching of the fibers. This results in fiber tapes with reduced variations in fineness, an increased fiber orientation in the tape and an increase in the average fiber length. The tensile strength of the composites produced from these fiber tapes shows an improvement in strength, which can be attributed to the reduced fiber damage and the increased uniformity of the fiber tape. The reduced fiber damage is the result of increased elastic deformation of the roller surfaces, which leads to an increase in the contact area with the fibers. This distributes the acting forces over a larger area, reducing local stress peaks on the fibers. This also promotes better interlocking of the fibers, which means that the tangential rotational forces are transferred to the fibers more efficiently.

In summary, as a result of the project work, the processing of recycled carbon fibres (rCF) into high-performance fiber tapes was successfully realized with the development of coatings for drafting rollers. This is a significant contribution to an effi cient circular economy. ■