Leibniz-Institut für Polymerforschung Dresden

APPLICATION OF A VARIABLE-AXIAL FIBER DESIGN

Torque arm

Continuous glass fiber reinforced thermoplastics meet the demands of high impact resistance, high fiber parallel modulus and strength as well as fast production cycle capabilities and low material costs. Furthermore, these materials exhibit a much better recyclability compared to continuous fiber reinforced thermosets.

Optional functional components can be easily applied by various injection molding processes. However, due to the high melt viscosity of the thermoplastic matrix and an inadequate sizing of commercially available glass fibers, fiber wetting is more complex than with thermosets. The most promising process for achieving a homogeneous fiber/matrix distribution are online spun hybrid yarns in which matrix and reinforcing fibers are homogeneously mixed during the melt spinning process and a tailored sizing can directly be applied.

The full potential of these materials can only be exploited in complex components by a load case adapted variable axial fiber pattern.

New

- On-line spun glass fiber / PA 6.6 hybrid yarn
- Combination of continuous glass fiber reinforced PA 6.6 with short glass fiber reinforced PA 6.6
- Tailored sizing of glass fibers
- Variable-axial load adapted fiber layout made by Tailored Fiber Placement

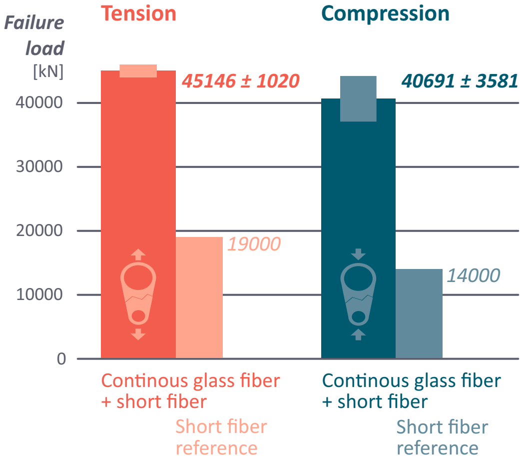
Continuous glass fiber reinforced thermoplastic demonstrator using advanced manufacturing and design technologies

To demonstrate the potential of continuous glass fiber reinforced thermoplastics (GFRP), a torque arm was chosen as demonstrator within a "ZIM" research project funded by German government. In cooperation with different research institutes and SMEs material properties, manufacturing conditions and part design methods were developed and evaluated.

The main objective of the IPF Dresden was the development of a spinning process for a glass fiber (GF) polyamide (PA) 6.6 hybrid yarn as well as the application of new and adequate sizing. Furthermore, novel in-house developed software tools for fiber layout and mold design have been applied.

Torque arm made of glass fiber reinforced thermoplastic composite material

Left: TFP preform
Middle: After hot press molding
Right: Final part – short fiber GF / PA 6.6 coated by injection molding



Due to the sophisticated manufacturing process of the hybrid yarn, outstanding mechanical properties in terms of fiber on-axis and off-axis modulus and strength could be obtained. Using the Tailored Fiber Placement (TFP) technology for preform manufacturing and a thickness adapted hot pressing mold, a prototype torque arm with a stress adapted variable-axial fiber layout was manufactured. With this approach, the outstanding material properties could be fully utilized for to this part.

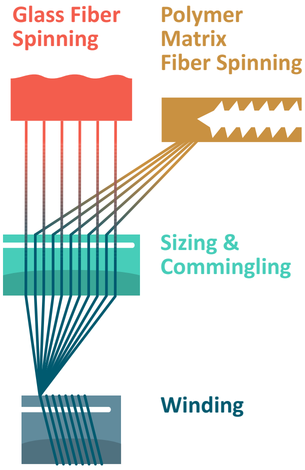
The homogeneous fiber matrix distribution and the stress-adapted, ondulation-free fiber layout enabled an increase in stiffness and strength of approx. 120 % compared to the GF / PA 30 reference part with the same geometry.

Work flow GF / PA 6.6 torque arm

STEP 1

Development of an on-line spun GF / PA 6.6 hybrid yarn with adapted sizing

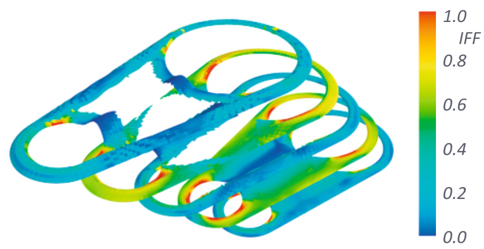
- No fiber damage during hybrid yarn production
- Uniform distribution of GF and PA 6.6 filaments
- Significantly improved fiber matrix adhesion
- No additional manufacturing steps required
- Variable axial load adapted fiber layout made by Tailored Fiber Placement



STEP 2

Structural design by using the design software tool AOPS

- Automated derivation of a fiber pattern according to the principal stress directions
- Automated generation of a 3D-FE model considering variable-axial fiber orientation and thickness distribution
- Layerwise numerical analysis of fiber failure and inter fiber failure according to Cuntze Failure Mode Criteria (FMC)



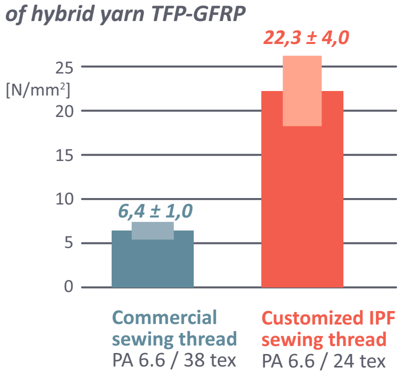
Layerwise inter fiber failure analysis according to FMC (iff)

STEP 3

Manufacturing of the preform by application of TFP technology

- Textile preform with a complex curvilinear fiber pattern
- Use of a customized PA 6.6 sewing thread with tailored sizing for GF / PA 6.6 composites

Transverse tensile strength of hybrid yarn TFP-GFRP



Customized sewing thread: significantly increased transverse tensile strength

STEP 4

CAD mold design enabled by automatically created surface topography

- Surface topography is numerically derived based on the predefined fiber pattern and the applied roving material

STEP 5

Hot mold pressing and finishing

- Extraordinary part quality in terms of surface quality, void content, fiber orientation and fiber matrix distribution due to the use of a thickness adapted press mold

Cross sectional view showing a homogeneous fiber / matrix distribution

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