Univ.-Prof.

Prof. h.c. (Moscow State Univ.)

Dr.-Ing. Dipl.-Wirt. Ing.

Thomas Gries

Head of Institute

Lukas Lechthaler

Scientific Assistant

My Sign: LL

10.12.2018

Project title: CarboYarn - Technologischer Vergleich von Spinnverfahren zur Herstellung von rCF-Stapelfasergarnen
Research Agencies: ITV Denkendorf, ITA RWTH Aachen University
Running Time: 1/2018 – 12/2019
Conveyor Carrier: Aif

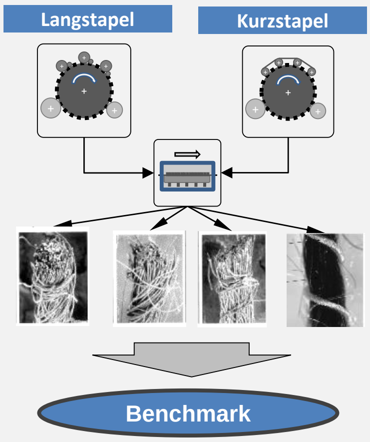
Central image of the AiF-Project CarboYarn

Problem: Eignung von Garnherstellungsverfahren zum Recycling von Carbonstapelfasern unbekannt

Stand der Technik:

- hohe Abfallkosten bei Weiterverarbeitung von Carbonfasern
- starke Konzentration der Forschung auf rCF-Vliese
- Isotrope Faserablage in Vliesen → geringe Festigkeit
- grundlegende Eignung von Spinnverfahren zur Herstellung von rCF-Garnen

Vorgehensweise:



Ergebnis:

- Wirtschaftlichkeit: maximal 80 % der Prozesskosten im Vergleich zum Roving
- Bauteilfestigkeit: durch rCF-Garne mindestens 80 % im Vergleich zum Roving
- Bewertung der prozessbedingten Faserschädigung

Relevanz:

- weltweit steigende Carbonfaserproduktion (2014: 59.000 t/a → 2020: 200.000 t/a)
- Schärfere rechtliche Rahmenbedingungen (Recyclingquoten, CO2-Emissionen)
- Potentieller Umsatz für rCF: 87 Mio. € in EU, mindestens 25 Mio. € in DE

Issue

The use of carbon fibre reinforced plastics (CFRP) in the aerospace, automotive and mechanical engineering sectors will lead to a sharp increase in the number of end-of-life (EoL) components to be recycled in the coming years (service life approx. 10 - 30 years). A fiber demand of 130,000 t is forecast by 2020 (Figure 1, left). The expected annual growth in the demand for carbon fibers (C-fibers) is between 12 and 15 %.

At the same time, the amount of dry C-fiber waste is also increasing. At present, the fibre ratio in the production of CFRP is up to 40 %. On the other hand, there is a high energy requirement of approx. 700 MJ/kgC fiber for the production of C fibers. This results in a considerably poorer CO2 balance when C-fibers are used in a single fiber than when steel or aluminum are used (Figure 1, right).

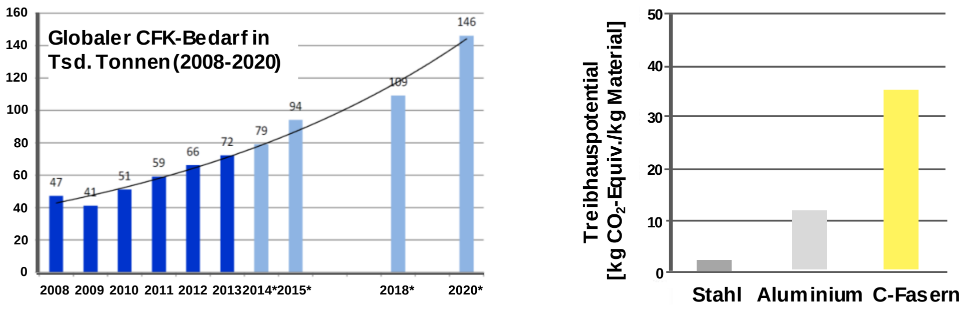


Figure 1: Global CFRP demand (left) and global warming potential (right)

Closing the material cycle when C-fibres are used is therefore an essential economic and ecological prerequisite for increasing the resource and energy efficiency of CFRP. This increase in efficiency is already demanded by the legislator through a landfill ban and the EU End of Life Vehicles Ordinance.

C-fibres (rCF) recovered through recycling are up to 64% cheaper than new filaments (12 €/kg instead of approx. 30 €/kg). However, the disadvantage is that rCF always have a finite length due to the process. The reason for this is that the majority of fibre composite components have to be crushed in order to be processed economically with existing recycling processes and machines.

Due to a lack of processes, fibre waste from CFRP production is therefore mainly used as ground material for injection moulding applications or processed into flat semi-finished products, such as undirected staple fibre fleeces. Both options lead to downcycling of C fibres, as the excellent structural-mechanical performance level of the original filament fibre can no longer be used due to a lack of fibre orientation.

<u>Goal and approach</u>

The aim of the planned research project is therefore the holistic investigation of the material recycling of recycled C-fibres in the form of staple fibre yarns instead of filaments in structural fibre composite applications. The approach is to investigate the suitability of established and special spinning processes for the production of rCF staple fibre yarns on the basis of a common spinning preparation.

For this purpose, the recycled C-fibres will be spun into staple fibre yarns in combination with thermoplastic matrix fibres. Staple fiber yarns enable a higher orientation of the C-fibers in the textile compared to a nonwoven. In this way, the high structural-mechanical performance potential of the C-fibres in structural fibre composite applications can be maintained and downcycling of the fibre properties prevented. Furthermore, the thread-like shape of the yarns, similar to that of a roving, makes it possible to further process recycled C-fibres into fabrics, scrims, braids or by winding. A holistic investigation of the suitability of different established staple fibre spinning processes for the

recycling of rCF has not yet been carried out. It has not yet been researched which yarn properties can be achieved by different spinning processes in the processing of recycled C-fibres. In particular, the high transverse force sensitivity of the C-fibres poses a challenge during spinning. Therefore, the performance limits of the individual spinning processes still have to be defined. In addition, the project aims to achieve process costs for component production of approx. 80 % compared to the use of a filament.
Furthermore, it is unknown which component properties can be achieved by the different yarn structures. In particular, the properties of fibre composite components are presumably influenced by the different hairiness and twist coefficients of the individual yarn structures. The rCF yarns produced in the project are tested in test specimens for their potential for use in fibre composite components. The goal is a component strength by rCF yarns of at least 80 % (tensile strength, bending load) compared to a 12k roving.

Economic Importance and Benefits

Currently, around 59,000 tons of carbon fibers (vCF) are produced annually worldwide. A production volume of 200,000 t is expected for 2020. The resulting increase in the amount of carbon fiber waste (2015: 30,200 t) represents a challenge for many fiber and end product manufacturers. Already during further processing, approx. 30 % of the carbon fibers produced are primary waste. With an average fiber price of 20 €/kg for vCF, high additional costs arise. Furthermore, higher recycling rates of up to 95 % will have to be met in future due to increasingly stringent legal framework conditions (ban on landfilling, reduction of CO_2 emissions, EU End-of-Life Vehicles Ordinance). By reusing recycled carbon fibres (rCF), a potential turnover of € 87 million (€ 12/kg rCF) can currently be expected in Europe.
The use of recycled carbon fibres (rCF) has already been the subject of research projects. The main focus is on the reuse of rCF in nonwoven form. However, due to isotropic fiber deposition and short fiber lengths, only low strength characteristics can be achieved compared to vCF. rCF nonwovens are not suitable for use in fiber composite structural components. If rCF is used in the form of staple fibre yarns, higher strengths can be achieved than with rCF nonwovens due to the higher orientation of the fibres in yarn structures. The basic suitability of different spinning processes for the production of rCF yarns has already been investigated in previous research projects. A benchmark of the individual processes with regard to the most gentle possible process control, economic efficiency and mechanical component properties has not yet been carried out.

Solution:

Processing in recycling processes increasingly reduces the staple length of carbon fibers. For this reason, the benchmark for a short and long staple process line is carried out. The opening and strip formation of the rCF is carried out both by a carding process (long stack) and by carding (short stack). The stretching of the fiber slivers is carried out on a needle bar draw frame. Afterwards, rCF staple fiber yarns are produced in rotor, air, wrap

and friction spinning processes. Finally, the produced yarns are mechanically tested and evaluated. The process-related damage to the fibres is recorded throughout the entire process chain. The aim of the project is to achieve a component strength through rCF yarns of at least 80% compared to filament. Process lines are assessed as economical if they account for a maximum of 80 % of the costs of filament production.
The individual work packages will be divided equally between ITA and ITV. The distribution is based on the core competencies of both research institutes.

Acknowledgement
The research project 19814 N of AiF Projekt GmbH, Berlin is funded by the Federal Ministry of Economics and Energy within the framework of the Forschungskuratoriums Textil e.V. on the basis of a decision of the German Bundestag.

Contact
Lukas Lechthaler
Lukas.lechthaler@ita.rwth-aachen.de
0241 – 80 – 247 06