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The CAE chain for Filament Winding

For centuries, bamboo poles have been joined by winding ropes around them to create durable yet lightweight load-bearing structures. At the wbk Institute of Production Science at the Karlsruhe Institute of Technology (KIT), 6-axis robots are now being used to wrap carbon fibers around hollow profiles made of fiber-reinforced composites. The joining technology of this highly automated filament winding process opens up new, resource-efficient and cost-effective possibilities for lightweighting framework constructions and supporting structures and for mobility on wheels.

The Development Agency for Lightweighting Baden-Württemberg presents this innovation in the February 2020 edition of the ThinKing. Leichtbau BW GmbH uses this label to showcase excellent lightweight technology products or services from Baden-Württemberg every month.

At a glance:

- Filament winding for **joining profiles** made of fiber-reinforced composites
- **Highly automated** winding process due to **complete CAE chain**
- Application of material in line with the load path, therefore **particularly resource-efficient**
- **Non-destructive** joining process
- **Cost savings** in the weight-reduced end product

Thanks to a continuous virtual process chain (CAE chain), the flexible **joining process** involving filament winding offers new possibilities for the production of lightweight hollow profiles. The idea is based on bamboo joining techniques which have been used successfully in Asia for centuries. The bamboo poles are joined by crossing and winding ropes around the nodal points of the poles (cf. illustration).

Frameworks formed of hollow profiles or supporting structures (frame constructions) made of hybrid, fiber-reinforced plastics offer a great potential for lightweighting while at the same time possessing very good mechanical properties – however, the joining technique for two profiles that meet at an angle still represents a great challenge, as none of the known joining techniques are able to securely join the profiles without limitation.

Highly automated process

At the wbk Institute of Production Science at the Karlsruhe Institute of Technology (KIT), 6-axis robots are now being used to wrap carbon fibers around hollow profiles made of fiber-reinforced composites. What is special about this is not only the joining technique itself, but also the continuous mapping of the process in a **complete CAE process chain**. The winding process can be designed, planned and conducted via a graphical user interface. This includes calculating the winding pattern, designing the connections according to FEM and simulating the movements of the winding robot.

“The production unit is a complex, comprehensive technical system that could be used as a whole by end users for the assembly of profiles. Due to its modular design, the system can be flexibly adapted to the task at hand”, says Marius Dackweiler, Research Associate at the wbk Institute at the KIT.

As well as the **complete CAE chain**, a model-based method of synchronizing robot movement and winding-ring rotation has been developed in the last few years. This ensures that the **actual winding movements always correspond to the modelled movements** or that, in case of deviations, the intended movements are quickly restored. In addition, the fiber pretensioning system has been extended to include a pressure sensor-based control unit to allow for a more even distribution of the tension.

“Moreover, the process is **particularly resource-efficient**, as the fibers can be deposited in line with the load path, so that a particularly small amount of material is consumed,” says Dackweiler, describing an important advantage of the new technology. In this case, being optimally designed for a given load path means that, during joining, fibers are only deposited where they are needed for the load-bearing capacity of the entire system. There is hardly any real alternative. Dackweiler explains: “Traditional joining techniques such as gluing, welding or screwing either **perform worse, destroy the fiber structures or cannot be used for duromere fiber composite profiles**.”

Many possible applications for lightweight structures

Considering their load-bearing capacity, framework structures generally have a low net weight compared to other common construction methods. The joining technique could therefore make it possible to have particularly light, rigid and at the same time **cost-effective truss structures**, especially in the construction and crane industry. Crane booms, for example, are usually made using metal profiles or elaborate, metal node elements. These metal node elements are replaced by filaments that are wound in line with the load path. The result is a structure of lightweight profiles that, when joined using the filament winding process, experiences a significant weight reduction.

Further applications are conceivable in automotive and two-wheeler construction. In these industries, space frames for chassis are used as so-called lattice frames. “The charm of this joining process lies in the fact that **no damage** is caused to the sophisticated fiber composite profiles during joining, as would be the case with welding or screwing,” Dackweiler explains.

The progress made in the past two years means that full automation for potential customers is now possible, making this a major step on the path to series production. Already today, a fully functional prototype exists, for which reason the wbk Institute is currently **looking for a partner for industrial implementation**.

(ca. 5.500 characters incl. spaces)

About the wbk Institute of Production Science at the KIT

With almost 100 employees, the wbk Institute of Production Science at the Karlsruhe Institute of Technology (KIT) forms part of the Faculty of Mechanical Engineering. The three departments, Manufacturing and Material Engineering; Machines, Equipment and Process Automation; and Production Systems, headed by Prof. Dr.-Ing. habil. Volker Schulze, Prof. Dr.-Ing. Jürgen Fleischer and Prof. Dr.-Ing. Gisela Lanza respectively, focus on applied research, education and innovation in production science at the KIT. www.wbk.kit.edu

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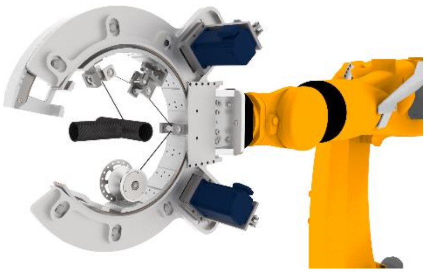
Photographs



Prototype1.jpg and Prototype2.jpg

6-axis robot with open C-arm as EoAT (End-of-Arm-Tooling) for filament winding.

Prototype3.jpg:

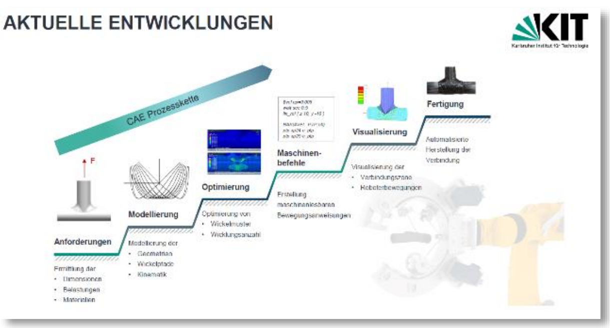
When using filament winding as the joining method, the crossed profiles are in the center of the open C-arm.

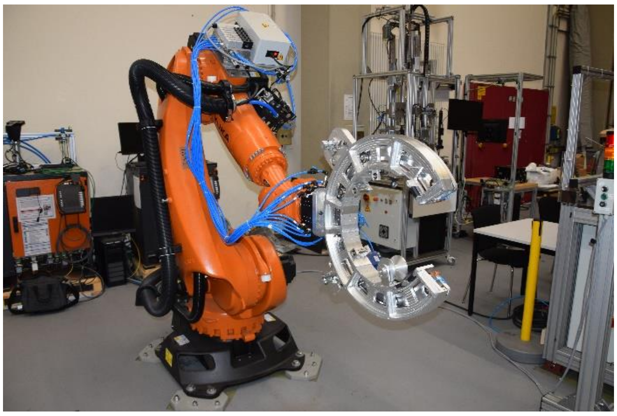
FilamentWinding.jpg:

Unlike welding and screwing, filament winding does not damage the material.

CAE.jpg:

The complete CAE chain for the process of joining hollow profiles through filament winding was finalized last year: Requirements can now be stored in the tool and the optimized windings as well as the wind paths of the robot and of the winding ring can now be integrated into a master control system.





Prototype4.jpg:

A fully functional prototype has already been developed. The wbk is now looking for a partner for industrial implementation.

Source: wbk Institute KIT. Reprint free of charge.