Development of durable FRP based on tailored 3D woven fabrics

T.A.M. Huynh[1], J. Pilgrim[1], T. Gereke[1], D. Nuß[1], P. Krzikalla[2], C. Brauner[2], C. Cherif[1]

[1] TUD Dresden University of Technology, Faculty of Mechanical Science and Engineering, Institute of Textile Machinery and High Performance Material Technology (ITM), 01069 Dresden, Germany, e-mail: thi_anh_my.huynh@tu-dresden.de

[2] University of Applied Sciences and Arts Northwest Switzerland (FHNW), Windisch (Switzerland)

Abstract: The resource efficiency utilization through weight reduction in the mobility industry compels the substitution from conventional metallic structural materials towards high-performance fiber-reinforced polymers (FRP) like glass or carbon fibers combined with a polymeric matrix material. FRPs, with their outstanding strength-to-weight ratio, fatigue resistance, and specific natural frequency properties, are particularly suitable for applications exposed to dynamic loads, such as those encountered in airplanes, cars, or trucks [1]. Currently, these FRPs, including leaf springs, car body pillars, and other mechanical parts, are manufactured through a complex sequential preforming process, which frequently proves to be both time- and cost-intensive. Additionally, adverse incidents during this complex production, such as wrinkling, deviations in the load-bearing direction, and delamination, may also occur. The development of tailored 3D woven fabrics with integrating reinforcement in the z-direction offers a solution to these deficiencies.

Keywords: *high-performance fiber-reinforced polymers, durable FRP, tailored 3D woven fabric*

The application of the new shedding technique with double-flat-steel healds enables a stacked arrangement of the warp yarns, aimed at increasing the warp yarn density while reducing friction between threads during weaving. Thereby, a z-reinforcement can be incorporated to unite the layers, effectively absorbing shear loads and reducing the risk of delamination failure in the FRP component. The fiber volume content in the X, Y, and Z directions can be flexibly tailored to meet precise specifications, regardless the number of layers. This advancement facilitates the development of near-net-shape 3D preforms, known as tailored 3D woven fabric [2].

To achieve the project's objective, a simulation chain comprising numerical models is established to analyze the developed textile structure, including the consideration of fiber orientation. Subsequently, this structural model will be integrated into the composite model to analyze its mechanical behavior, adapting different load cases. This virtual analysis will serve for reducing the need for trial-and-error approaches during the development stage. In the findings, a near-net-shape 3D woven preform with high durability performance will be produced, minimizing both cost and time requirements. This concept offers significant improvements applicable not only to FRP leaf springs but also to all investigations carried out on generic structures and general load cases. It also aims to benefit many applications with low geometrical complexity but high demands towards load-bearing properties. Examples include beams, struts, and other component substitutions in the area of mobility, wind energy or mechanical engineering.

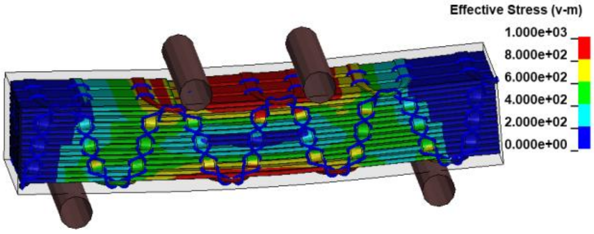

Figure 1: Bending test simulation of FRP from 3D tailored woven fabric

ACKNOWLEDGEMENT:

The IGF research project 330 EBR of the Forschungsvereinigung Forschungskuratorium Textil e. V. is funded through the DLR within the program for supporting the „Industrielle Gemeinschaftsforschung (IGF)“ from funds of the Federal Ministry for Economic Affairs and Climate Action (BMWK) by a resolution of the German Bundestag.

REFERENCES

[1] „Industrie anzeiger,“ Mubea, 10 10 2017. [Online]. Available: https://industrieanzeiger.industrie.de/top-news/composite-blattfeder-schlaegt-stahlfeder/. [Zugriff am 17 04 2024].

[2] W. D. S. C. H. G. Vorhof M., „New method for warp yarn arrangement and algorithm for pattern coversion for three-dimensional woven multilayered fabric,“ *Jounal of Industrial Textiles* , pp. 1334-1356, 2020.