Injection overmolding of aircraft components

R. Fachtan, M. Mühlbacher, T. Neumeyer and H. Ruckdäschel

Neue Materialien Bayreuth

Abstract

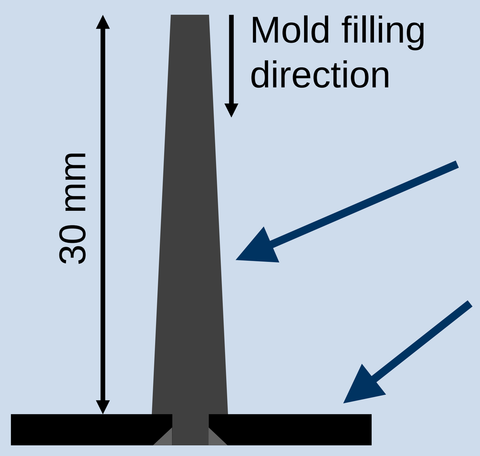
This poster shows the results of a study examining strategies to enhance the adhesive strength of rib-overmolded CFRP structures based on a high-performance thermoplastic polymer matrix by introducing a rivet-like form-fit bonding between rib foot and laminate. For this purpose, different breakthrough geometries are milled into the laminate in the area of the rib foot base and are filled during injection overmolding. This approach seems particularly appealing due to its flexibility since the form closure is realized within the laminate with no need to adjust the injection mold design. Unfortunately the procedural hurdle of an insufficient ventilation leading to voids within the rivet-like structure fails this approach.

Motivation and Objectives

To shorten process chains for aircraft components the use of thermoplastic fiber composites in combination with function integration via injection molding - especially one-step injection overmolding - is currently under investigation [1]. This approach combines forming of thermoplastic laminates and subsequent injection molding of reinforcing structures (e.g. ribs) or other functional integrations [2]. For aerospace components, however, the use of high-performance thermoplastics is required, for which these processes are not yet state of the art. The objective of this study is to achieve locally increased connection strength of the overmolded ribs to the laminate through form-fit bonding (form closure).

Adhesion by form closure – A challenging approach

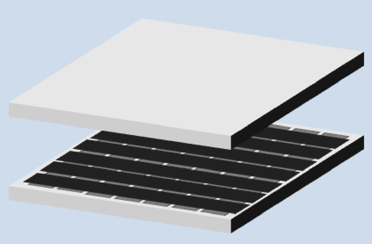
Materials



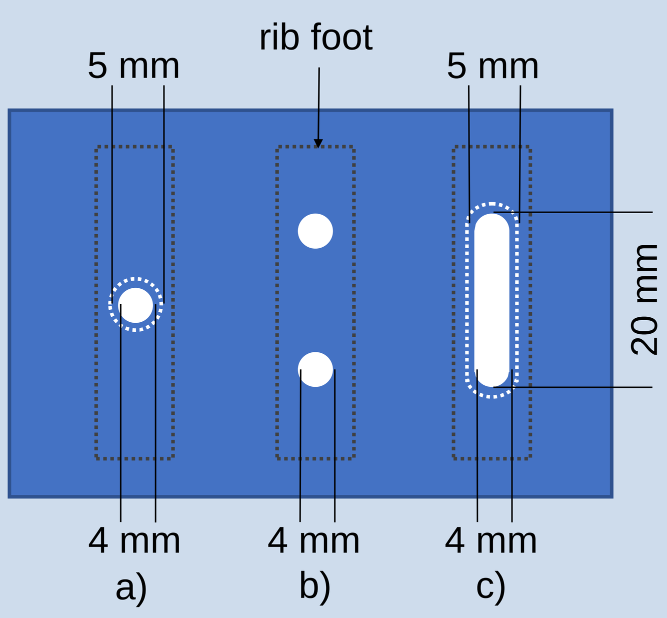
Injection Overmolding Mass: PEKK-CF30 (Arkema Kepstan® 8010C30, PEKK/CF 30 wt. %)

UD-tapes for laminates: PEKK-CF UD-tape (HexPly® PEKK/34%/UD194/AS7, PEKK/CF 60 vol. %)

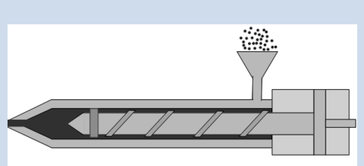
Processing



1. Step:
Consolidation of $[45/0/45/90]_{3s}$ layups in a static hot press (380°C, 10 bar, 30 min).

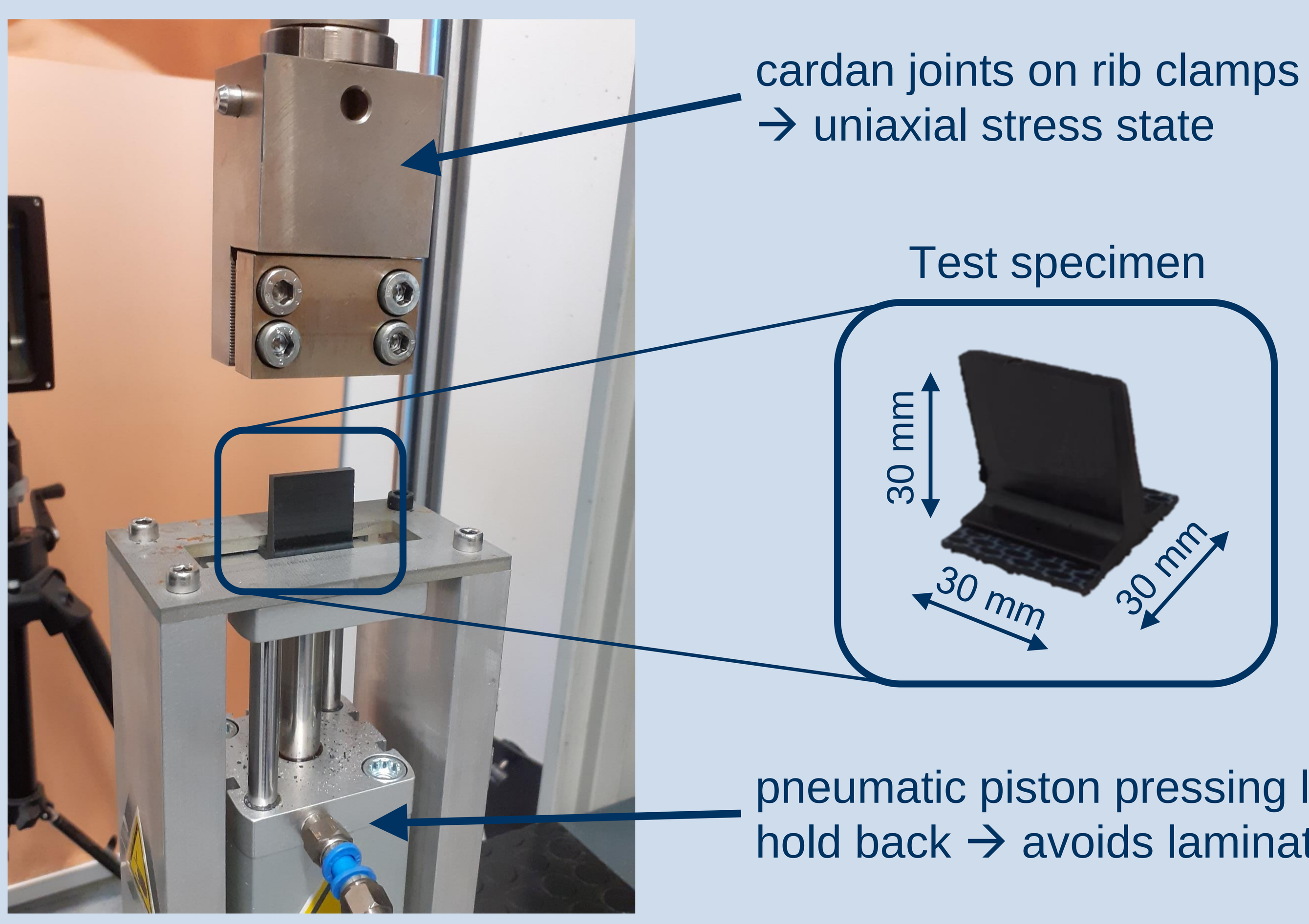


2. Step:
Preparation of different breakthrough geometries into laminate by CNC milling
- a) Single, centered hole with Ø = 4 mm with and without chamfer at bottom side
- b) Two holes Ø = 4 mm
- c) Sloped hole (20 mm x 4 mm) with and without chamfer at bottom side



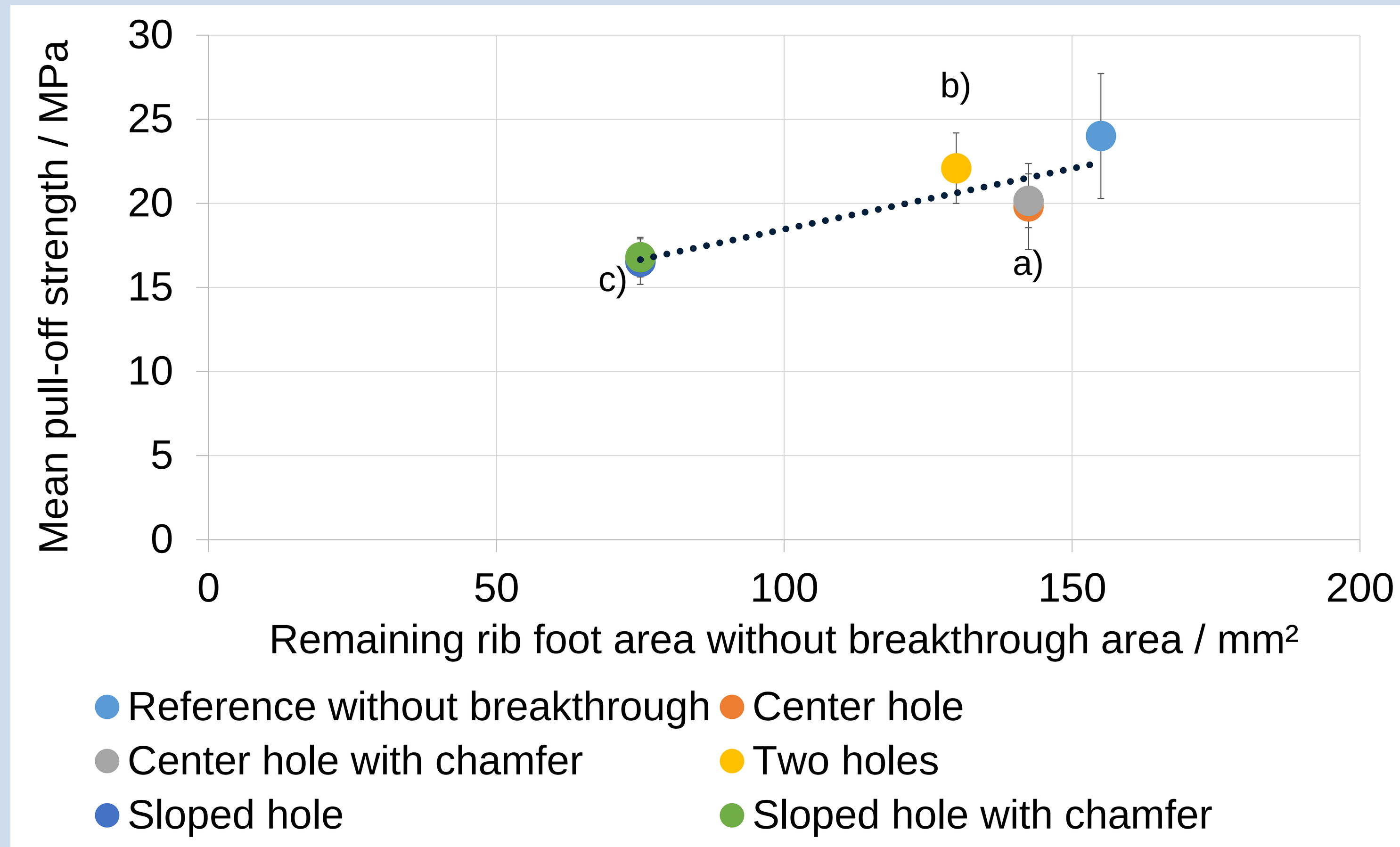
3. Step:
Rib-overmolding of preheated laminates (400°C; IR-fields) in one-step overmolding at 230°C or 250°C mold temperature

Testing – Customized uniaxial rib pull-off rig

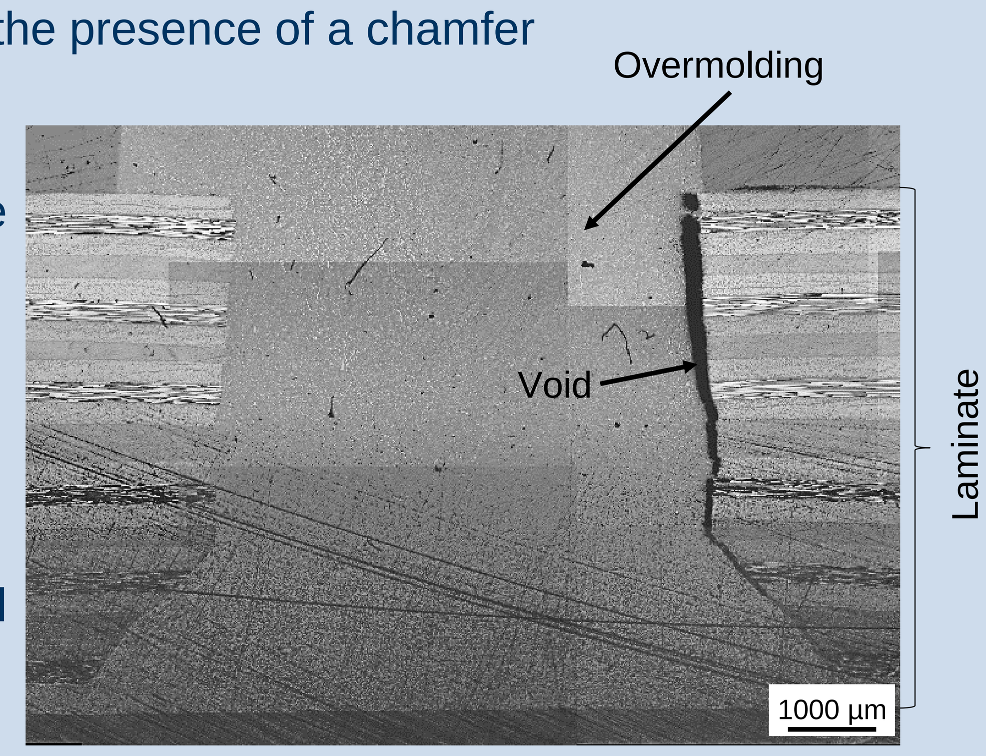


Results & Discussion

- All of the samples with form closure show an unexpected decrease in pull-off strength compared to the reference with only material closure (reference)



- Examinations of the fracture surfaces of the specimens with form closure show that failure starts in the rivet-like breakthrough structures
- The crack then propagates from this point upwards and develops to an interlaminar failure of the remaining laminate below the rib foots base
- This is observed independently of the presence of a chamfer



- Cross-sectional microscopic evaluations show air pockets in the rivet-like structures
  → insufficient venting of the small structures
  → significantly reduced strength of the rivet-like structure
- Resulting pull-off strength can be traced back to remaining interfacial area between rib foot base and laminate

The insufficient venting causes process-induced defects leading to an early failure. Nevertheless a full pullout of the rivet-like structure from the laminate has not been observed in any test. This indicates a good adhesion to the walls of the breakthrough geometry, when intimate contact is realized.

Conclusions

- **A locally increased adhesion of overmolded ribs to the carrier by creating breakthrough structures inside the laminate to form rivet-like structures with form closure fails in this approach due to procedural hurdles.**
- **To avoid insufficient ventilation in those break-throughs adjustments to the injection mold design would be required. This would result in the flexibility of the approach examined here being lost completely.**

References and Notes

[1] M. Kropka et al., „From UD-tape to Final Part – A Comprehensive Approach Towards Thermoplastic Composites," Procedia CIRP, p. 96–100, 2017.

[2] H. Lengsfeld et al., Composite Technology - Prepregs and Monolithic Part Fabrication Technologies, Munich: Hanser Publications, 2021.

Acknowledgement

The authors gratefully acknowledge the support of the StMWi for the kindly funding (LABAY110B) aswell as the support of the project partner Christian Karl Siebenwurst GmbH & Co. KG, the associated project partners Airbus Helicopters Deutschland GmbH and Hexcel Composites GmbH and Arkema S.A. for the provision of the injection molding grades.

Neue Materialien Bayreuth GmbH • Gottlieb-Keim-Straße 60 • 95448 Bayreuth • Germany
Contact person: Dipl.Ing. Robin Fachtan • Email: robin.fachtan@nmbgmbh.de • www.nmbgmbh.de

Sponsored by
Bavarian Ministry of Economic Affairs, Regional Development and Energy