Friedrich-Alexander-Universität Erlangen-Nürnberg

LEHRSTUHL FÜR KUNSTSTOFFTECHNIK
Prof. Dr.-Ing. Dietmar Drummer

Joining using Pin Structures

Motivation

In times of climate change, intelligent lightweight construction can help reducing the CO_2 emissions in the transportation sector and especially the aviation industry. For this purpose, the combination of different materials such as different incompatible polymers or fiber reinforced thermoplastics to multi-material hybrid components can combine superior properties of different materials that could not be achieved with mono material parts (Fig. 1). Due to chemical incompatibilities and different physical properties, such as thermal expansion coefficient of the different materials, the joining operation itself is the main challenge within this approach. Therefore, a demand for flexible and cost effective joining strategies for multi-material joints is apparent.

Fig. 1: Polymer door module in steel door main structure

Application

One promising approach to this challenge is the use of pin structures in one joining partner that can be embedded in the second, locally heated thermoplastic joining partner. These structures can either be located on a metal component, for metal-composite joints or on a polymer component for adhesion-incompatible polymer connections (Fig. 2). The pin structures can directly be generated in the primary forming process or subsequently by a further forming or structuring step.

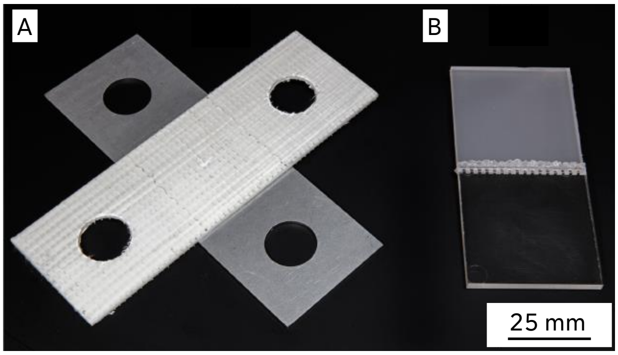

Fig. 2: Form-fit pin connections using pin structures:
A) cross-head joint, polymer-metal
B) butt joint, adhesion-incompatible polymers

[1]: *Brose Fahrzeugteile SE & Co. KG*

| Institute of Polymer Technology
| Am Weichselgarten 10 | 91058 Erlangen-Tennenlohe, Germany
| Phone: +49 9131 85 710 00 | Fax: +49 9131 85 710 07
| Mail: lkt-info@fau.de | https://www.lkt.tf.fau.eu/

Research focus

The focus of research in the field of joining using pin structures lies in the process development and the investigation of the fundamental mechanisms, such as fiber displacement, flow and filling characteristics, and (micro-)mechanical behavior, to create an in-depth understanding of the process. Hereby, existing interactions between material, (pin) geometry, process and resulting joint properties are to be developed and joining strategies for optimized connections using pin structures for multi-material joints are to be derived.

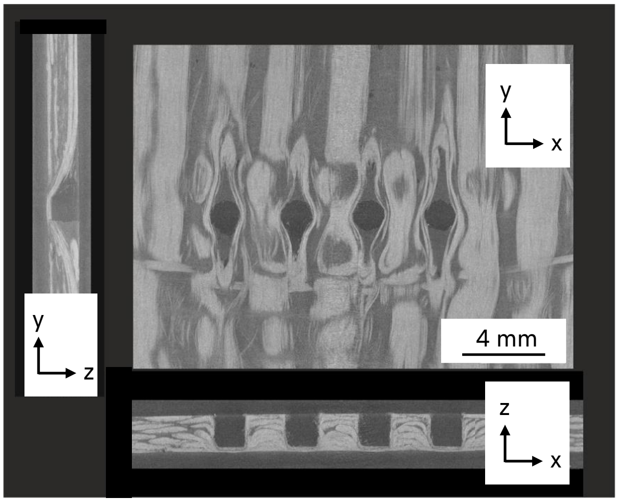

Fig. 3: Computed tomography images of a 1D pin array of metal pins in a glass fiber polymer composite

Main research results

The fiber displacement in metal-composite joining via pin structures is initially dominated by a fiber and matrix displacement along the direction of pin insertion. Following, during reconsolidation stage, a lateral matrix and fiber displacement fills voids, which leads to characteristic concave fiber orientations (Fig. 3). Fiber damage can be inhibited, with a sufficiently large heated area, so fibers can rearrange around the inserted pin structures.

The bond properties for joining polymer multi-material connections using pin structures depend in particular on the geometrical design of the structures and the filling behavior. While high filling is consistently achieved with amorphous thermoplastics (Fig. 4), the use of semi-crystalline thermoplastics requires a process adaptation due to shrinkage effects. For dimensioning the pin-foot width of the structures, the ratio of the base material strengths can be used. In addition to high bond qualities, the adhesion-incompatible connections are also characterized by their recyclability. In investigations, a complete and pure separation without material degradation was achieved.

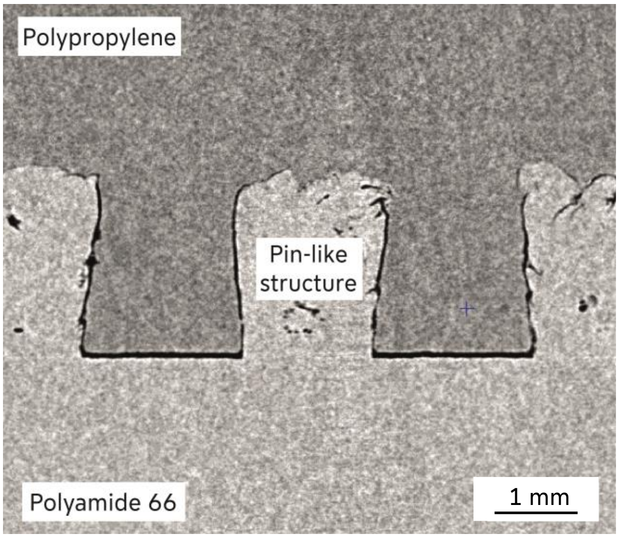

Fig. 4: Computed tomography image of a 1D pin array for an adhesion-incompatible polymer multi-material joint

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