LOAD ADJUSTED FIBER REINFORCED POLYMER/METAL JOINTS IN CATHODIC DIP PAINT CONDITIONS

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1. Introduction

The Flow Drill Joining Concept (FDJ), developed by the Institute of Lightweight Structures, allows the load adjusted joining of continuous fiber reinforced thermoplastics (FRP) and metallic sheets without auxiliary joining elements. As there is no scathe done to the fiber reinforcement, due to a radial realignment of the fibers during the process, high-strength joints with high lightweight potential can be easily realized [1].

In terms of their use in automotive lightweight construction, an important requirement for new joining technologies is the resistance to temperature loads and chemicals, applied in the production processes, e.g. in vehicle lacquering. Therefore, force flux aligned FDJ-joints were investigated in cross tension (DIN EN ISO 14272) and shear testings (DIN EN ISO 14273), after passing through a cathodic dip painting process.

2. Methods

2.1 Specification of Materials

In the current study, FDJ-joints made of continuous carbon fiber reinforced polyamide 6 (t = 2.4 mm) and a representative hot-dip-coated and galvanized micro-alloyed steel (HX420LAD, t = 1.5 mm) were examined. The thermoplastic FRP was made of unidirectional prepreg tapes (PA6-CF60), stacked and formed to a symmetric, orthotropic $[(0/90)_4]_s$-composite with a fiber volume content of 60%. The mechanic properties of both, the composite layers and the HX420LAD sheets are shown in Tab. 1.

Tab. 1: Mechanical properties of basis materials

	PA6-CF60	HX420LAD+Z100
Young's Modulus E_{II}	98.1 GPa	210 GPa
Tensile Strength σ_m	1938 MPa	470 - 590 MPa
Fiber content φ	0.6	-
Layer structure	$[(0/90)_4]_s$	-
Layer thickness t_L	0.15 mm	-
Sheet thickness t	2.4 mm	1.5 mm

2.2 Flow Drill Joining Concept

With the use of the automated FDJ process, the high lightweight potential of multi material designs with FRP and modern metal alloys can be utilized in a more efficient way. Compared to well known joining technologies like riveting or bolting, there is no negative affection of the basic materials by damaging the fiber structure due to machined boreholes or cutting edges of e.g. self-piercing rivetings. Furthermore, next to a renunciation of auxiliary joining elements, there are no cost-intensive operations, such as grinding, etching or degreasing, necessary.

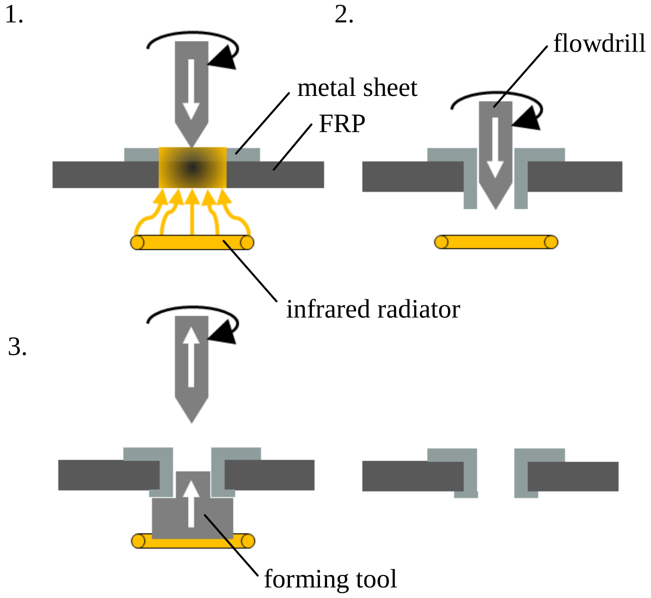

Fig.1: Principle of manufacturing a load adjusted FDJ-joint

The multi-stage joining process is shown schematically in Fig.1 and may be described by the three main steps:

1. Plasticizing of the thermoplastic matrix
2. Forming of a metallic bushing with a flowdrill
3. Forming of a closing head to realize a form lock between FRP and metal sheet

The rotating mandrel is applied to the upper side of the metallic sheet first, and forms the required bushing throughout the plasticized FRP in two phases afterwards. The first phase serves the heat influx to increase the plasticity of the metal sheet. By forming the bushing through the previously plasticized FRP, the containing reinforcing fibers are redirected tangentially, and therefore non-destructive, around the punctiform joint. The sectioned processing allows a defined energy input into the metallic part, to guarantee a high quality of the bushing for every material. In a final step, the bushing is folded by a forming tool to obtain a traction and form lock between the two basic materials.

As a result of the process-induced fiber realignment and the displacement of the thermoplastic matrix, a local accumulation of material occurs in the fringe of the joining area. According to that, FDJ joints contain, in contrast to established technologies, a process-related reinforcement in the critical areas next to the joint [2].

The process parameters of the FDJ-joints used in this study are summarized in Tab.2.

Tab. 2: Process parameters FDJ-joints

	Value	Unit
Sheet thickness t	2.4/1.5	mm
Diameter of the joint d_p	5.3	mm
Diameter of the melting area d_s	20	mm
Rotational speed n	3000	U/min
Feed rate 1 v_1	300	mm/min
Feed rate 2 v_2	1300	mm/min
Change-over point l	1.0	mm
Forming force F_U	18	kN

2.3 Cathodic Dip Painting

The cathodic dip painting (CDP) is an electrochemical coating process, which has proven itself a very uniform coating of metal surfaces and cavities with consistent layer thicknesses and good surface qualities in vehicle construction. The CDP primer is used to protect structures against corrosion and serves as an adhesion base for subsequent coatings.

Due to the inconsistent temperature profile, with top temperatures in the range of 130 to 190 °C, and the highly divergent coefficients of thermal expansion in FRP and metals, the baking of lacquers represents a particularly critical load for joints in multi material design. Thus, thermally induced residual stresses can lead to damages if the joining technology is not suitable for CDP treatments.

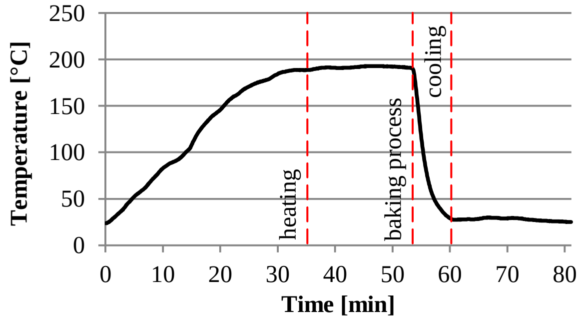

Fig.2: Temperature profile of tested CDP treatment

The traversed temperature profile of the tested CDP process shows an approximately 35 minutes lasting, steady heating of the specimen. As to be seen in Fig.2 the duration of the baking process with a maximum temperature of 190 °C (±2.8 °C) takes about 20 minutes, followed by a rapid cooling to 29 °C (±3.9 °C) within about 10 minutes.

3. Results

The results of the cross tension and shear testings in accordance to DIN EN ISO 14272 and 14273 confirm the high strength and strong resistance of FDJ joints against thermal and medial loads within the cathodic dip painting process.

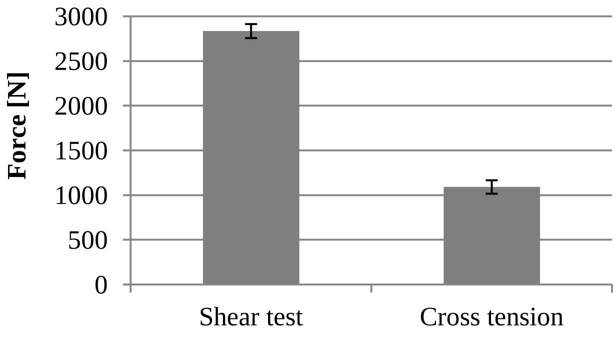

Fig.7: Results of shear and cross tension tests

With tolerable shear loads of approximately 2.8 kN and cross tension forces of about 1.1 kN after passing the CDP treatment, FDJ joints seem suitable for highly loaded body parts in modern car concepts.

4. Conclusion

The findings of the current study show a particular suitability of the novel Flow Drill Joining Concept for the manufacturing of structural automotive parts in multi material design with fiber reinforced thermoplastics and metal sheets. In addition to a load adapted design of the joining zones, the stability of the high-strength FDJ joints against thermal and medial influences during electrochemical coating and baking processes was proven in this study.

References

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