On the capabilities of static resistance welding of carbon fiber-reinforced thermoplastic composites

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Excerpt on the capabilities of the static resistance welding process at test bench level, as well as applied in the automated assembly of fiber composite structures in an exemplary representation of the thermoplastic rear pressure bulkhead and the Multifunctional Fuselage Demonstrator (MFFD) upper shell.

Towards increased maturity

Welding technologies for the assembly of carbon fiber-reinforced thermoplastics (CFR-TP`s) offer enormous potential for the production of fast, reliable and material-compatible joints forming an integral assembly. Static resistance welding is one of the most mature and yet often underestimated joining technologies for thermoplastic composites. Extensive research has been carried out to increase the robustness, reliability and range of applications of the static resistance welding process based on a carbon fiber heating element.

Extended opportunities

The most important requirements for the selection of a thermoplastic welding process can be summarized as:

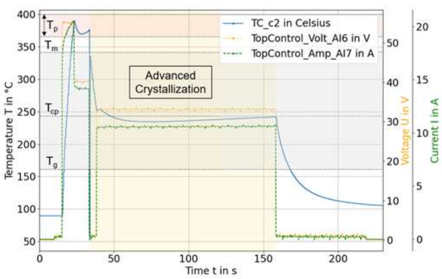
- Weld Seam Formation
- Weld Continuity
- Mechanical Performance
- Advanced Process Control
- Technological Applicability

To classify the mechanical performance, thermoplastic welding processes are compared with a co-consolidated or hot-pressed reference.

In both processes, highest joint properties are achieved by specifically controlling the factors of pressure, temperature and time.

Resistance welding allows to follow a defined temperature-time curve by selectively applying an electric current to a heating element. Within static resistance welding, a weld seam is produced in a defined, closed tool. This also enables precise control of the pressure according to the temperature-time curve, analogous to the processes used in the production of reference specimen.

Exemplary process cycle for static resistance welding of carbon fiber-reinforced polyetherketoneketone (CF/PEKK) at a sample weld area of (200.0 x 12.7) mm².



Due to locally initiated matrix melting at the weld line in combination with outstanding temperature control capabilities, resistance welding can be used to specifically influence the width of the heat-affected zone and the crystallinity.

A geometrical optimization of the heating element/ caul plate configuration allows besides full-surface connectivity of the welded components for a defined edge contour to decrease stress concentration towards the open cutting edge.

Applying the -6 dB criterion (according to AITM6-4010) for water-coupled ultrasonic testing at resistance welded joints resulted in a very high weld seam quality with a conformance area percentage (OK) of 99.6 % and a flaw area percentage of 0.4 %. However, flaw attenuation losses were found being very close to be conformant at (6.4 ± 0.2) dB.

The outstanding mechanical performance of resistance welded joints, demonstrating weld factors of up to 0.96 (single lap shear testing, according to AITM1-0019) was confirmed for various high-performance thermoplastics, e.g. polyphenylene sulfide (PPS), low-melt polyaryletherketone (LM-PAEK) or PEKK. Thus, mechanical characteristic values close to the reference level can be achieved.

The ability for the automated assembly of full-scale aerospace structures applying the resistance welding technology was demonstrated within the latest projects HoTStufF and MFFD. Thus, demonstrating a wide range of applications, from robot-based cleat integration to automated frame integration within the MFFD, up to 1.5 m weld lengths demonstrated for the world's first all-thermoplastic rear pressure bulkhead within HoTStufF.

Concluding remarks

Resistance welding for the assembly of high-performance CFR-TPs shows enormous potential for the production of an integral, high-quality welded assembly. Possibilities of preferential weld seam formation, weld seam continuity, mechanical performance, advanced process control and the applicability of static resistance welding for the assembly of full-scale aerospace components are highlighted.

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