Deliverable 4.2

Report on repair strategies

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Main contact:	Senne Sterk – senne.sterk@nlr.nl

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Title	*Deliverable 4.2 - Report on repair strategies*
Scope / purpose of deliverable	*This report describes the obtained test results and associated overall quality of the different repair techniques, applied on the material combinations under research. Composite-to-composite material and composite-to-flexible material combinations are analyzed for thermoplastics and thermosets*
Expected outcomes / contribution to impact	*The differences between the obtained results for the repair techniques under research are summarized. The outcome shows the possibilities for repair of thermoplastic and thermoset composites. Successful repair of composites lower replacement parts costs and utilizes 100% of the part lifetime*
Editor	*Senne Sterk – Senne.Sterk@nlr.nl* *Ruben Nahuis – Ruben.Nahuis@nlr.nl*
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006952

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ABBREVIATIONS

Acronym	Description
CF	Carbon Fibre
CMT	Cold Metal Transfer
CPT	Consolidated Ply Thickness
CTE	Coefficient of Thermal Expansion
EoL	End of Life
EPDM	Ethylene Propylene Diene Monomer Rubber
FKM	Fluorine Kautschuk Material
FRP	Fibre Reinforced Plastics
HPDC	High Pressure Die Casting
ILSS	Interlaminar Shear Strength
KET	Key Enabling Technology
KPI	Key Performance Indicator
LDED	Laser Directed Energy Deposition
LM-PAEK	Low Melting Poly Aryl Ether Ketone
LPBF	Laser Powder Bed Fusion
NDI	Non-Destructive Inspection
PMMA	Polymethyl Methacrylate
PPS	Poly Phenylene Sulfide
RPT	Roller Peeling Test
SHM	Structural Health Monitoring
SIPN	Semi-Interpenetrating Polymer Networks
SLS	Single Lap Shear
TEP	Thermal Expending Particles
TP	Thermoplastic Composite
UD	Uni Directional
WAAM	Wire Arc Additive Manufacturing

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2 PUBLISHABLE SUMMARY

Within SUSTAINair research on joining and repair of metal-to-metal, metal-to-composite and (thermoplastic) composite-to-composite material combinations has the aim of enhancing cost-competitive, high performance joints in line with circular economy concepts. The focus is on enabling integral design of subassemblies, so welding and bonding are in the centre of technologies chosen, replacing rivets at maximum – being aware of the challenging need for innovative repair methods for integral assemblies and its modular sections, as well.

The research focused on repair of thermoplastic and thermosetting material and on metallic components. For repair of thermoplastic material (T700 UD/LM-PAEK), two different approaches will be researched; repair of thermoplastics by reconsolidation (1) and patch repair of thermoplastics by welding (2). For both approaches induction welding was used to repair the samples.

Reconsolidation tests were conducted on impacted samples with delaminations and matrix cracks. It proved to be challenging to repair the local damage caused by the impact. Higher pressure was needed to prevent deconsolidation of the undamaged sections of the samples and to fuse the delaminated layers together. Depending on the size of the damage multiple weld runs are needed to fully cover the damage. The best results were obtained and smaller damage with a stationary of single continuous weld run at high pressure. However, it was not possible to fully repair the samples. Further research is needed to optimize the process and welding setup.

Patch repair focused on welding scarfed single lap shear samples and on rectangular scarfed patches with rounded corners. To successfully weld the scarfed SLS samples multiple parallel runs were needed. C-scan inspection proved good quality across the entire width of the scarf. Furthermore, a layer of resin film was added in some specimens. It had a negligible effect on the induction welding process, but it did increase the lap shear strength by approximately 24% compared to a welded scarf without resin film.

Welding tests on the rectangular patches (120 x 50 mm, R = 25 mm at corners) showed that higher pressure was needed to prevent deconsolidation of the skin outside the scarf area. Furthermore, the order in which the multiple weld runs were carried out affected the quality of the repair. During welding the temperature was highest in the rounded corners as was already found in heating tests monitored with an infrared camera. Overall, it can be concluded that scarf repair by induction welding is a very promising technique to repair thermoplastic structures. The technology was developed to TRL 4.

For repair of thermosetting material, the approach of detachable joints was researched. Two types of joints were studied which for type one consisted of integrating thermal expanding particles into the adhesive (tested on two rigid thermoset components) and for the second type by adding a functional interlayer between a thermoset and flexible FKM (similar to EPDM) component. The interlayer consists of two layers of thermoplastic PMMA with or without a stainless-steel mesh in between the components. Both joints will expand by the effect of higher temperatures which allows the components to detach without damaging the bonded parts. After detaching the components were postprocessed and bonded again using the same procedure as during the first bond process. Two detachable joint types for thermoset – thermoset and thermoset – flexible components were studied and successfully applied. The technology was developed to TRL 4.

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