DCMC innovation track 5: Developing automated repair techniques for repair of composite structures

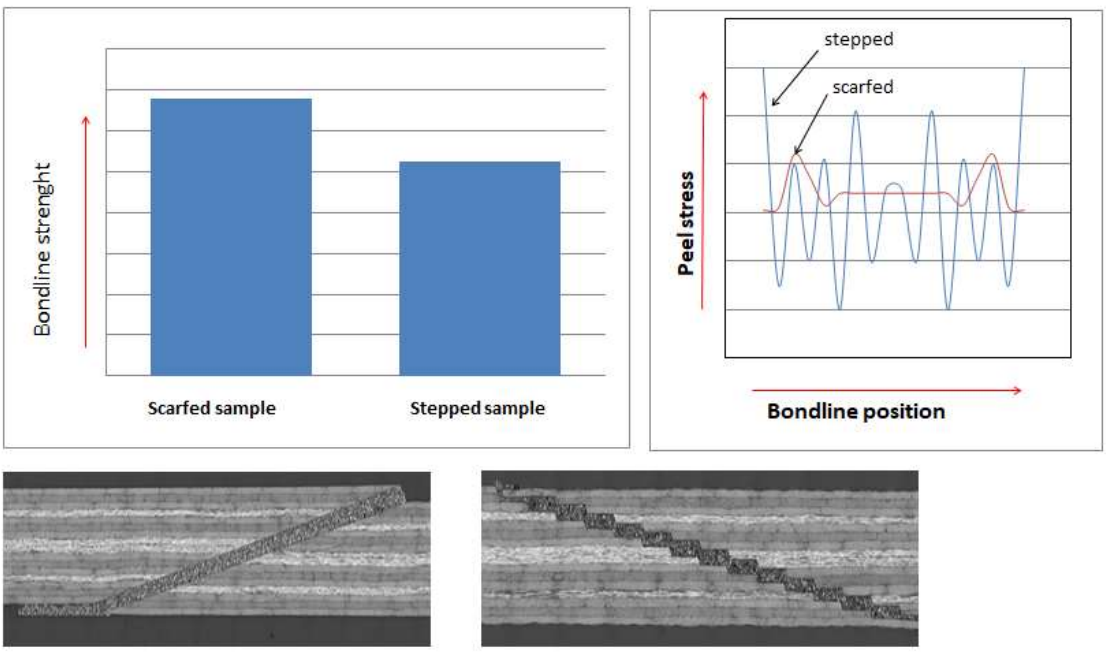
Project progress

- Milestone 1: Determining the repair method /Augustus 2017
- Milestone 2: Selection of the inspection method / February 2018
- Milestone 3: Development of software for combining inspection and geometry data (data fusion) / November 2018
- Milestone 4: Demonstration / December 2019
- Milestone 5: Development of AM methods / May 2021

The first 4 milestones were finalized end 2019 after a demonstration repair was performed on a representative fuselage panel.
Within this project the following activities were performed:

- Tests on samples to define the optimal milling strategy
- Inspection, geometry measurements on a damaged fuselage panel
- Data fusion and definition of the milling file
- Automation trials
- Repair of the fuselage panel demonstrator
- Application of Additive Manufacturing (AM) technology to the repair of composite aircraft structures

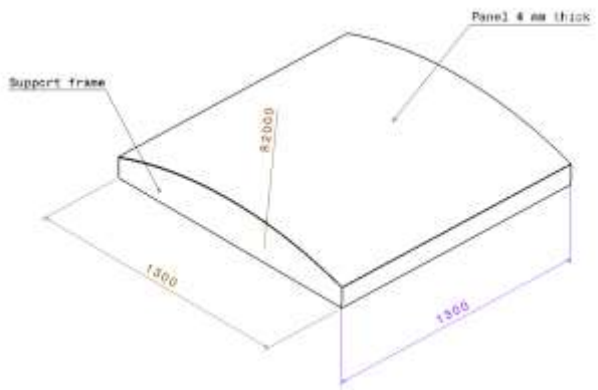
Tests on samples to define the optimal milling strategy
Small sized 2mm thick epoxy/carbon tensile samples were manufacture and adhesive bonded. The bonded surface was prepared using a number of milling/sanding strategies. As an example the stepped and scarfed prepared samples are displayed in the figure below.



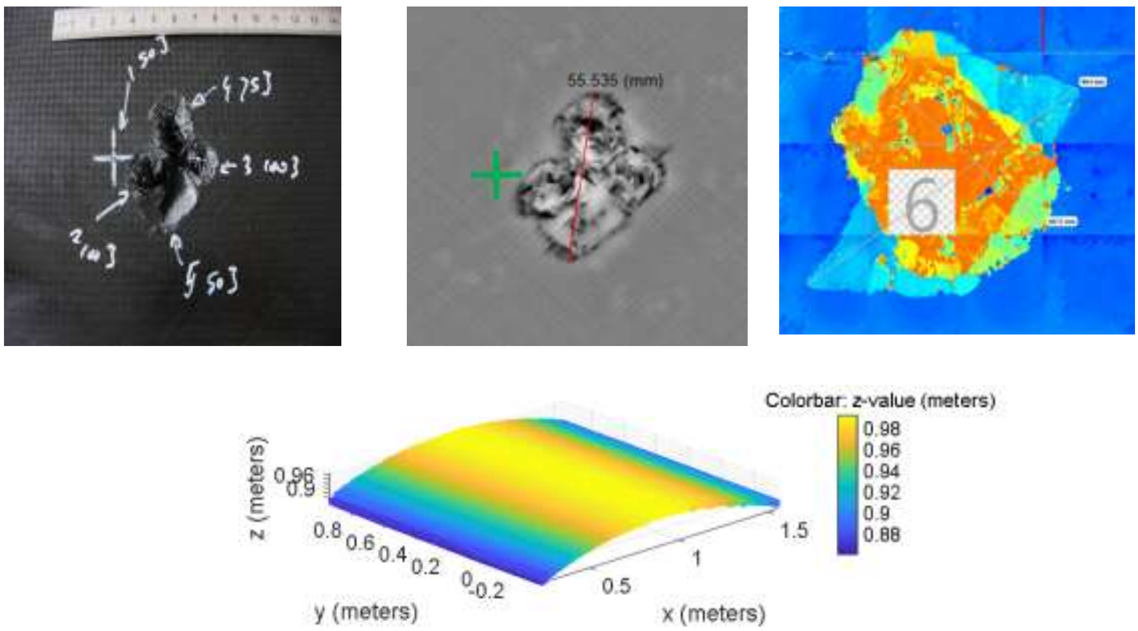
The micro sections show clearly the difference between the two samples. The peel stresses are calculated by using the NLR developed Excel based BondedJoint® software. Due to the high peel stresses for the stepped surface the resulting strength is lower compared to the scarfed surface.

Inspection, geometry measurements on a damaged fuselage panel

A 4 mm thick epoxy/carbon panel was manufactured and assembled to a support frame as shown in the picture below.



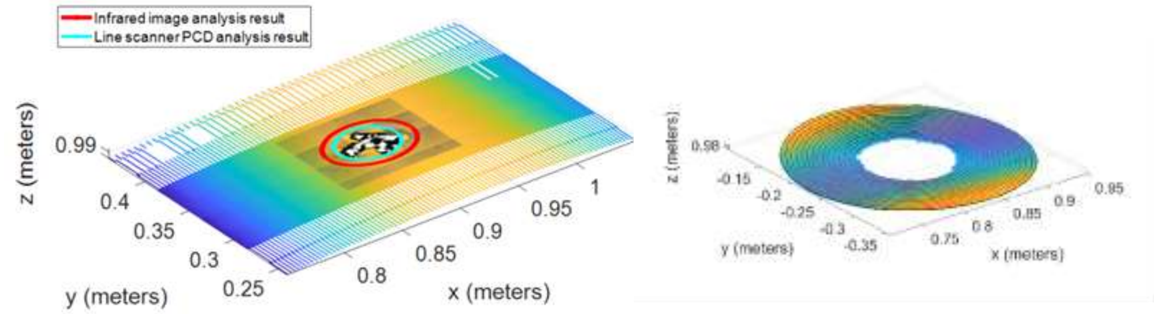
Impact damages at different energy levels were applied to the centre of the panel followed by Non Destructive Inspections (NDI) and geometry measurements.



The picture above shows the NDI inspection results for visual, thermal and ultrasound inspections (left to right) and the geometry measurement results.

Data fusion and definition of the milling file

The data of the NDI measurements were merged into one milling file for the panel. The scarfed milling pocket was defined around the damaged area to incorporate the visual and non-visual damage detected by the NDI inspections. The picture below shows the scarfed pocket definition that was used to generate the milling file.



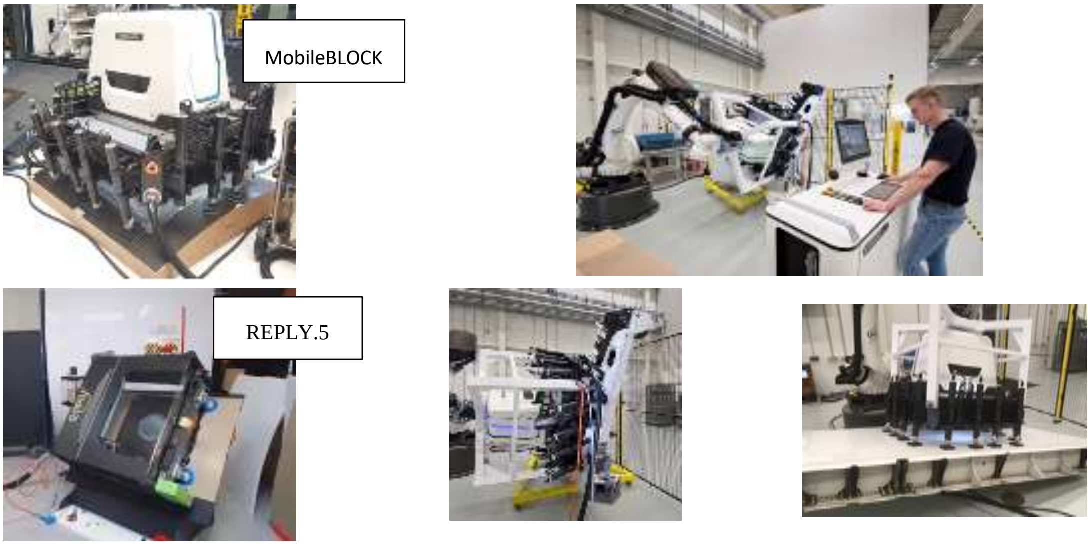
To compensate for any in-accuracy of the milling process the milled pocket was 3D measured after milling and the repair patch definition was done by subtracting the required adhesive gap width (0.2 mm) from the milled patch bonding surface. The resulting data file was used to generate the milling file for the patch.

Automation trials

Two different milling robots were evaluated in the project (in combination with DCMC innovation track 6):

- The MobileBLOCK® developed and manufactured by DMGMORI
- The REPLY.5® Water Jet cutting robot developed and manufactured by BAYAB

The MobileBlock (MB) milling robot that was demonstrated can only be used for large airframe surfaces. Application on smaller and complex shaped surfaces (like the NH90 tail) is not possible. Also the large weight and size makes it difficult for positioning on aircraft structures. The MB was coupled to the NLR robot and positioned on a NH90 tail section and a 787 elevator (see pictures below).
A promising abrasion method that was demonstrated in this project is the light weighted water jet machine developed by the French company Bayab, this machine can easily be positioned over the damaged area by the operator. Also for this machine it is not possible to use it on smaller and complex shaped surfaces.
Based on the experiences in this project an alternative approach will be investigated in follow up projects. This approach is concentrating on small and light weighted co-bot systems that assist the operator and can be used to automate the inspection and repairs on smaller and complex shaped locations.



MobileBLOCK and REPLY.5 positioned on sample panels and MobileBLOCK positioned on the NH90 tail and 787 elevator.

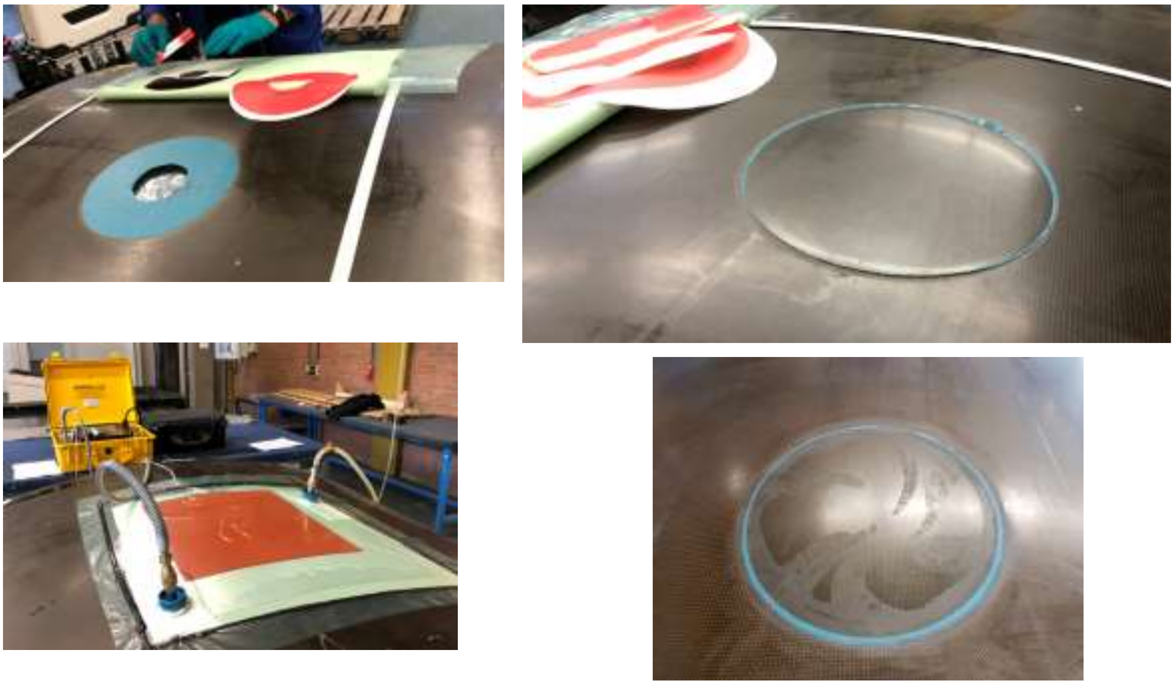
Repair of demonstrator fuselage panel

The MobileBLOCK was used to prepare the fuselage panel. In principle the generated milling file can be used by the MB for milling the panel pocket and repair patch but the required software modifications were out of the project budget. Therefore the automated MB pocket definition procedure was used by scanning the surface with the internal 3D scan head and after input of additional data (cut-out size and shape, scarf angle, panel thickness) the pocket was defined and milled.

The patch was milled from a second composite panel with the same lay-up as the demonstrator panel, the generated milling file was used for CNC milling of the bonding surface.

Patch milling fixation tool and milled patch.

The patch was bonded to the panel using a film adhesive as shown in the pictures below.



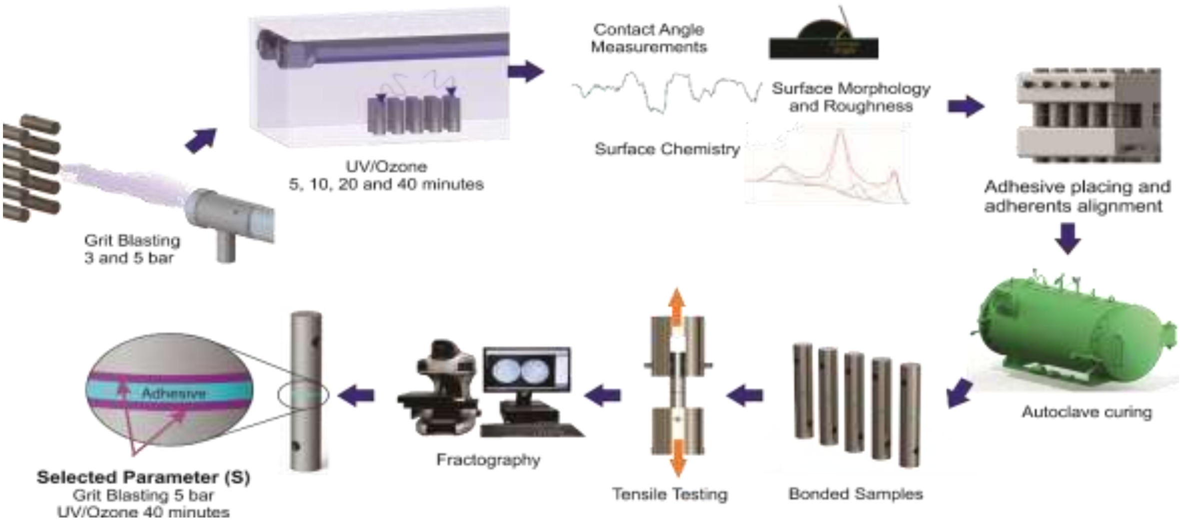
Adhesive bonding of the patch

Application of Additive Manufacturing (AM) technology to the repair of composite aircraft structures

This activity has the main objective to investigate the potential for applying AM technologies to Titanium printed patch repairs for composite structures. The reason for printing these perfectly fitting 3D parts is, that they can be applied to the composite fuselage by adhesive bonding. However, environmentally friendly durable adhesive bonding to (printed) Titanium is not an off the shelf technology, and that is why this research is needed.

The first experimental step was to characterize the effect of grit blasting pressure and different exposure times to UV/Ozone pre-treatments on the morphology, oxidation, and wettability of normal wrought Ti6Al4V alloy to find the surface pre-treatment that provides the lowest contact angle (thus the best wetting) and the best initial adhesive bond performance in a mode I strength (following the ASTM D2095).

The first research results revealed that the wrought titanium was increasingly oxidized with an increasing UV/Ozone treatment time, which leads to a reduced contact angle and a better adhesive performance in a mechanical mode I



The sequence of steps to test the Titanium surface preparation and to test the adhesive bond strength.

test. Furthermore, the addition of a sol-gel in combination with a corrosion inhibiting water-based primer showed to give an additional improvement in both the initial adhesion as well as after different degrees of aging by exposure to salt-spray during 3, 6, and 12 weeks. Once the best wrought titanium alloy adhesive behaviour was obtained, we were ready to copy this pre-treatment to the additive manufactured samples to evaluate their potential application in repairs.

The additive manufactured samples (AM) are now being printed with the same shape of the wrought samples, but with three different surface morphologies depending on the build orientation (0^{o},45^{o} and 90^{o}). These morphologies will replace the grit blasting step. Their adhesive behaviour, together with the same UV/Ozone treatment as before, will (again) be evaluated by mode I strength and 0, 3, 6 and 12 weeks of salt spray exposure, and the results will be compared to the first set of tests described above.

Eventually this will indicate the best surface treatment to additive manufactured Titanium samples (AM) for the use as a patch repair part on composite fuselages.

This project is part of the ERDF OPZuid project PROJ-00730 - Building the DCMC and is made possible by:

Europese Unie
Europees Fonds voor Regionale Ontwikkeling

OPZuid
Europees Innovatieprogramma Zuid-Nederland

Provincie Noord-Brabant