Development Center for Maintenance of Composites

Developing automated repair techniques for repair of composite structures

E-Lass presentation, 16 September 2020

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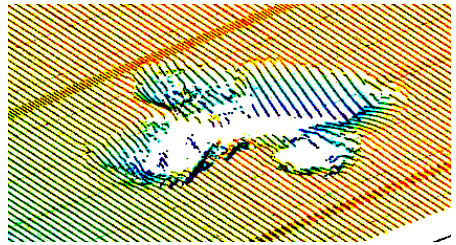
Development Center for Maintenance of Composites

Research & Innovation

<u>Research & Innovation program Focusing on:</u>

1. Hybrid structures maintenance & corrosion prevention
2. Quality improvement through Automation
   - Spider robot
   - Laser Ablation/Waterblast scarfing
   - Automation of NDI
3. More efficient NDI through data Fusion



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Content

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1. Milling strategy
2. Automation
3. Further Developments at DCMC

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Milling strategy

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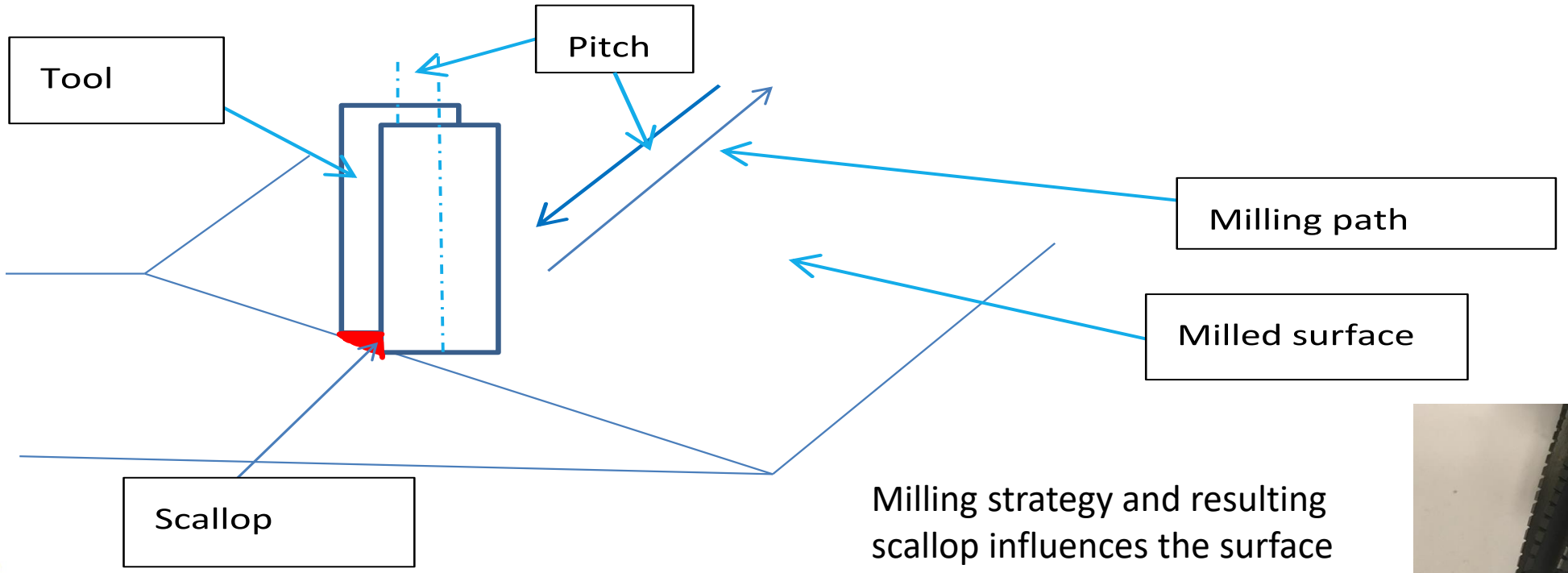
Variations in surface roughness as result of the milling strategy of the scarfed bonded joint were investigated.
All tests were performed on 2 mm thick BMI/carbon samples (16 QI layers) using EA9394 paste adhesive and a scarf ratio of 1:10 (to assure failure in the bondline).



Milling strategy and resulting scallop influences the surface roughness

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Milling strategy

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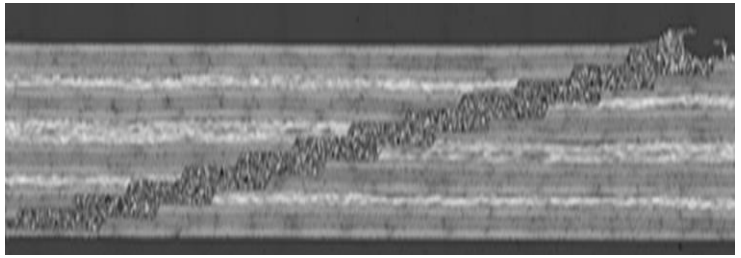
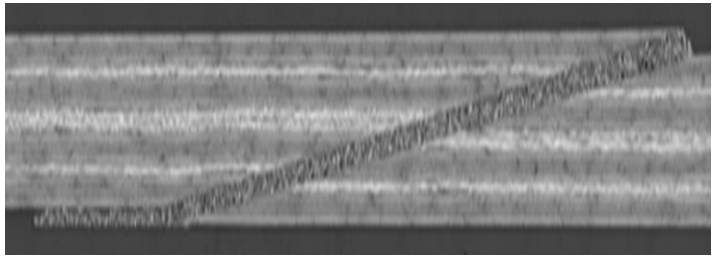
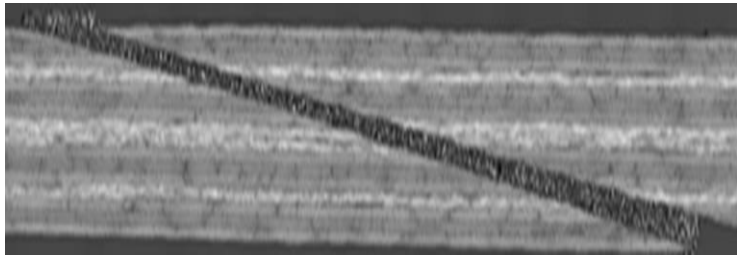
Sample definitions (pictures not on scale)



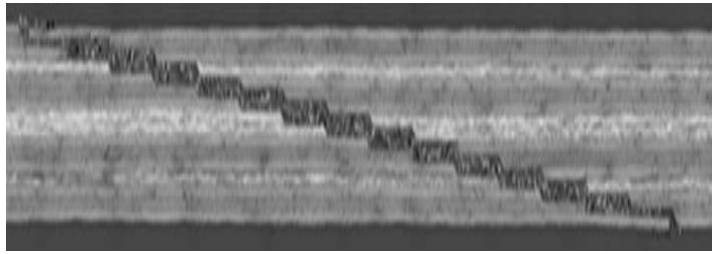
A Scallop 0.2 mm



B Scallop 0.01 mm (scarfed)



C Manually sanded to a smooth surface (scarfed)



D Scallop matches ply thickness (stepped)

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Milling strategy (stepped/scarfed)

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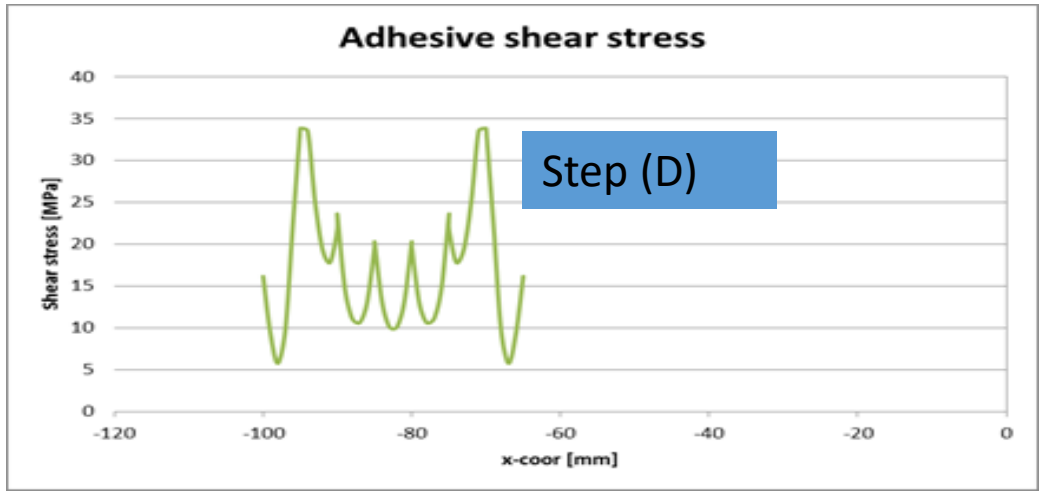
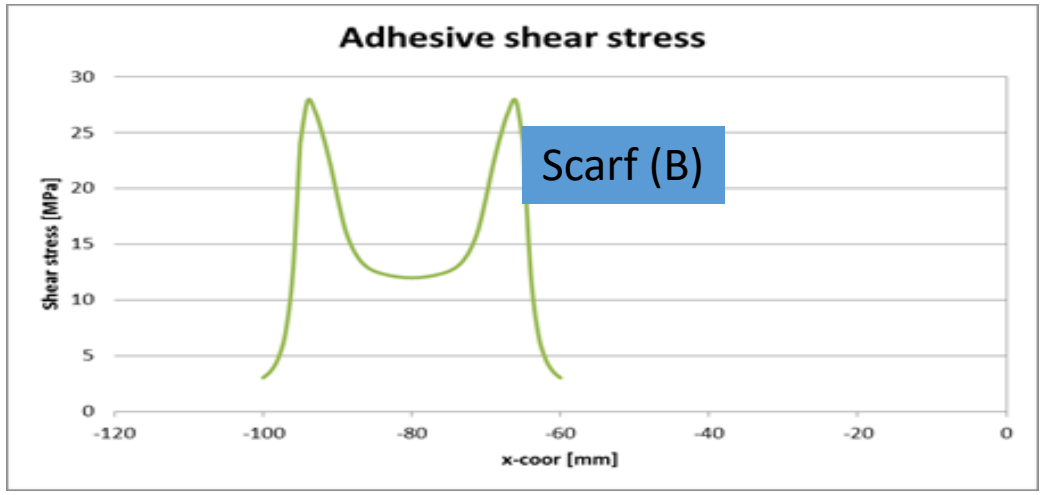
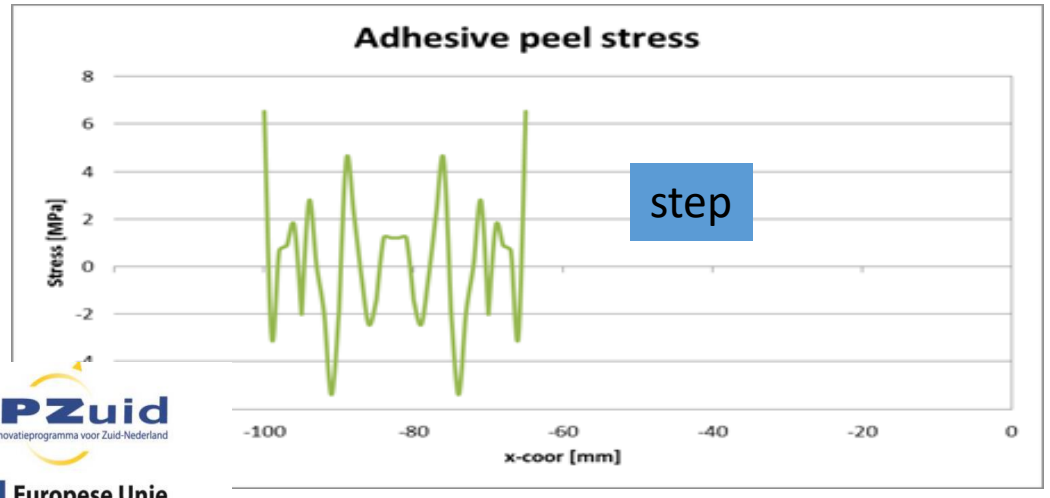
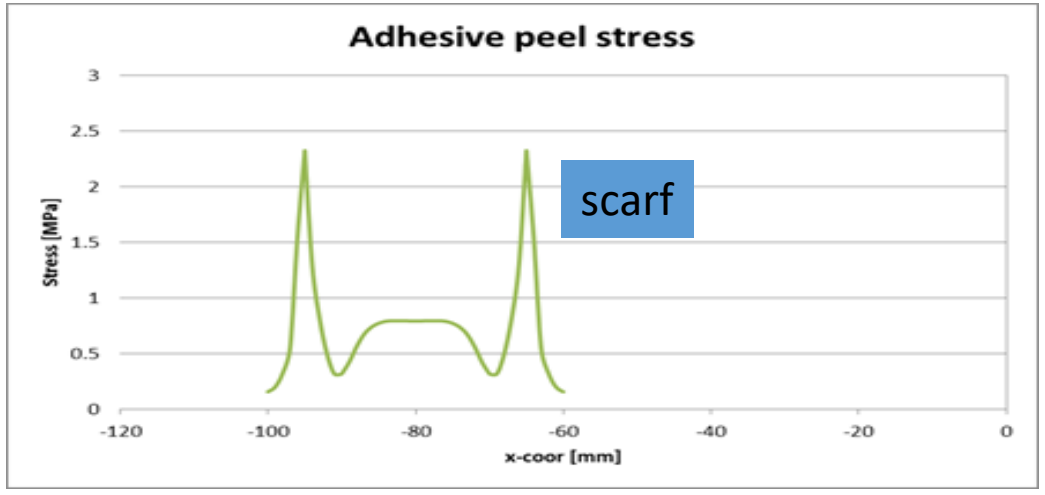
Shear and peel stresses were calculated to compare step and scarf joints using the NLR developed BondedJoint® tool (load 12 kN, ratio 1:20)









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Milling strategy

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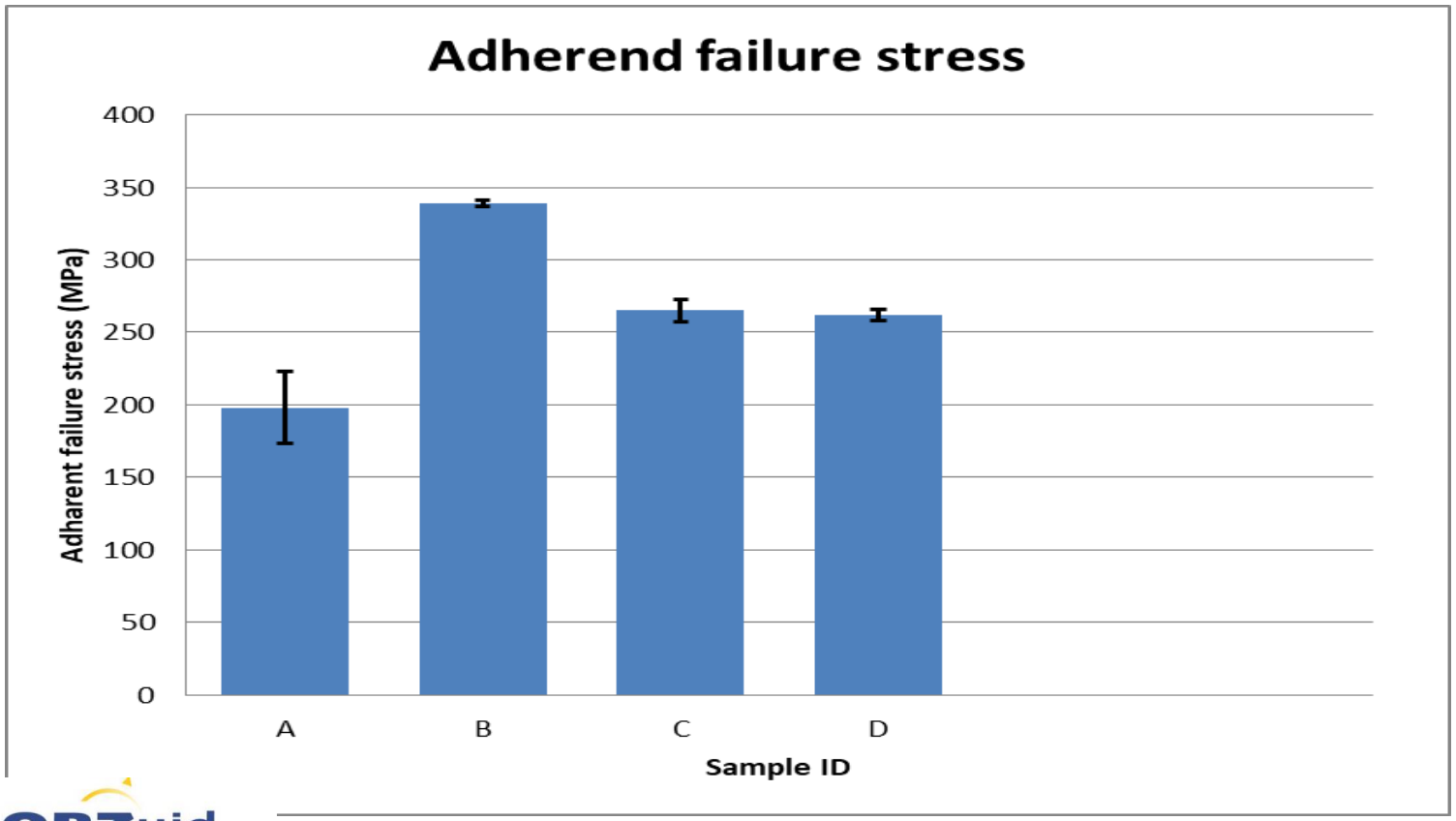
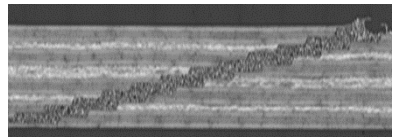
Tests were performed on stepped and scarfed samples and a significant difference in failure load was found.

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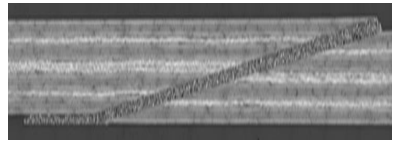
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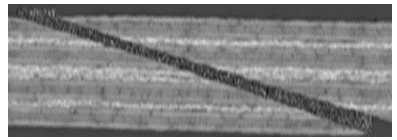
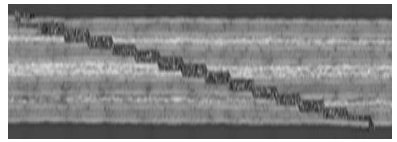

C


D

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Milling strategy (conclusion)

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From a strength point of view the machined scarfed surfaces with a low scallop height (≈0.01 mm) are preferred, however in practice higher scarf/step ratios of 1:20 or even 1:40 are used. In this case the bondline strength is not critical and manufacturing or economical issues are leading in selecting the milling strategy.

For DCMC and NLR research the focus will be on machined low scallop bonding surfaces.

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Automated surface preparation

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There are a number of surface preparation robots on the market, two of them were selected for evaluation.

- The MobileBlock® milling robot manufactured by DMGMORI (https://en.dmgmori.com/)
- The Reply.5® waterjet robot manufactured by Bayab (www.bayab.fr)

Source: DMGMORI

Source: BAYAB

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Automation (MobileBlock)

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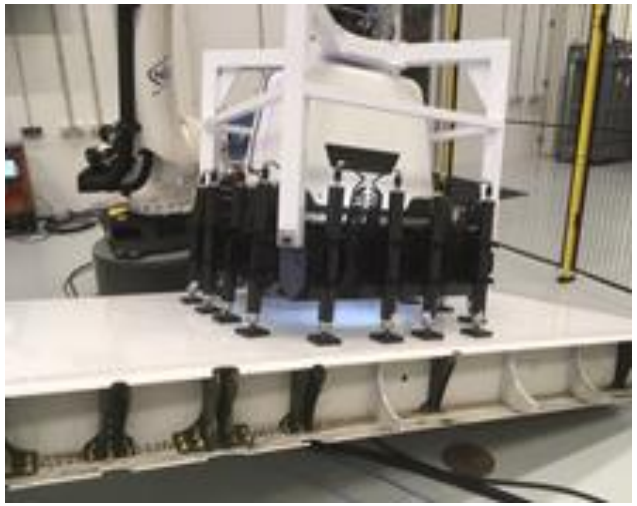
The MobileBlock is a compact 5-axis milling machine with an internal laser scan system for geometry measurement. Milling area around 500 x 500 mm.
After positioning the MobileBlock on the damage location a fully automated preparation of the surface is possible. Only size and shape of the milling pocket has to be selected. After input of the milling parameters and material thickness the scarf geometry is calculated and the machine starts working.



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Automation (MobileBlock)

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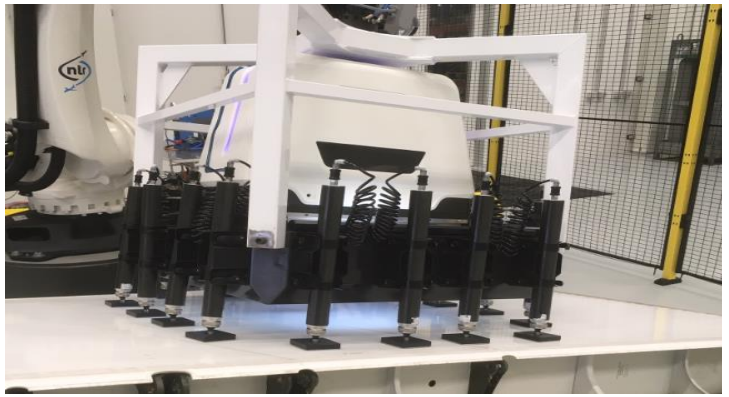
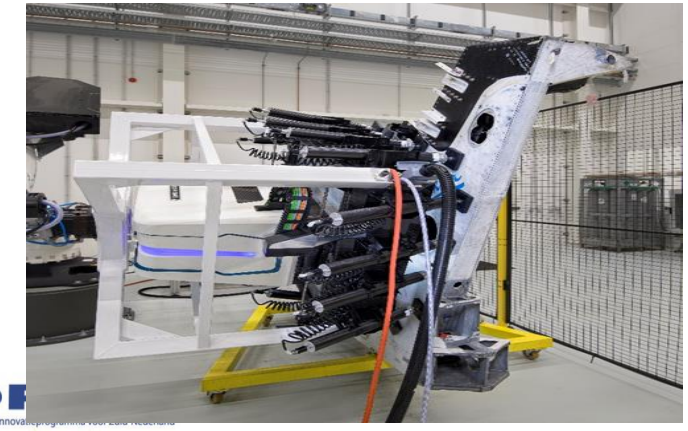
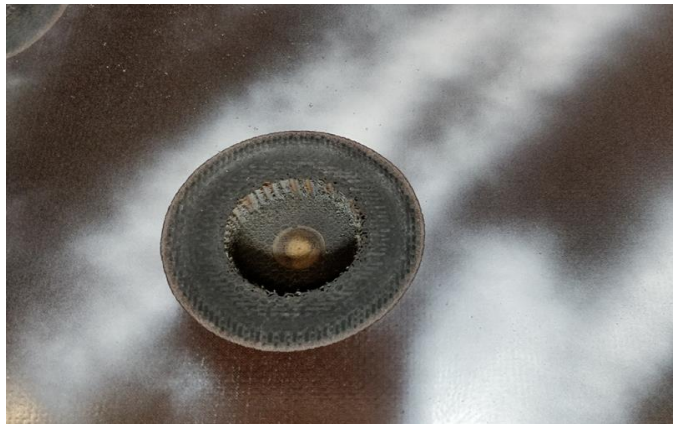
The MB can be used for positioning on larger low curved structures like fuselage sections or larger parts. Sandwich materials can be machined but require a specific milling approach for each sandwich material.



Positioning the MB on an 787 elevator (provided by KLM)





Milling trials on a NH90 tail and sandwich materials by Fokker Services

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Automation (REPLY·5)

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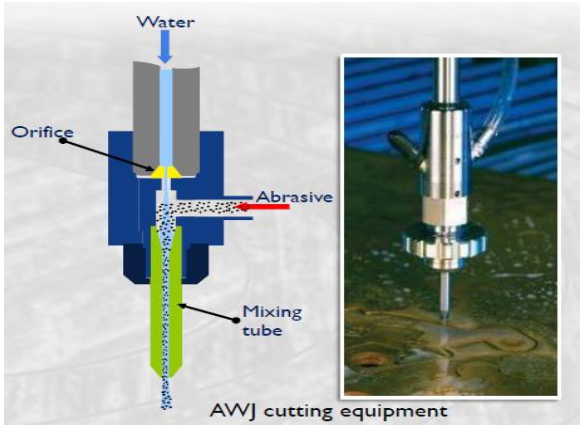
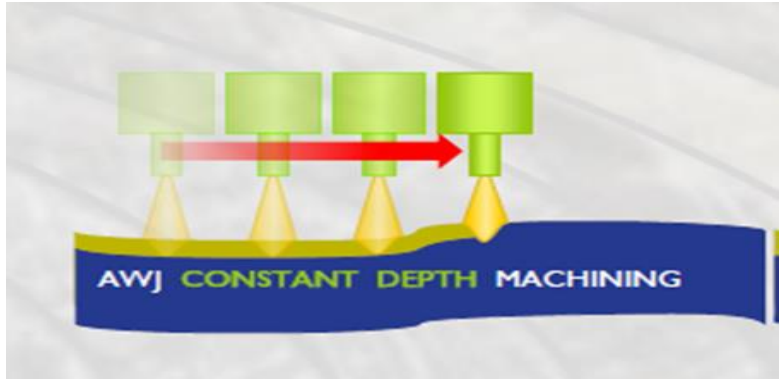
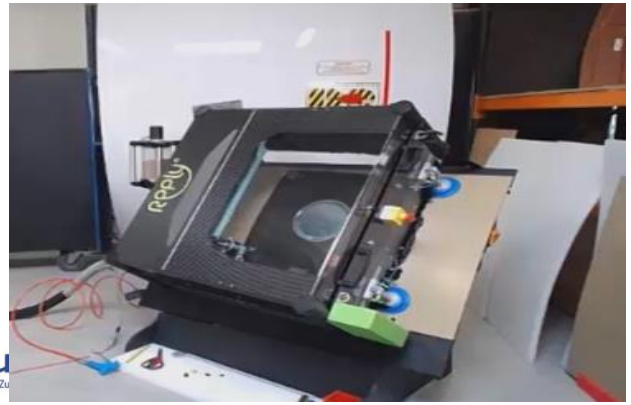
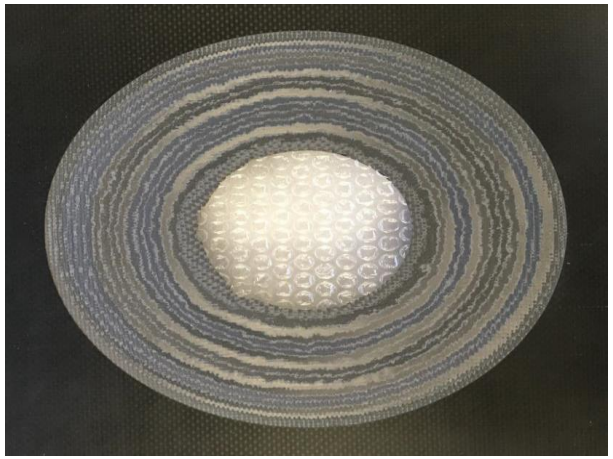
The REPLY·5 water jet is a light weighted robot capable of fully automated preparation of scarfed and stepped repairs. Water jet machining allows for a simple 2D positioning mechanism to prepare 3D curved structures.





Principle of water jet machining (source Bayab)





Milling trials on test panels

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Automation (Laser ablation)

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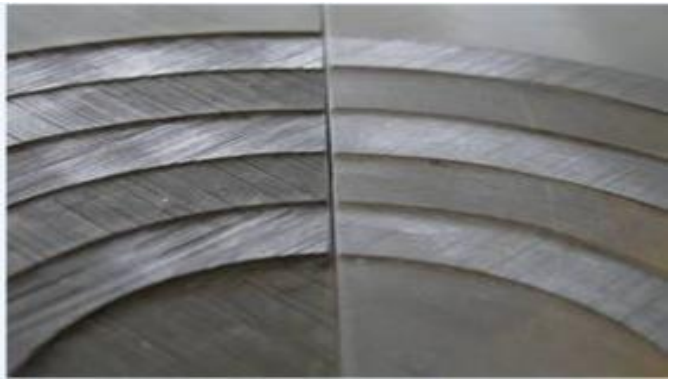
Laser ablation is under investigation by DCMC partner Fokker Services, first trials on coupons using a SLCR CO_2 laser shows promising results. Preparation of curved 3D structures has to be investigated.



CO_2 laser equipment (left) and stepped prepared pocket using laser ablation (left) and manual sanding (right)

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Automation (Conclusion)

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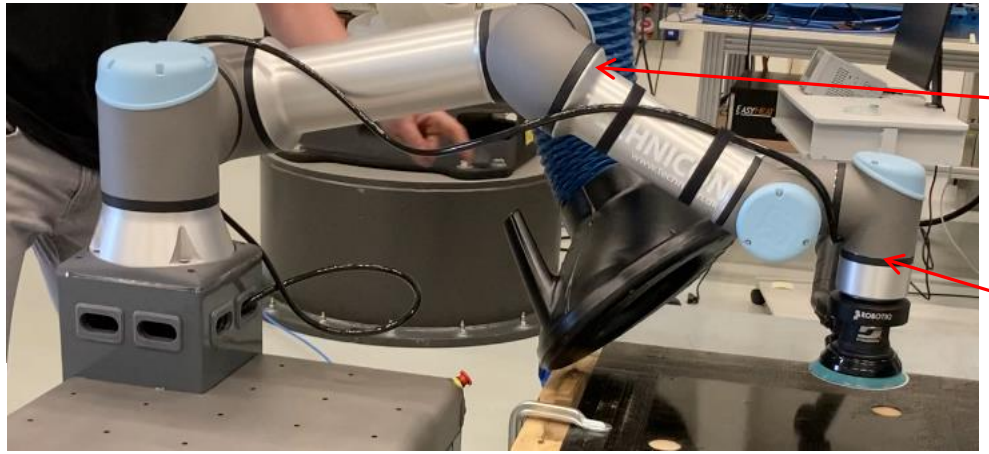
- Laser ablation needs further investigation for use on 3D structures
- The MobileBlock is capable of automated preparation of larger structures. The milling process is well known and relatively fast
- The REPLY.5 is a light weighted machine that can easily positioned on a damaged structure. The process is relatively slow compared to milling (factor 10). Positioning on smaller highly curved 3D structures is not possible.

The DCMC partners are further investigating automated processes for use on highly curved structures (leading edges,...) with more interaction with the operator (cobot systems)



Cobot

End effector
- Thermography NDT
- Milling/Sanding
- Patch positioning
- ....

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Provincie Noord-Brabant

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