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Eco friendly production method for composite grid stiffened panels

SAMPE Europe Conference 2020 Amsterdam

CUSTOMER: European Commission

NLR – Royal Netherlands Aerospace Centre

EXECUTIVE SUMMARY

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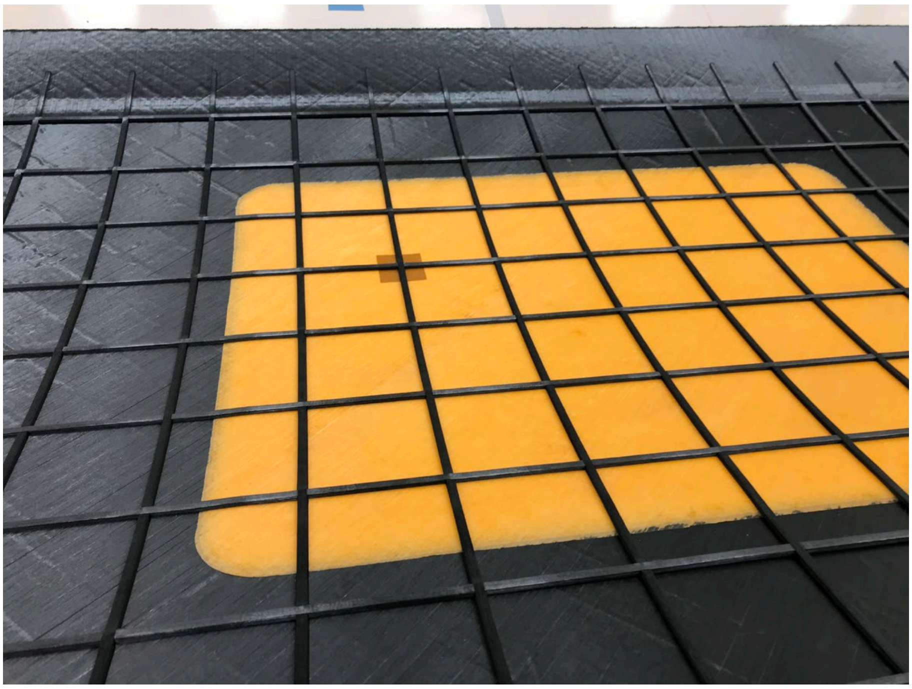

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AUTHOR(S)
P. Nijhuis

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Problem area

Aircraft fuselage structures in composites normally exist of a skin with bonded, welded or bolted stingers. NLR has optimized the fibre placement process to create skins with grid stiffeners. Normally, curing of such structures requires a large amount of tooling blocks to support the grid in an autoclave or oven. Every production cycle, the blocks have to be heated up and cleaned and a complete vacuum bag has to be discarded.

Description of work

This paper describes the development of a more ecological friendly process to cure a skin with grid stiffeners. A method was developed to cure the panel using a re-useable silicone bag. The method was demonstrated on a three meter long fuselage panel made by fibre placement. The prepreg skin and grid stringers were automatically placed by the machine. The stringers were supported by the silicon bag during the cure cycle in an autoclave.

Results and conclusions

A preform for a grid stiffened panel can be made fully automatic in a very efficient way with very low scrap rates. By using silicone bags, also the curing of such panels can be done affordable. The environmental impact is reduced since the vacuum bag can be re-used and cleaning of tooling blocks is not necessary any more. The dimension of stiffeners can be optimised by adjusting the shape of the bag, if a more rectangular shape of the stiffeners is required.

Applicability

The process can be used for different kind of stiffened panels such as the fuselage panel as described in this paper, but also radomes, control flaps, streamline fairings or blended wing body crown panels. For higher stiffeners, most probably the bag has to be stiffened itself to create a straight stiffener. The bags can be used for other grids but also for normal stringers or random stringer patterns. The use of silicones in a composite facility is often discussed. However, by using a fully automated and isolated preform manufacturing cell, the preform manufacturing can be separated from the curing. If no human handling is required during the placement of fibre layers, the change of silicone contamination within the laminate is very limited.

GENERAL NOTE

This report is based on a presentation held at the SAMPE Europe conference in Amsterdam, 2020.

NLR
Anthony Fokkerweg 2
1059 CM Amsterdam, The Netherlands
p) +31 88 511 3113
e) info@nlr.nl i) www.nlr.nl

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Summary

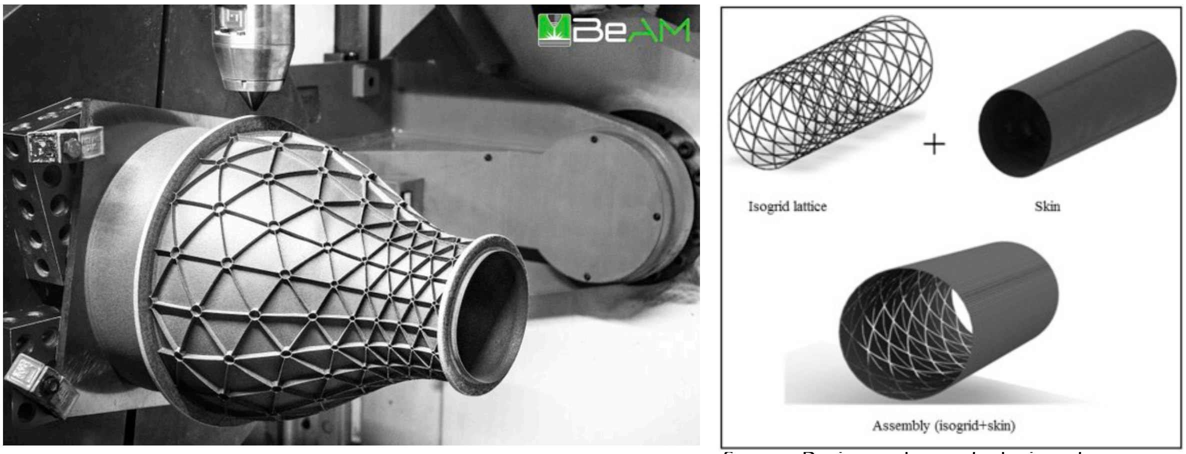
As part of a European research project called ACASIAS, integrated antennas in grid stiffened panels are investigated. NLR has optimized the fibre placement process to create grid stiffened structures. Normally, curing of such structures requires a large amount of tooling blocks to support the grid in an autoclave or oven. Every production cycle, the blocks have to be heated up and cleaned and a complete vacuum bag has to be discarded. A method was developed to cure the panel using a re-useable silicone bag. This paper describes details and results of the fibre placement and curing process of a three meter long demonstrator.

Contents

1 Introduction

In the last decade, the main driver for aircraft structures has more and more moved to lowering the manufacturing costs of a structure in combination with a lower environmental impact. New aircraft structures have to be made highly automated and labour costs should be low. Grid stiffened structures are known to be light and stiff and can be made in one piece without fasteners. Some examples are given in

Figure 1. In metal those structures can be made by milling away large sections of the base materials. Additive manufacturing creates new methods to make the parts more affordable. Without the use of automatic machines, composite grid panels are almost impossible to make. Creating grids by hand lay-up would be very time consuming. Winding machines are used for different parts, but it is hard to create parts with a good quality in the crossings.

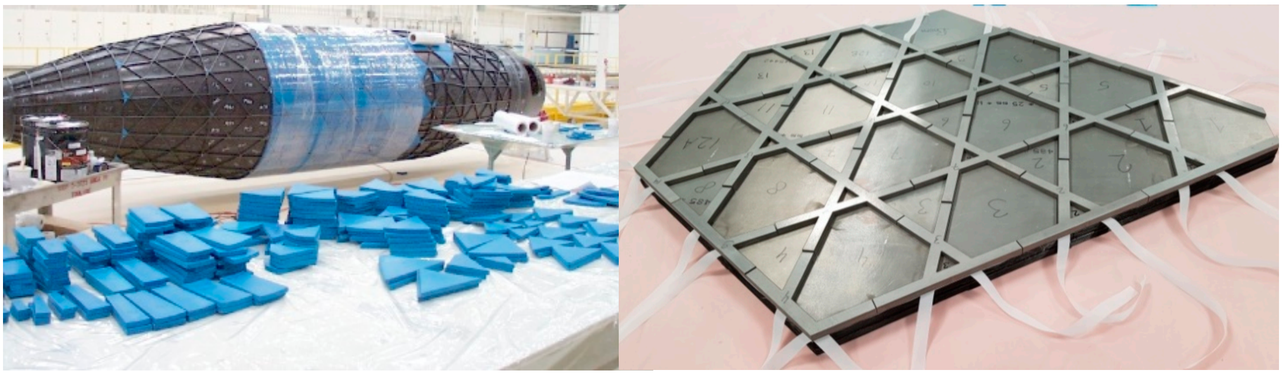


Source: BeAM Machines, Twitter

Source: Design and manufacturing of an isogrid structure in composite material: Numerical and experimental results, Elsevier, Composite Structures Volume 143

Figure 1: Grid stiffened panel examples

During curing of most of the composite grid structures a vacuum bag has to be used. During the cure cycle in an autoclave or oven the grids have to be supported by a large numbers of tooling blocks to keep the stiffeners in shape, see Figure 2 for two examples. By this, a composite grid stiffened structure even made by filament winding or automated fibre placement would still be very costly. Every production cycle, the blocks have to be heated up and cleaned and a complete vacuum bag has to be discarded after curing.



Source: www.airforcemedicine.af.mil NLR

Figure 2: Tooling blocks during a cure cycle of grid stiffened structures

As part of a European research project called ACASIAS (Advanced Concepts for Aero-Structures with Integrated Antennas and Sensors), integrated antennas in grid stiffened panels are investigated. Within this programme NLR has optimized the fibre placement and curing process to create grid stiffened or so called lattice structures in an affordable and eco-friendly way. By using a re-usable silicone vacuum bag, no tooling blocks are required. By this, a more ecological friendly production method is created without solvents for cleaning and Frekote application of tooling blocks and less vacuum bag waste. Also the cure cycle can be shorter since no tooling blocks have to be heated up and cooled down, saving energy and time. In the next sections the details and results of the fibre placement and curing process of a three meter long demonstrator are presented.

2 Fibre placement of Grid stiffened panel

Within the ACASIAS programme, a fuselage panel of a single aisle aircraft was used as research object. The design was based on loads on a Fokker 100 aircraft in the forward crown section of the fuselage and was made together with CIMNE (International Centre for Numerical Methods in Engineering). To be able to position the antenna inside the fuselage instead of on top, hence reducing the drag of the airplane, the skin of the panels is partly made of glass prepreg. Since the antenna tiles are square, the grid structure used was an orthogrid, although an isogrid is better for the shear transfer off the shear loads. However, since shear loads in this section of the fuselage are relatively low the orthogrid concept was feasible. See Figure 3 for the different types of grids.

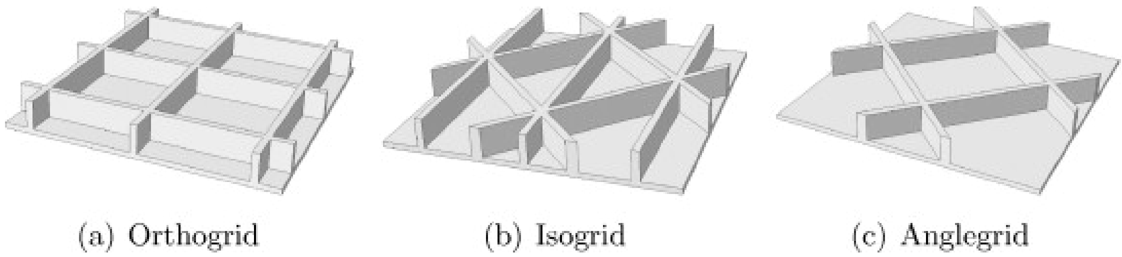


Figure 3: Typical grids

A CATIA image of the final panel design is given in Figure 4 with in the middle the glass skin. At the edges of the panels, the stiffeners were build-off and the skin thickness was increased, to be able to introduce the loads during the mechanical test at the end of the programme with internal pressure and axial tensile loads.

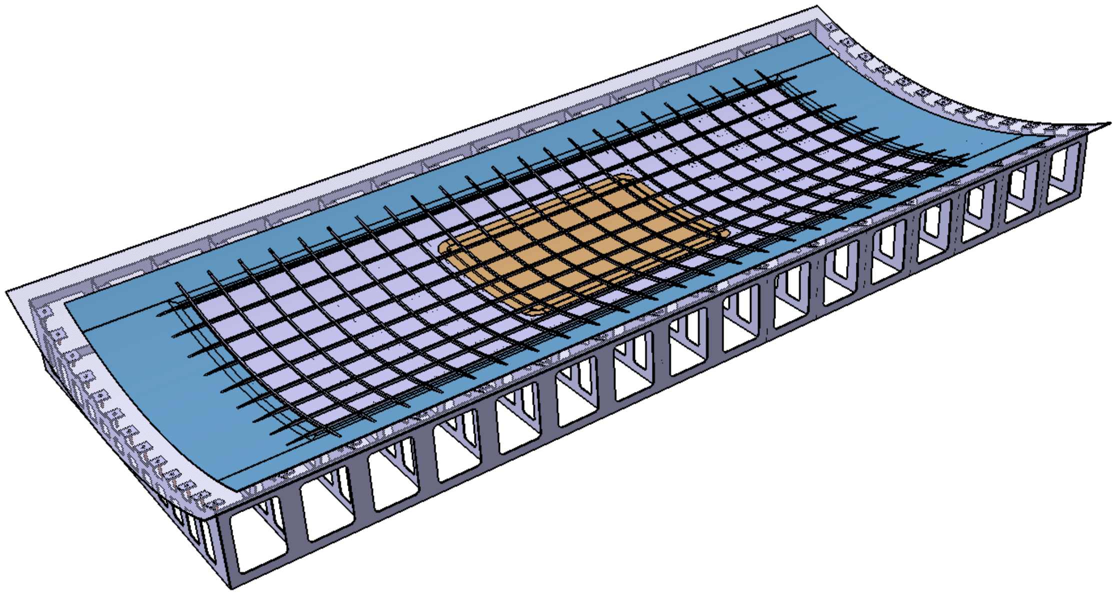


Figure 4: Final design of the ACASIAS grid stiffened panel with the mould used for fibre placement and cure

The following materials were used to manufacture the panel:

- Carbon skin and stiffeners: Hexcel 8552 prepreg tape with AS4 carbon fibres
- Glass skin: Cytec FM906 prepreg with S2glass fibres

First the skin including the build-ups was placed on the mould and after that the stiffeners were placed on top of the skin. For both activities the automated fibre placement machine of NLR was used. The skin was placed with 8 tows simultaneous and the stiffeners with one tow with a width of 6.35 mm. To prevent a thickness build-up of the stiffeners in the crossings, half of the tapes were cut in one direction and half of the tapes were cut in the other direction, see Figure 5.

Figure 5: Cutting of tapes in the crossings of the stiffeners. In blue a random layer and in orange a next layer

The ends of the stiffeners were trimmed using a vibrating knife and after that four additional layers were placed on top of the stiffeners till the edges of the panel, see Figure 6. The complete laminating process was carried out automatically or can be automated (trimming).

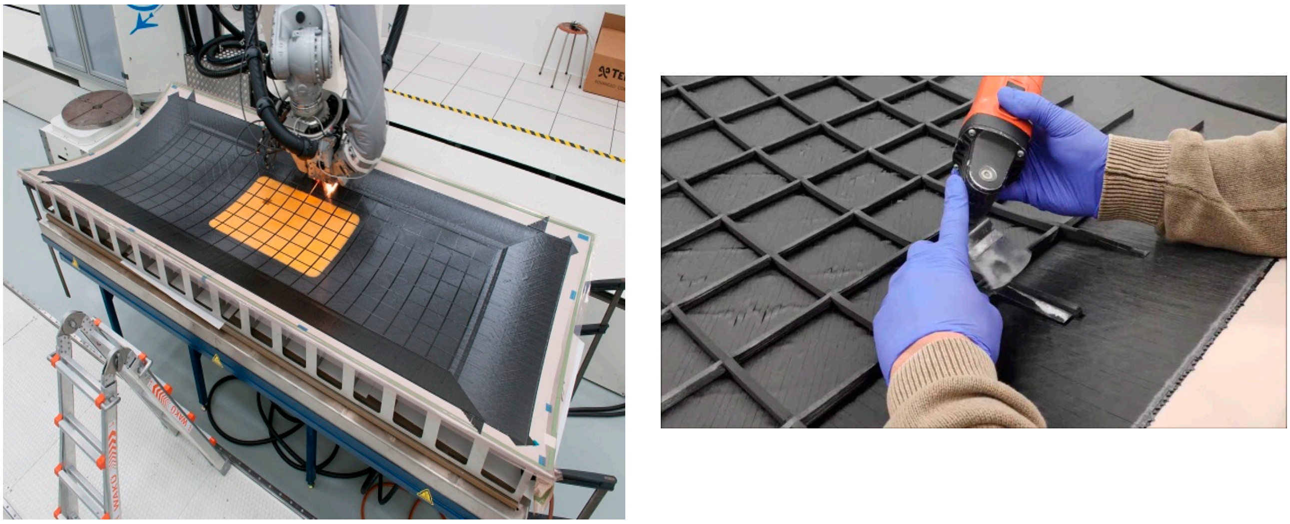


Figure 6: Panel fibre placement and stringer run out trimming before cure

3 Curing of Grid stiffened panel

During curing of the panel in the autoclave, the stiffeners have to be supported. As described in the first section, the number of tooling blocks would be very high. Especially for a curved panel, as can be seen in a cross cut sketch as given in Figure 7. The blocks would be clamped by the shape of the stiffeners and demoulding would not be possible. Therefore every block should be divided in two parts, which makes the number of blocks for this panel already more than 500. The thickness steps in the panel would also require a large number of different shapes, causing a logistic puzzle during every manufacturing cycle.

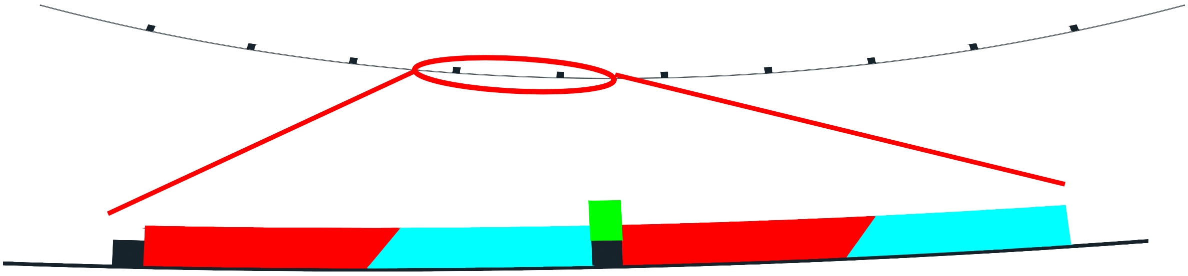
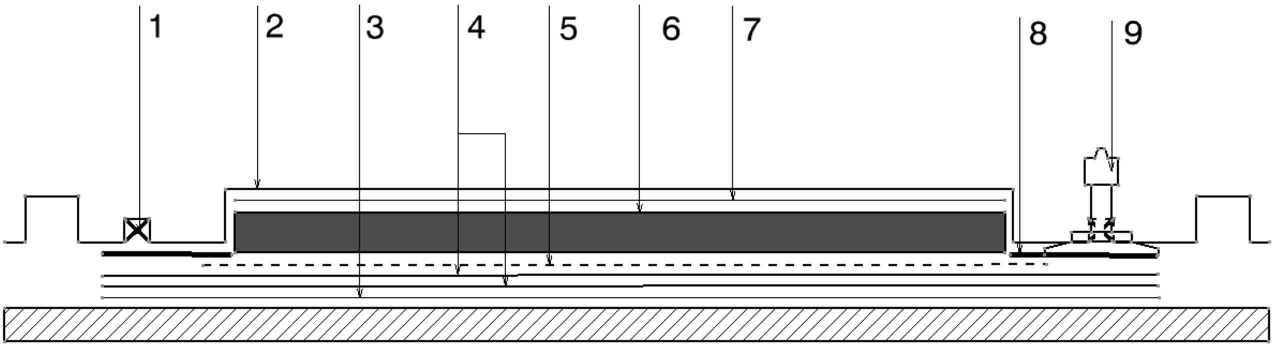


Figure 7: Cross cut of the panel to show the necessary divided blocks for demoulding (red and blue)

Therefore the possibilities to support the stiffeners with a re-usable silicone bag were investigated. First a small silicone bag was created. An aluminium grid was used to create a silicone bag made of EZ-brush Vac Bag Silicone, see Figure 8.

Figure 8: Manufacturing trials of a silicone bag on an aluminium grid

With the silicone bag several small panels with four stiffeners were made. The air transport within the vacuum bag has to be done on the mould side of the panel. During the first trails, the surface quality was not as good as desired. The resin flow towards the silicone was less by the surface tension of the silicone. Therefore an extra release foil was used at the silicone side, see Figure 9. Also the use of tacky tape did not worked well. Normal often used tacky tapes did not stick to the bag and silicone based tapes were cured to the bag after an autoclave cycle. Therefore a groove was made at the edge of the final bag to increase the vacuum tightness without tape at all.



1	Chain for vacuum transport in 6x6 mm groove	6	Product
2	**Silicon vacuum bag**	7	A4000 release film *
3	A4000 release foil	8	**2 layers** Airweave super 10
4	**2 layers** glass fabric US7781	9	Vacuum points, see picture below
5	A4000 release foil perforated **50 x 50 mm**		

Figure 9: Vacuum bag overview

In Figure 10 the final vacuum bag is shown which was made on an aluminium grid. Since the bag was much bigger and the pot life of the EZ Brush silicone was limited, the final bag was made of Transil 20 parts A&B from Mouldlife with an automatic mixing machine. The bag was made at NLR by MC Technics. The silicone used is a two component Platinum-based cure silicone elastomer that crosslinks at room temperature by polyaddition reaction. Polyester knitted fabric reinforcing cloth SC00251 and SC00277 and ADD PA Thixo rheology modifier additive fluid from Silicone Composites were used near the vacuum grooves. The silicone can be used up to temperature of 220-240 °C.

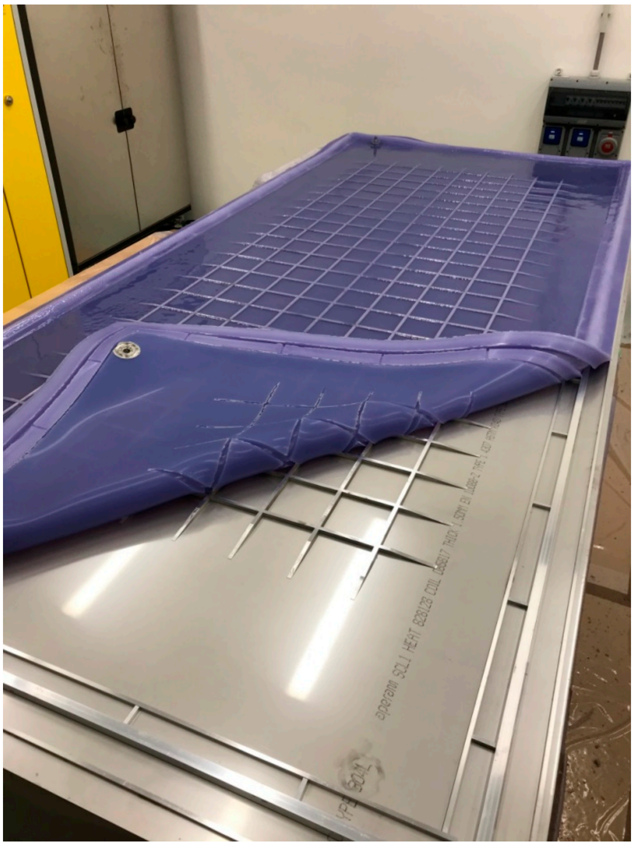


Figure 10: Vacuum bag with manufacturing mould

In Figure 11 the bagging is shown with the release foil on top of the panel. The panel was cured in an autoclave at 7 bars with 20 % vacuum and a temperature of 180 °C for 2 hours.

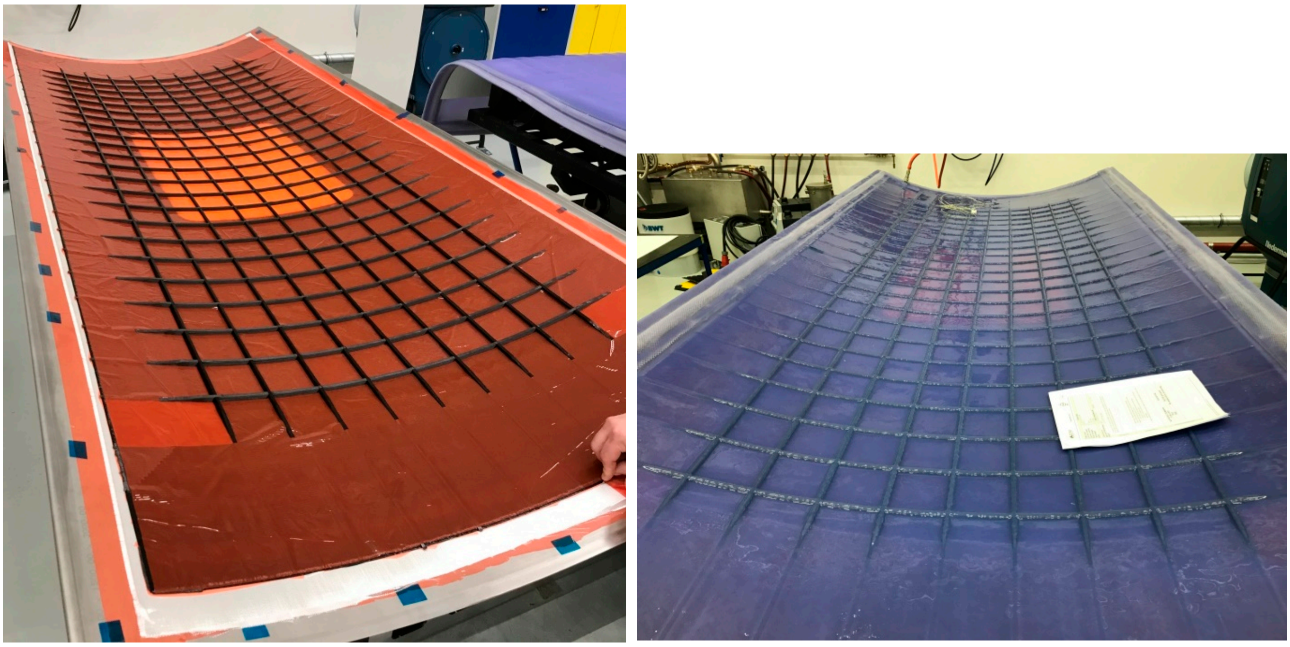


Figure 11: Vacuum bagging of the panel

4 Results

After the cure cycle the panel was visually and ultrasonic inspected. The quality of the panel was very good, see Figure 12. The flexible bag creates a more uniform pressure distribution then with metal blocks. By this, no areas with a lower pressure during curing were present. An attenuation image of the C-scan is given Figure 13, note that this is a combined image of three separated scan for the different thicknesses in the panel. As can be seen the quality is very uniform. The shape of the stiffeners was slightly tapered by the flexible vacuum bag. This shape will be better for stiffness performance of the panel, but the strength of the connection of the grid to the panel will be less. The final mechanical test should prove if the panel can withstand the loads.

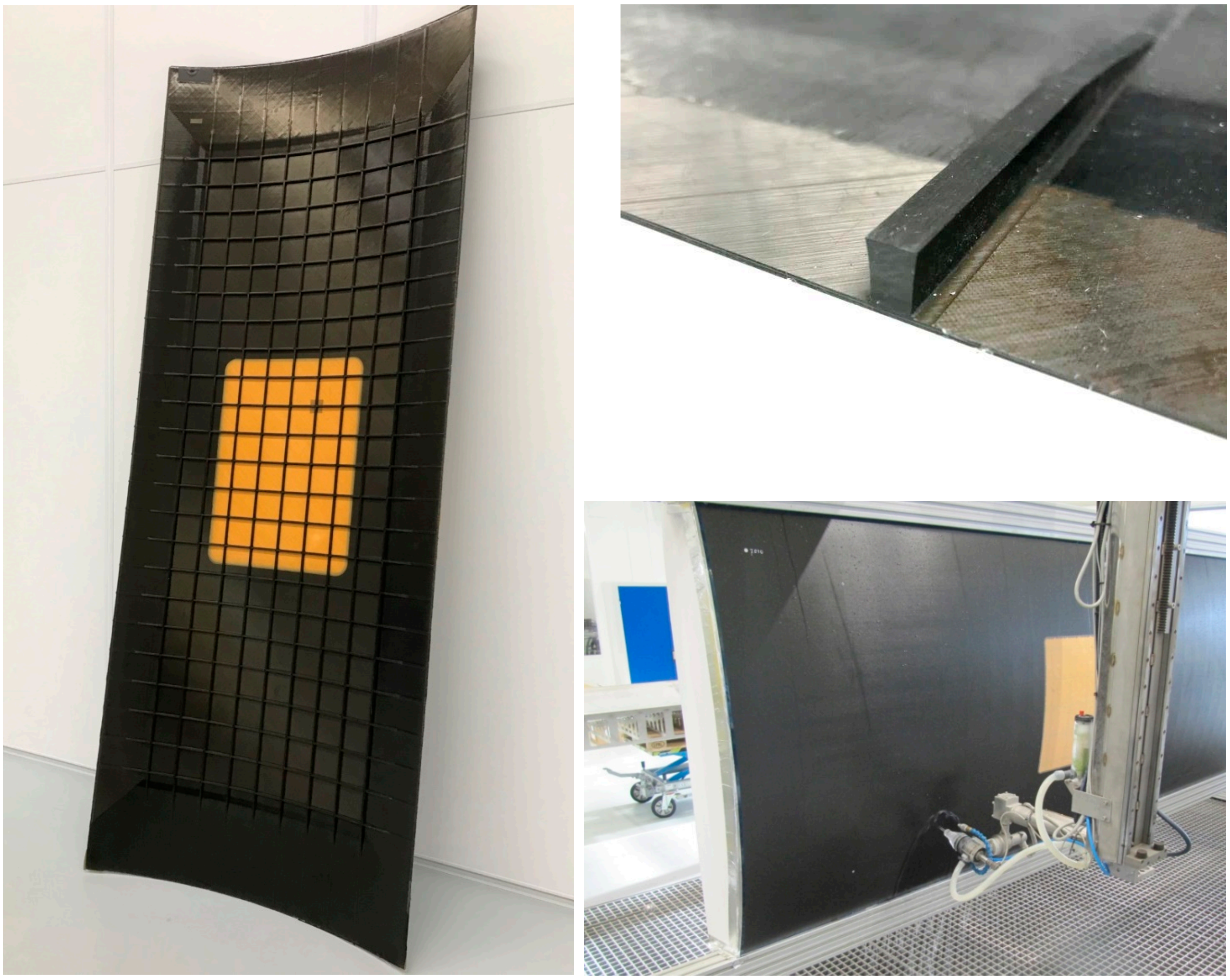


Figure 12: Final panel after cure with a detail of a stiffener and the panel during C-scan

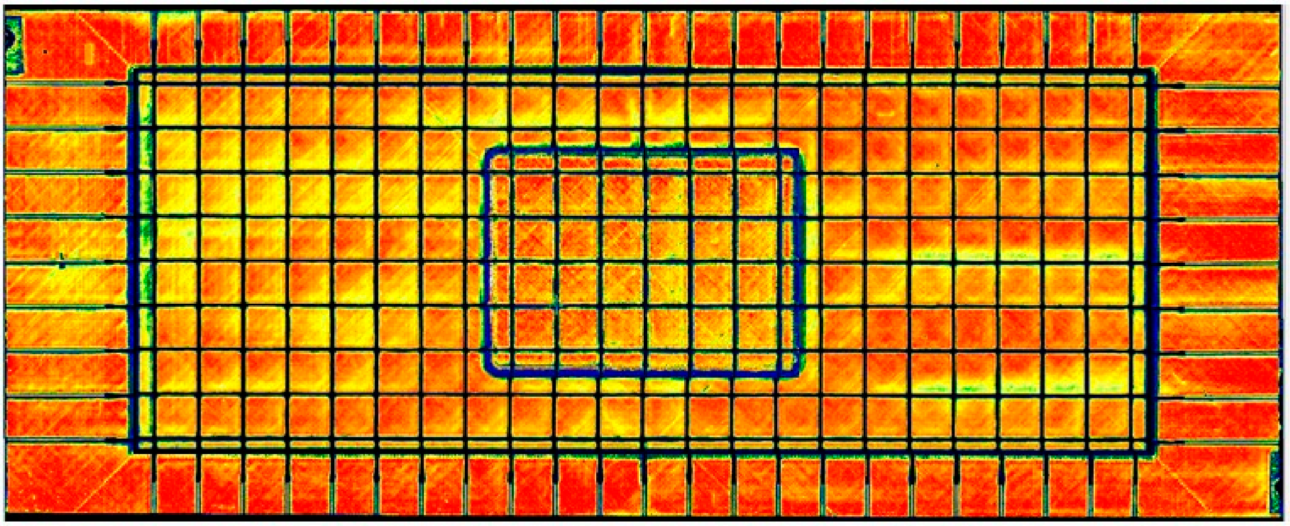


Figure 13: Attenuation image of the ultrasonic inspection

5 Conclusions and remarks

A preform for a grid stiffened panel can be made fully automatic in a very efficient way with very low scrap rates. By using silicone bags, also the curing of such panels can be done affordable. The environmental impact is reduced since the vacuum bag can be re-used and cleaning of tooling blocks is not necessary any more. The use of silicones in a composite facility is often discussed. However, by using a fully automated and isolated preform manufacturing cell, the preform manufacturing can be separated from the curing. If no human handling is required during the placement of fibre layers, the change of silicone contamination within the laminate is very limited. The dimension of stiffeners can be optimised by adjusting the shape of the bag, if a more rectangular shape of the stiffeners is required.

Acknowledgments

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For more information visit: **www.nlr.org**

Postal address
PO Box 90502
1006 BM Amsterdam, The Netherlands
e) info@nlr.nl i) www.nlr.org

NLR Amsterdam
Anthony Fokkerweg 2
1059 CM Amsterdam, The Netherlands
p) +31 88 511 3113

NLR Marknesse
Voorsterweg 31
8316 PR Marknesse, The Netherlands
p) +31 88 511 4444