WINGCOVER

EFFICIENT PRODUCTION OF WING SHELLS IN DRY FIBER PLACEMENT TECHNOLOGY

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Abstract

The overall objective of the BMWi funded WingCover project (01/2013-06/2015) was the development of a complete process chain for the production of CFRP wing shells, including the corresponding system concepts. A further goal of the project consortium – AIRBUS Operations GmbH, DLR and CTC GmbH (associated) – was to determine the basic requirements for a high volume production of large double curvature shells, dependent on cost, reliability and productivity.

The main DLR objectives in the project were the development of prepreg (resin pre impregnated fibers) and dry fiber placement manufacturing technologies for production of wing shells on an industrial scale using robust, reliable and automated machinery and the increase of productivity at constant or improved quality using online quality sensor systems.

Within the scope of the project a process chain for a high volume production of CFRP shells was developed. Furthermore a new Dry Fiber Placement unit was integrated into the GroFi fiber placement facility at DLR Stade. Manufacturing trials for large scale vertical layup on a complex tool were performed and the manufacturability of very thick laminates was demonstrated. Finally one AFP and one DFP part of the same design were manufactured to compare and validate the manufacturing technologies.

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1. Introduction

The next generation of aircrafts needs a further reduction in structural weight to fulfil future environmental regulations and to stay competitive in a growing market. This weight reduction can only be achieved by using new part designs and materials. Carbon fiber reinforced plastic (CFRP) has the highest potential to meet these demands. Furthermore the manufacturing methods for next generation aircrafts need to be capable of high volume production at low cost and high reproducibility. Robust production methods, the current production costs and the safe production ramp-up are the crucial criteria for a competitive product.

2. State of the art

The state of the art manufacturing methods for large scale shells made of carbon fiber reinforced plastic (CFRP) are “Automated Tape Laying” (ATL) and “Automated Fiber Placement” (AFP). The production of composite wing shells is performed by huge single head gantry ATL machines with a layup speed of 10-20kg/hr. To achieve the production rates for the next generations of aircrafts, a ten times higher material placement rate has to be achieved compared to the state of the art.

Since 2010 the DLR is setting up a very flexible facility called GroFi, combining Automated Fiber Placement (AFP) and Automated Tape Laying (ATL) technology in one plant. Up to four robot based layup units work coordinated on one part, controlled by a supervisor system. Furthermore the up to 20m long molds in the production area of this facility are fixed in a vertical position to reduce the plant footprint and allow to work from two sides of the tool carrier. Finally non value adding secondary processes, such as repair and maintenance or the change of material spools, which can make up to 40% of the process time, can be kept to a minimum being able to move the affected layup units by a rail system to an adjacent maintenance area. All these measures can lead to the pursued up to ten times higher material layup rate whilst keeping the investment costs low by using mostly standard off the shelf machinery. [1] 2] [3] [4]

Figure 1. GroFi facility at DLR Stade

It is not yet clear whether future composite wings will be build in prepreg or dry fiber technology, since both technologies have their advantages and disadvantages. Compared to dry fiber material the layup of prepreg is easier, the fiber volume content can be easier preset and controlled and mechanical properties. On the other hand the resin ages and the prepreg expires very fast, if not stored in huge deep freezing storages. Furthermore huge and expensive autoclaves have to be used for resin curing and are seen as a big bottleneck for the manufacturing process.
For the positive side of the dry fiber material we can state, that it does not have to be deep-freezed and no autoclave is needed for the curing. But on the other hand layup is more difficult, the resin infusion is challenging and the fiber volume content and mechanical properties are harder to be controlled.

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AIRBUS is manufacturing its current A350 composite wing shells by Automated Tape Laying on huge gantry based machinery [5]. The new AIRBUS competitors like the Bombardiers C-Series or Irkuts MC-21 are using dry fiber. Whilst Bombardier is manufacturing the wing shells in a semi-automated process from carbon fiber fabrics [6], the Russian Irkut supplier AeroComposit uses fully automated Dry Fiber Placement machinery [7].

To meet the demands of future developments, the Dry Fiber Placement technology was introduced to the GroFi facility in the WingCover project, expanding the plant with a third manufacturing technology.

3. Machine Concept

After some market inquiries, the project consortium decided to obtain a 16x ¼'' Fiber Placement machine from Coriolis Composites, since their technology is currently the most advanced regarding robotic based systems.

To be able to be moved within the GroFi rail system, the standard components of the Coriolis machine had to be adapted to fit onto a GroFi platform, keeping in mind the center of gravity and the allowed loads for emergency stop from full speed. The connection to the rail system is implemented by roller cassettes by the rail system supplier Strothmann. The power is supplied by collectors underneath the platform and the movement is ensured by two drives underneath the platform. The creel was put on the back of the platform adding a slide mechanism to allow access to the front of the creel. The necessary compressed air for the creel and the head is provided by a huge compressor with a dryer unit. The robot is a KUKA KR500 with Siemens drives and drive encoders similar to the existing GroFi AFP units. A Siemens Sinumerik 840D control is used. The drive control and PLC are all set up in one electric cabinet to the side of the platform.

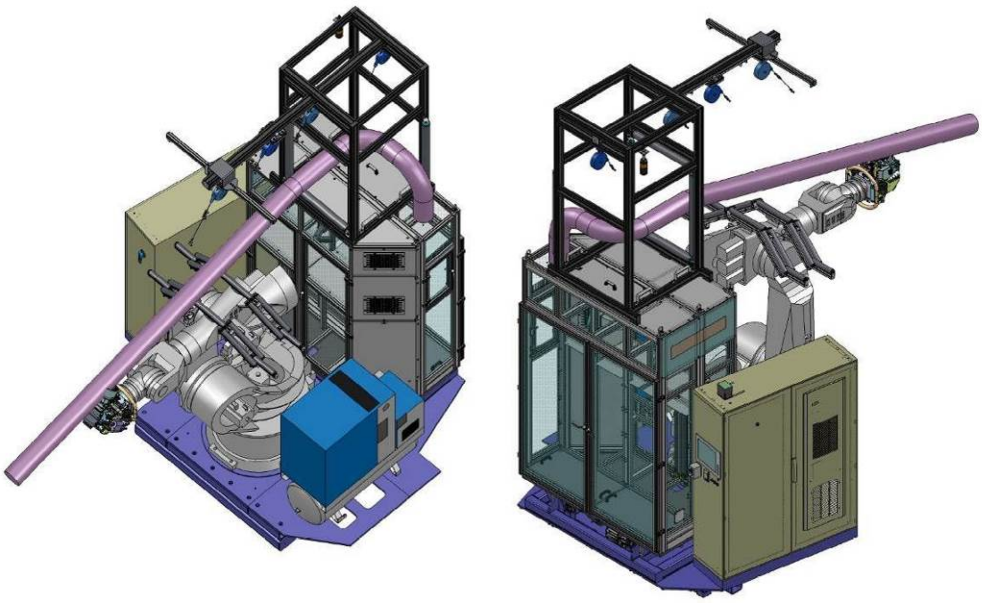

Figure 2. CAD-Model of the Dry Fiber Placement Unit [Coriolis Composites]

To allow the unit to be moved within the GroFi rail system and over the turntables, the GroFi drive routine had to be implemented into the Coriolis machine. Especially the drive adjustments when moving over a gap in the rack between a rail segment and a turntable had to be assured. At last the wireless communication with the supervisor system had to be established.

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An additional modification had to be implemented for the material heating system to melt the binder. Since the usage of a laser heating system is not usable in the GroFi facility, because the hole plant would have to be capsuled due to Laser radiation regulations, a new infrared heating device consisting of three IR-lamps (one facing the fibers to be laid and two facing the layup surface) was developed and tested by Coriolis to allow binder activation at layup speeds of 0,8 m/s. Related to this new heating device an active drive for the compaction roller was implemented to avoid overheating of the compaction roller due to IR lamp radiation inertia during off surface movements in between two tapes.

Figure 3. WingCover Dry Fiber Placement (DFP) Unit at DLR Stade

4. Manufacturing Trials

After the installation of the DFP unit into the GroFi facility, manufacturing trials regarding accuracy and speed of the dry fiber layup were performed to validate the machine performance. For these trials a dry fiber ¼ ‘’ slit tape from CYTEC UK has been used. Both speed and accuracy (fiber cut and add, fiber gap and overlap, layup orientation) could be validated, although the layup parameters for the IR heating and the compaction force were not optimized and the deposition quality for very short fibers was poor due to a guiding plate that had to be removed because of overheating.

To improve the first ply adhesion of the dry fiber material on the vertical layup surface, a small parameter study was performed to find the best process window for the material. A high compaction force of around 1000N was found to work best for the fiber deposition, although the high compaction was seen critical for a subsequent resin infusion.

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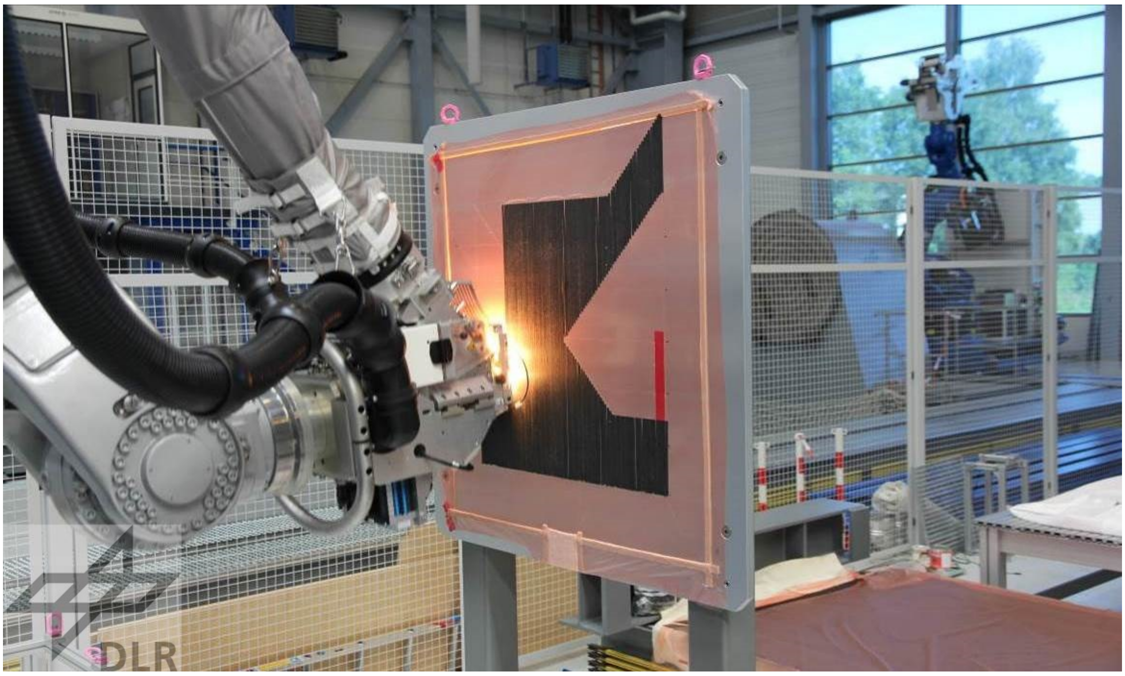

Figure 4. Manufacturing trials with the Dry Fiber Placement (DFP) Unit on a vertical tool

The wing root of a state of the art composite wing can consist of up to 100 plies of high grade (268g/m²) carbon fiber prepreg. Prior to the manufacturing of the demonstrator parts, pretrials had to be performed to demonstrate the vertical deposition of these thick laminates.

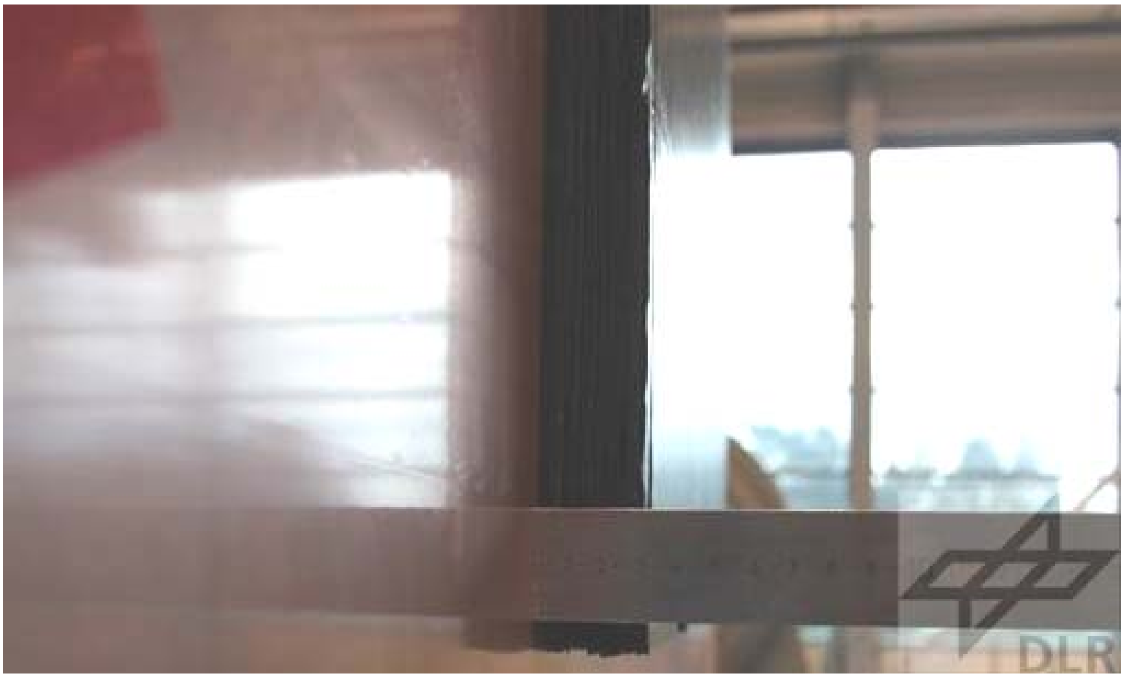

Figure 5. Vertical layup of very thick laminates

Pretrails for the first ply adhesion of prepreg on a flat vertical tool had already been performed in the GrOnQA project [2]. Building up on these results the vertical deposition of 100 plies was performed under climate controlled conditions. The deposition trials were performed with an Automated Tape Laying (ATL) machine using a 150mm prepreg tape of TORAY Japan with 268g/m² and an uncured

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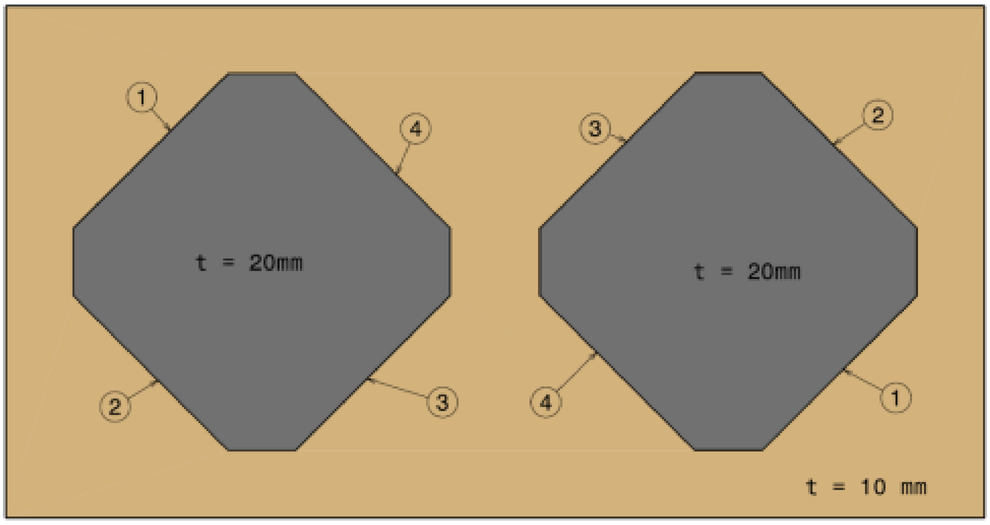
ply thickness of 0.26mm. The deposition area had the dimensions 750 x 750mm (5 Tapes) and the laminate was build up by alternating sequences of 0° and 90° plies until exactly 100 plies were reached by the end of the tape roll. Due to material bulking the final stack had a thickness of around 300mm (see figure 5). A limit for plies in vertical layup was not found during the trials. Vertical layup of more than 100 plies seems to be possible without restrictions.

5. Manufacturing of demonstrator parts

To compare the performance of the AFP and the DFP manufacturing technologies, demonstrator parts of the same design were manufactured in the GroFi Fiber Placement facility.



Ramp Number	Ramp Type
1	1 / 20
2	1 / 8
3	1 / 10
4	1 / 5

Figure 6. Generic demonstrator design

A generic design was created for the prepreg and dry fiber demonstrator. A double curvature pre-serial A350 wing root tool in vertical position was used for the layup. The deposition area had the dimensions 2900 x 1750mm with two octagonal patches and ramps of different inclinations (1/5, 1/8, 1/10, 1/20) on each side of the patches. The laminate consisted of up to 100 plies in the patch area and 50 full plies with an overall balanced, quasiisotropic stacking.

The prepreg demonstrator part was manufactured with a GroFi 16 x ¼'' Automated Fiber Placement machine from the GroFi OEM MAG. A HEXCEL ¼'' prepreg slit tape with 134 g/m² was used.

The dry fiber demonstrator part was manufactured with the previously described Coriolis 16 x ¼'' Dry Fiber Placement machine. The same material as for the pretrials, the CYTEC ¼'' dry fiber slit tape with 196 g/m² was used for the layup.

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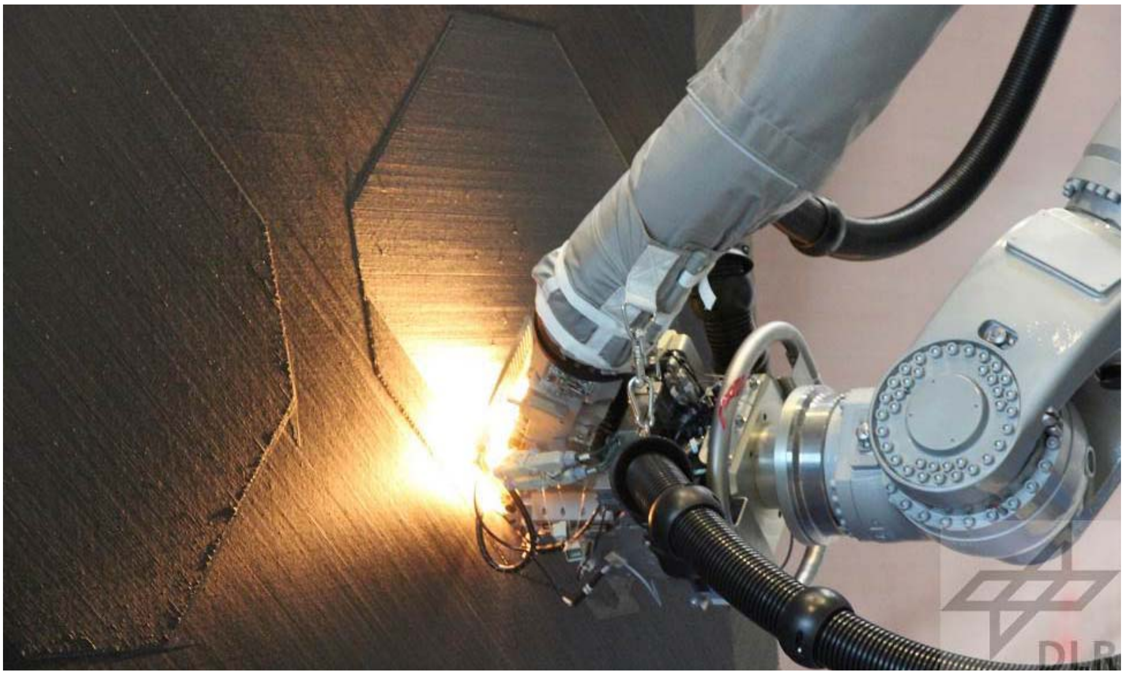

Figure 7. Dry Fiber Placement demonstrator manufacturing

During the layup of both demonstrator parts all process times and auxiliary process times were measured:

- Full process time
- Time for layup
- Time for repairs
- Time for machine maintenance
- Time for part inspection
- Pause time

Furthermore all occurring failures during layup were recorded:

- Missing tow
- Cutting error
- Tack error
- Twist
- Material defect
- Gap / overlap
- Foreign objects
- Fuzz balls
- Others

The failures were also analyzed regarding ply number, ply orientation, tow number and total number of failure type. This evaluation of the process times and failures gives a good first impression of the failure types and in what situations they mainly occur. It has to be pointed out though, that the failures and process times are also highly material dependent and do not finally describe the machine performance.

The main error during prepreg layup was gap / overlap of neighboring fibers. This failure is common for the layup of very short fibers in the AFP process. It occurs due to the fact that it is nearly impossible to perfectly guide the short fibers to the compression roller after cutting.

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The main error during dry fiber layup was fuzz balls and the related contamination of the layup head. This error is related to the fact, that the CYTEC tape has been slitted to ¼'' from a wider tape. Out sticking fibers accumulate in the head and build up fuzz balls until they get carried away by a following tape and settle down on the layup surface. Subsequent tests with a different, non slitted dry fiber material did not show any fuzz balls, confirming the material relation for the layup performance.

Both layups could be finished in the project time but only the prepreg demonstrator was successfully cured. The infusion of the dry fiber demonstrator could not be finished during the project, but was performed subsequent to the Wingcover project.

6. Summary

Within the three year joint project WingCover a process chain for a high volume production of CFRP shells was developed in cooperation with Airbus Operations GmbH and CTC GmbH. A new Dry Fiber Placement unit was integrated into the DLR fiber placement facility GroFi. Manufacturing trials for large scale vertical layup on a double curvature tool were performed and the vertical deposition of very thick prepreg and dry fiber laminates was demonstrated. Finally one AFP and one DFP part of the same design were manufactured to compare the machine performances and validate the manufacturing technologies.

Acknowledgments

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