Thermoplastic Matrix Composites: Xtra complex, Xtra Quick, Xtra Efficient

Manufacturing advanced composites for the A350 XWB and beyond

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ABSTRACT

The A350 XWB is the first aircraft of the Airbus family featuring a full composite fuselage. Due to the advanced design of the airframe and the widespread application of carbon fiber reinforced plastics the airplane has an extremely wide fuselage with passengers enjoying more headroom, wider panoramic windows and larger overhead storage space.

Premium AEROTEC GmbH is a major risk share partner in the A350 XWB program. Premium AEROTEC is responsible for the design and manufacturing of two fuselage sections of this exceptionally aircraft. Every single section of the composite fuselage is assembled from the 4 major skin panels and thousands of smaller detailed parts. These parts feature highly complexity and have to be produced in very high rates. Premium AEROTEC manufactures in Bremen more than 5000 CFK-Clips for every A350 XWB. For this application, thermoplastics have been proven to be the most efficient material choice with respect to processing time, process flexibility and quality assurance.

Over the last two years a highly automated thermoforming cell has been developed and put into operation in order to achieve those ambitious targets. Yet the need for even more revolutionary processing is more demanding. The key technologies for an even more efficient utilisation of thermoplastics in high end aerospace structures are: welding of sub assemblies, bolding of thermoplastics with titan, thermoplastic preforming and forming of unidirectional composites. With the present paper the authors would like to give an overview of the most challenging projects concerning the further optimisation of the A350XWB Clip production in Bremen and the development work aiming on the next generation airframes..

1 INTRODUCTION

The demand for greater efficiency led to the adoption of a composite airframe for the A350XWB of Airbus . Given the successful launch of the aircraft, the manufacturers now faces a huge backlog of orders and the heat is on all suppliers to develop efficient, and automated, composites production to meet accelerating delivery rates [1].

Airbus has chosen for the A350 XWB a fuselage design based on 4 panels that are assembled together in order to build a section. The main elements of a typical shell assembly as shown in Figure 1 are the skin, the stringers, the frames and the clips. Since in the A350 XWB the stringers are directly bonded to the skin, the clips are the elements connecting the skin to the frames.

For the manufacturing of the very large components of the aircraft the use of epoxy-prepreg materials and the autoclave curing is a good option [2]. On the other hand for the manufacturing of the clips the chosen process had to allow very short cycle times, low labor demand and high flexibility. In order to achieve all these characteristics the clips are made of thermoplastic matrix materials by a thermoforming process.

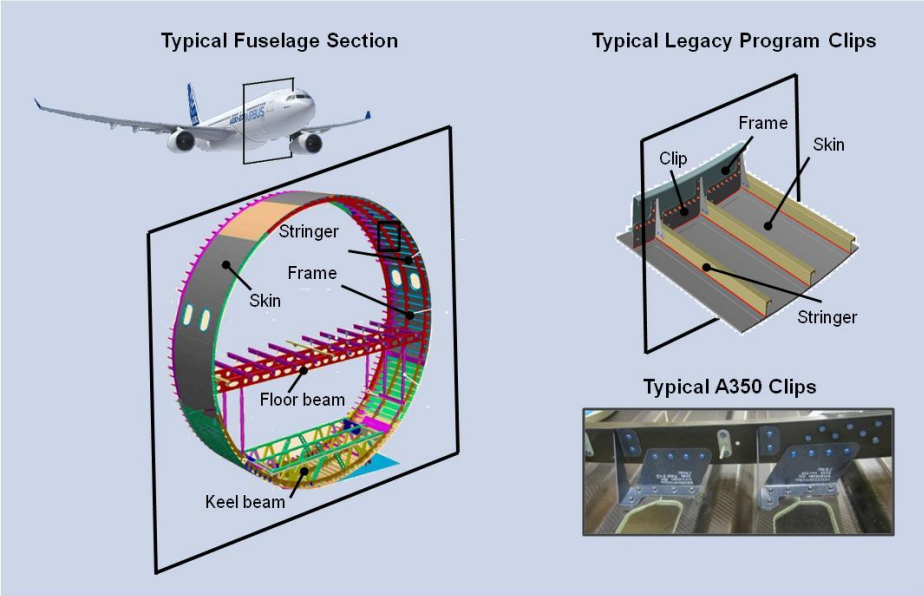

FIGURE 1: Mail structural elements of a typical fuselage design

Premium AEROTEC is a 100% subsidiary of the AIRBUS Group and a major risk partner of Airbus in the development and manufacturing of the A350 XWB. Premium AEROTEC is responsible for the design and manufacturing of 6 major fuselage shells and the structural assembly of a complete fuselage section. Figure 2 gives an overview of the major PAG work packages in the A350 XWB program [2].

FIGURE 1: Major work packages of Premium AEROTEC within the A350 program

2 THERMOPLASTIC CLIPS

The A350 clips are devided into 4 main categories: the L-shapes, the cleats, the auto stabilized clips (AS) and the Window-clips (Figure 3). The L-shape clips have the form of a simple L-shaped angle. On the other hand the auto stabilized clips have a more complicated form featuring a stabilizing element integrated on the L-Shape angle. The window clips are the longest of all (800 mm) since they

are assembled along the window region. A further category, the cleats are small stabilizing elements which are mounted on other clips in order to provide locally a higher stiffness of the structure. In order to fulfill the engineering requirements the clips are reinforced with T-300 carbon fiber woven fabrics. The layup is quasi isotropic with laminate thickness between 6 and 14 layers. The matrix system of the clips is either PPS or PEEK. In order to built the forward and rear section of a single A350-900 more than 5000 clips with more than 2000 different designs are manufactured [2].

FIGURE 2: Basic designs of the A350 clips

The production of the clips is based on the thermoforming of pre-consolidated thermoplastic composite panels. The semi finished products (panels) are delivered fully consolidated and with a predefined lay up. According to the clip geometry, blanks are cut out of the panels by a 2D milling process. In a next step the blanks are placed by a robotic system into an infrared oven. Once the temperature of the blank has reached the melting point of the polymer, the robotic arm removes the melted material out of the oven and places it on the press tool of the thermoforming press. The tool closes and presses the laminate up to the point where the material is fully reconsolidated. Once the matrix is again form stable, the robotic arm takes the formed part out of the press and delivers it to the next station. In the next processing step the formed parts are milled to their final contour and holes are drilled if needed with the help of a 5-axis milling and drilling device. In a final stage all clips undergo an ultrasonic testing and get a serial number.

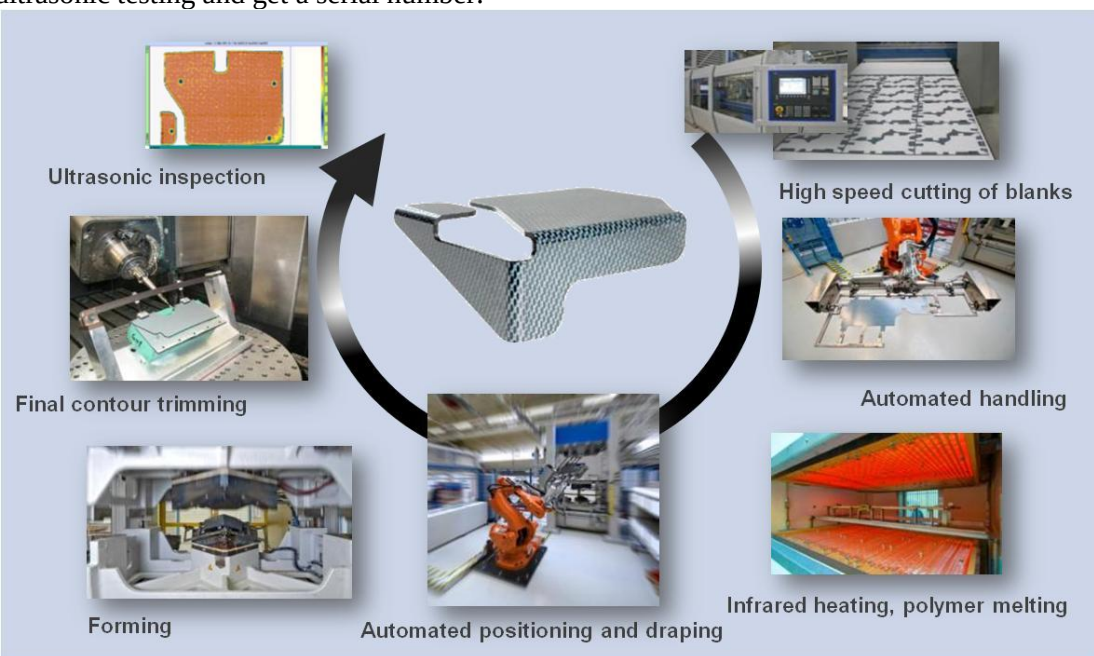

FIGURE 3: Main steps of the clip manufacturing process.

The developed manufacturing process due to the high automation degree is suitable for the serial production of the fuselage clips under high quality standards [3]. The clips have undergone an extensive test campaign according to the AIRBUS requirements.

3 INOVATIVE MANUFACTURING

In order to develop a highly automated process there was the need to develop new solutions for various problems.

The thermoforming operation is the process substep which has the greatest influence on the final quality of the produced parts. Furthermore quality assurance and process documentation is a very important point in the production of aerospace parts. Taken that into account the thermoforming cell was designed in order to be able to fulfil all the relevant requirements. Under these aspects the thermoforming cell of Premium AEROTEC can heat up the blanks under a predefined ramp with a closed loop control. The stamp form temperature is constantly monitored and controlled, the forming force is adjusted according to the part and all forming parameters are recorded and saved. Figure 5 presents an ideal thermoforming process cycle.

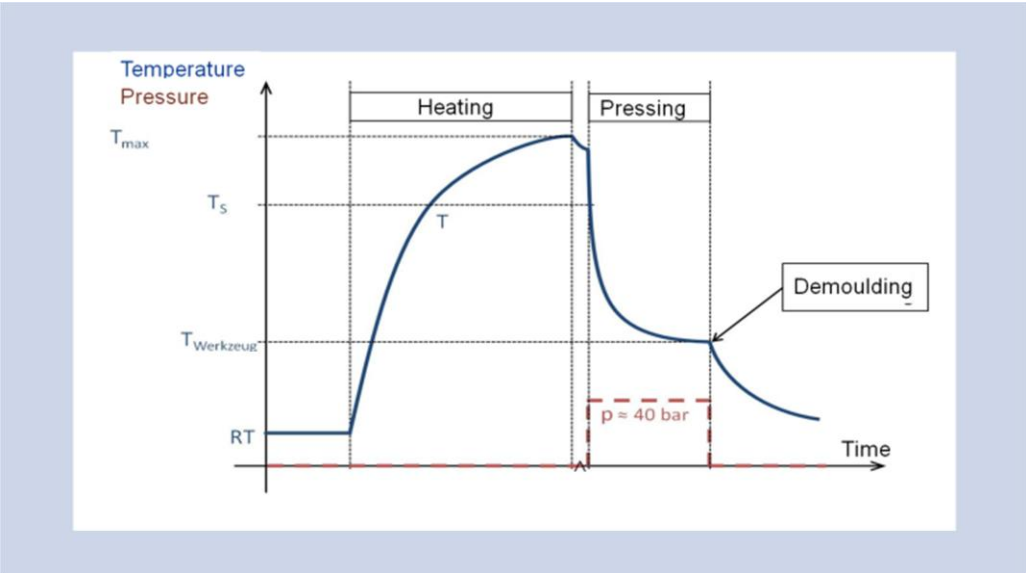

FIGURE 5: Time temperature and time pressure profile during the thermoforming process.

One of the most demanding specifications was the forming of the auto stabilised clips. These parts are folded in 3 directions. In order to be able to automatically perform this operation, an innovative handling system has been developed. The system is based on the use of a folding frame with 3 hinges. The frame is handled by a specially design robotic head that performs the folding and lays the melted bank on the pyramided shaped stamping form (Figure 6).

The production of more than 2500 different part geometries would not be possible without the use of an advanced tool changing concept. This concept is based on the clustering of the tools and the use of a modular master form. The clustering of the tools has allowed the production of more than one clip geometry on the same tool. On the other hand the use of a modular master form (Figure 7) provides the needed stiffness, ensures the parallel closing of the tool and allows a homogenous pressure application. Based on that, it was possible to design smaller pressing tools which can be easily placed on and removed from the master form. This operation is done by an industrial robot equipped with a specially designed handling system (Figure 8).

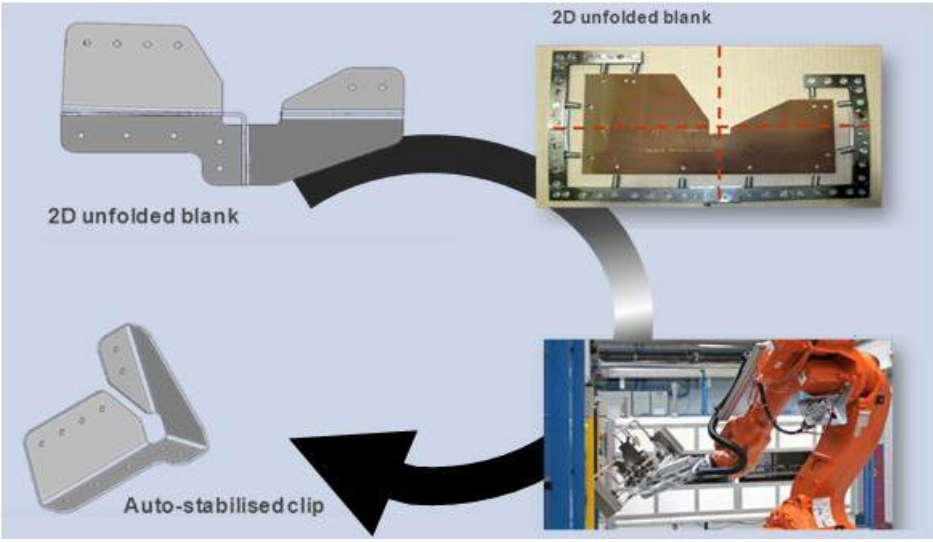

FIGURE 6: Blank folding system.

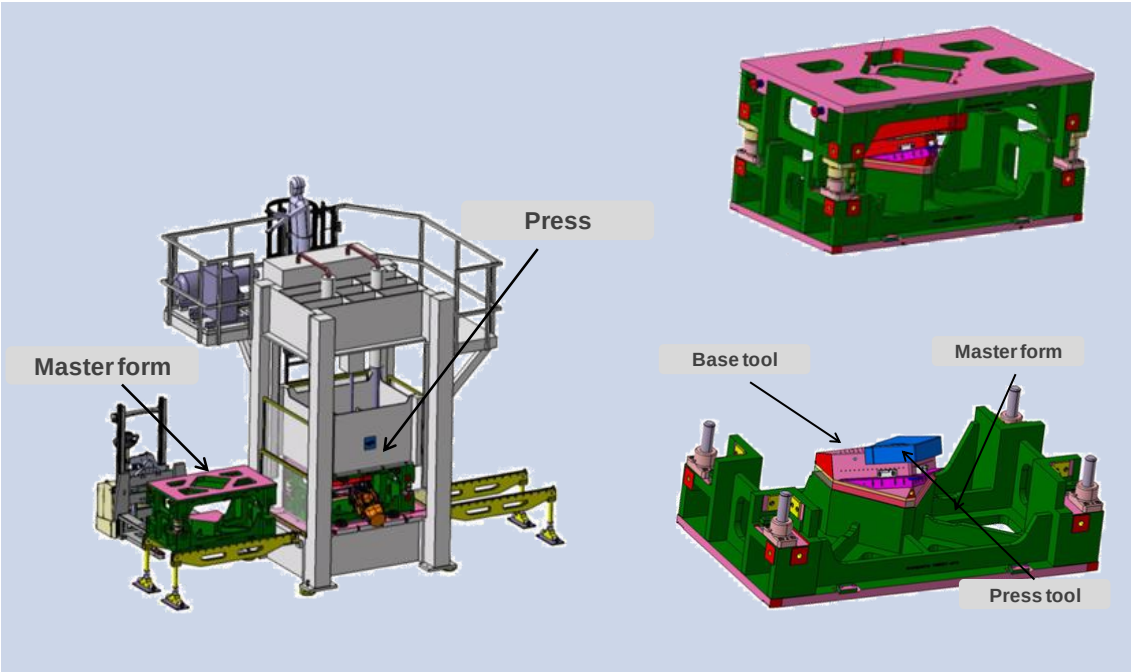

FIGURE 7: Schematic representation oft the press and master form concept used by Premium AEROTEC

Another challenging sub process was the milling of the final part contour. In order to achieve the required tolerances as well to ensure a quick mounting and release of the part from the table of the milling machine, a novel clamping has been developed. With use of this jig the milling operation lasts shorter than two minutes for every part.

The final step is inspection of all parts, using phased-array, pulse-echo ultrasonic equipment from a European supplier. The semi-automated testing involves immersing parts in a tank for C-scan testing, but a few, more complex clips with joggles are manually inspected, using hand-held A-scan transducers. Tested parts are marked with an identifying radio frequency identification (RFID) tag to enable paperless tracking throughout the fuselage assembly process. Parts cycle through the stations in a mere 85 seconds.

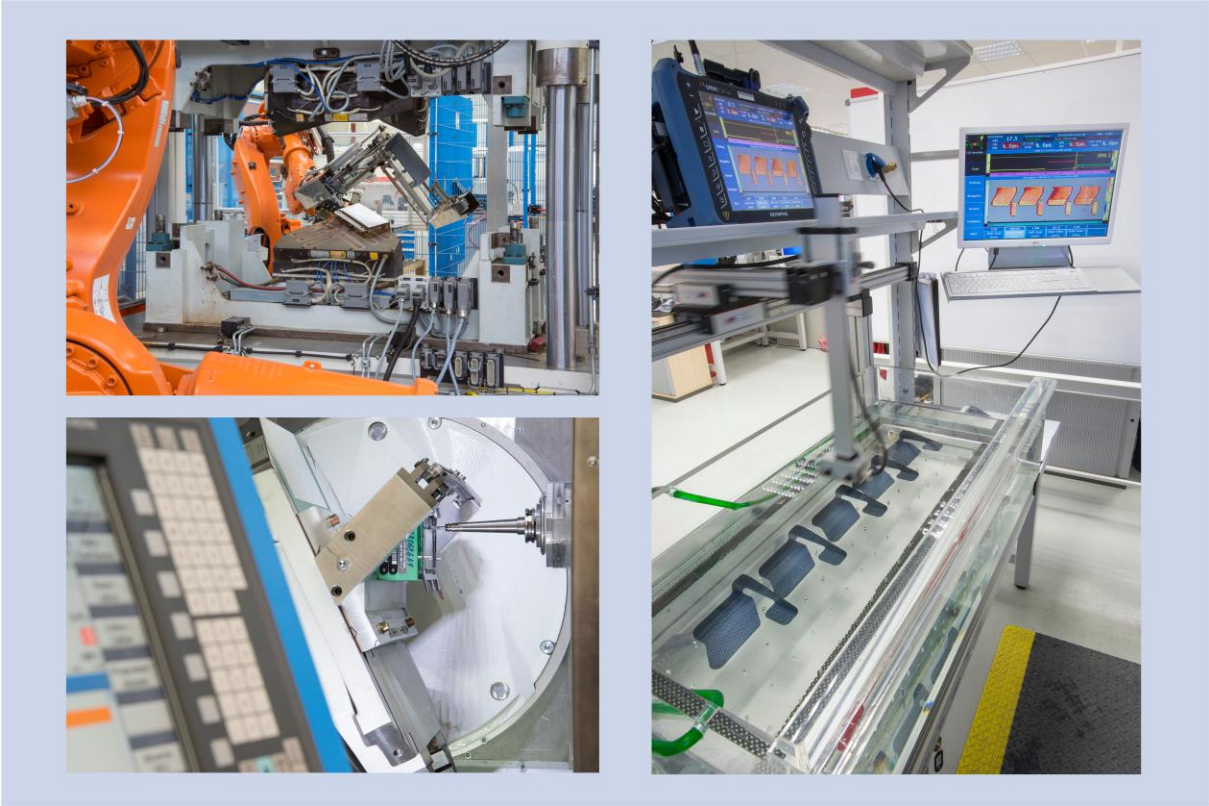

FIGURE 8:The final steps of the clip manufacturing operations: demoulding 3D-triming and NDI inspection

CONTINUOUS IMPROVEMENT

Although the three existing cells continue serial clip production, Premium Aerotec has already determined where improvements can be made. The company is in the process of validating and qualifying new technologies: The company has built a prototype demonstrator workcell to investigate local heating and forming of clips — that is, instead of heating the entire blank prior to thermoforming, a portion of the blank is heated only where the shape change is needed.

Local forming requires a infrared oven specially designed to heat only the specified region of the blank; robotic handling of the partially softened blanks; and a forming tool and press with positioning features that can locate the heated region correctly for forming. The concept has been extensively trialed, and parts have been tested using carbon fiber/PEEK and carbon fiber/PPS blanks. Mechanical tests and microsections without any signs of porosity of locally formed parts have shown that mechanical properties fulfill the design requirements. And, differential scanning calorimetry tests prove that resin crystallinity in the heated and formed region does not deviate from the crystallinity observed in the rest of the part.

In some cases, clips need to have a titanium L-Shape part attached, for additional strength. At present, the titanium pieces are manually bonded to the clips using an adhesive, which slows the overall production process. In order to reduce the labor demand and develop a more cost-effective welding technolog, two methods are under investigation: ultrasonic welding and induction welding. Tests have shown that the faster welding process holds the two materials together with strength adequate to endure handling, drilling and assembly on the shop floor, without damage to either material.

Lastly, Premium Aerotec is investigating alternative reinforcement forms, specifically, unidirectional tapes, to replace woven carbon/thermoplastic panels. The company is working with research partner Fraunhofer ICT (Pfinztal, Germany) to design an automated method to produce custom layups for specific clips. This would allow to optimize, in an unrestricted way, the stacking

sequence and ply orientation, for maximum design flexibility. Fraunhofer is developing a thermoplastic uni tape preforming sequence that employs Dieffenbacher's (Eppingen, Germany) Relay automated moving-table layup technology, originally developed by now-defunct Fiberforge, to create a flat preform. The preform blank then could be stamp-formed in a thermoforming cell. Tests on stamped uni tape demonstrator parts of high complexity have shown that they far surpass the performance possible using the woven carbon fiber-reinforced, semi-finished panel stock, with larger fiber volume fraction (60%, up from 55%) and less than 0.1% void content.

FIGURE 9:Advanced materials like UD-TP tapes allow the manufacturing of complex and more sofosticated parts

CONCLUSIONS

Over the last three years Premium AEROTEC has set into operation a high end thermoplastic composite production cell. The production unit delivers the clips for the fuselage of the A350 XWB under serial conditions. The thermoplastic composites have proven to be the right material choice since extreme short cycle times and high flexibility have became possible. Premium AEROTEC manufacturing sites deliver more than 5000 thermoplastic parts for every A350 XWB ship set meeting all airbus quality requirements. Yet the challenge is to further expand the use of thermoplastics in the aerospace industry. In order to achieve that goal new technologies have to be developed. Premium AEROTEC is on the way to establish new local forming techniques, to bring in to operation welding technologies, to use semi finish products like tapes and to ensure a sustainable product cycle life through the recycling of the material scrap. All these are ambitious targets but the very promising results generated from various research projects confirm the high potential of the thermoplastic matrix composites. Premium AEROTEC since its establishment in 2009 has proven to be a leading partner for the development and manufacture of advanced aerospace structures made of high tech materials in a truly sophisticated industrial environment.

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