FORMING THE FUTURE: STRUCTURAL APPLICATIONS FOR FIBRE REINFORCED THERMOPLASTICS IN NEXT GENERATION AIRFRAMES

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Abstract

Premium AEROTEC GmbH is a major risk share partner in the A350XWB programme and responsible for the design and manufacturing of two fuselage sections of this exceptional aircraft. Having established a sophisticated process for the production of more than 5000 CFRP-Clips for every A350XWB, Premium AEROTEC is capable of delivering on time, on budget and in the right quality. The authors present a process for the manufacturing of unidirectional reinforced thermoplastic composite structures, suitable for a use in next generation airframes. Therefore, various part geometries have been produced and thoroughly tested to ensure they meet the quality requirements in aerospace applications. Challenges met while preforming and thermoforming, as well as possible improvements are highlighted. Unidirectional reinforced thermoplastics offer a higher specific stiffness and strength than woven fabrics and the opportunity to thicken the part locally where high loads are applied. Furthermore, they can be engineered to be orientated in the main load directions, making it possible to pursue a more lightweight design approach.

1. Introduction

The A350XWB is the latest development of Airbus and a truly revolutionary aircraft featuring a fuselage and wings mostly made of fibre reinforced plastics. Due to its advanced design, the aircraft has an extra wide fuselage granting more headroom, panoramic windows and larger overhead storage for the passengers. The high end materials used result in lower fuel burn and easier maintenance which makes its operators benefit from 25% lower fuel burn , 25% lower operating costs and 25% lower CO_2 emissions. [1]

Premium AEROTEC is a 100% subsidiary of the Airbus Group and a major risk share partner of Airbus in development and production of the A350XWB. The fuselage of this aircraft is divided into five main sections, each assembled from four shells. Premium AEROTEC is responsible for the design and manufacturing of six shells and the structural assembly of a complete fuselage section. [2]

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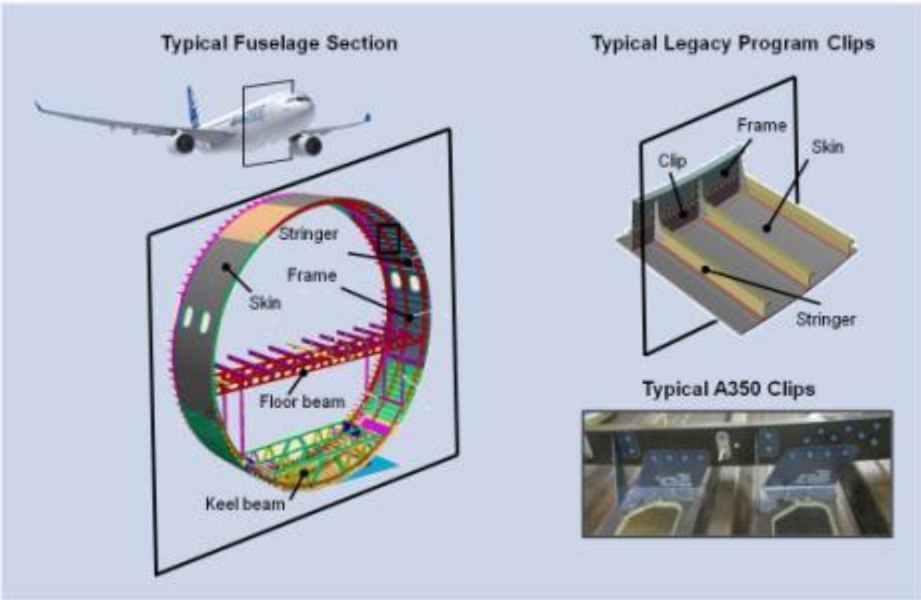

Figure 1: Main structural elements of a typical fuselage design [4]

The main elements of a typical shell assembly, as shown in figure 1, are the skin, stringers, frames and clips. Since the stringers are directly bonded to the skin, the clips connect the skin to the frames. The skins and frames, being very large parts, are made from epoxy prepregs and cured in an autoclave. Fibre reinforced thermoplastics are used for the production of the clips due to the demand for a process with short cycle times, low labour demand and high flexibility.

The clips are divided into four main categories: L-shapes, cleats, auto-stabilized clips (AS type) and window clips (see figure 2). L-shapes have the form of a simple L-shaped angle. AS type clips feature a stabilizing cleat like element attached to the L-shape. Window clips are among the longest clips manufactured by Premium AEROTEC with a length of 800 mm since they are mounted in the window section. Cleats are small stabilizing elements which provide a higher local stiffness when mounted on other clips. All clips are made from T-300 woven carbon fibre fabrics with a thickness ranging between five and fourteen layers. Their stacking sequence is quasi isotropic. The matrix is either PPS or PEEK. In order to build the forward and aft section of a single A350-900 more than 5000 clips with more than 2000 different designs are manufactured. [3-5]

The manufacturing process is suitable for a full scale serial production und high quality standards due to its high degree of automation. The clips underwent an extensive test campaign according to Airbus requirements and are already flying on board the A350XWB.

Figure 2: Basic designs of A350XWB clips [4]

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2. Applications for unidirectional reinforced thermoplastics

2.1 Production process for unidirectional reinforced thermoplastics

Although using technologically advanced materials in a highly sophisticated process, the full potential of fibre reinforced thermoplastics is not used yet. Today, preconsolidated sheets with a quasi isotropic stacking sequence are being cut into blanks, handled automatically by a robotic system, heated in infrared ovens, formed under pressure by hydraulic presses, trimmed to their final contour and inspected by NDI methods prior to shipping (Figure 3).

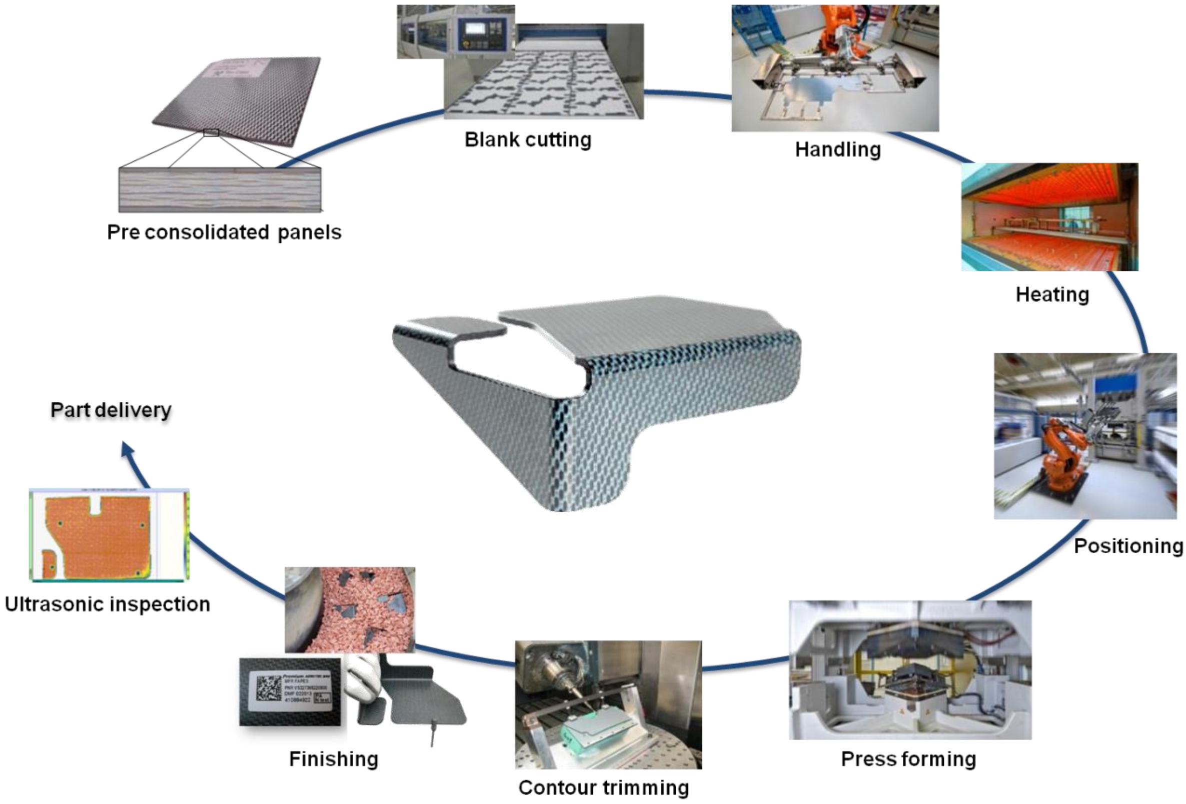

Figure 3: Current process for the production of thermoplastic composites

This means that there can be no variation in stacking sequence, local thickness, reinforcing elements or fibre types. Thus the production process has to be adapted to incorporate unidirectional reinforced thermoplastic tapes. Before the step 'High speed cutting of blanks' 3 additional process steps have to be added in the production chain: Cutting of tapes, stacking and consolidating. These three steps mean additional work but grant the designer the liberty to engineer their parts in a weight saving manner and thus combining the way of design known from thermoset composites with the benefits of thermoplastics like local forming, reforming and superior impact resistance and quasi unlimited shelf life of unprocessed material. Additional benefits are reduced waste, the possible use of hybrid materials and structural health monitoring from within the part. The process steps following consolidation are identical to the ones in the current process.

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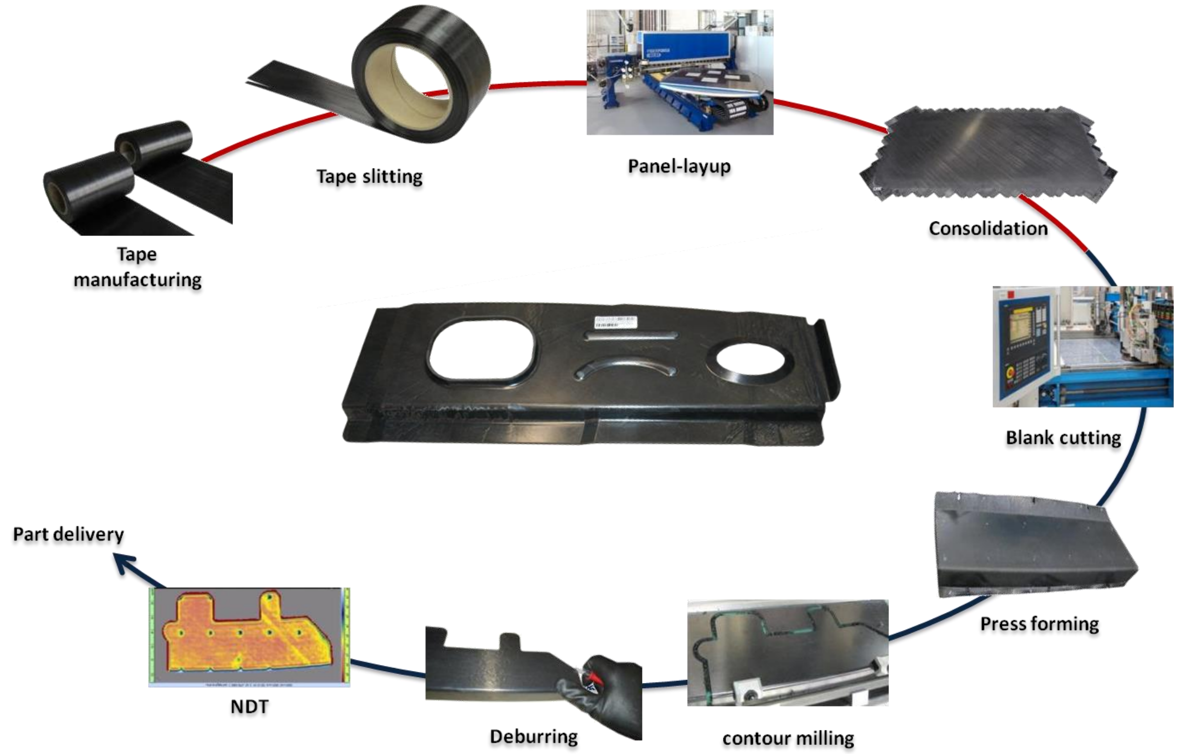

Figure 4: Future process for production of UD reinforced thermoplastics [4,6]

In order to guarantee a sufficient laminate quality and reasonable cycle times, cutting and stacking should be automated. The stacking can be done by bonding the layers together, ultrasonic welding or heat. Ultrasonic welding as a fast, reliable and well tested technique is used in most cases. Consolidation is a necessary step for the production of blanks. Without it, entrapped air between the layers functions as an heat insulator and inhibits a uniform through thickness heating of the bonded laminate. The significantly reduced porosity also prevents delaminations during thermoforming. Additionally, handling of the blank is improved. The consolidation is done under vacuum in an oven or in a heated press. The latter promises shorter cycle times than the oven process but requires a large pressing area and is not suitable for different local thicknesses within one blank without having to use unique tools for every blank.

2.2 Application of the UD process using the example of producing a frame segment

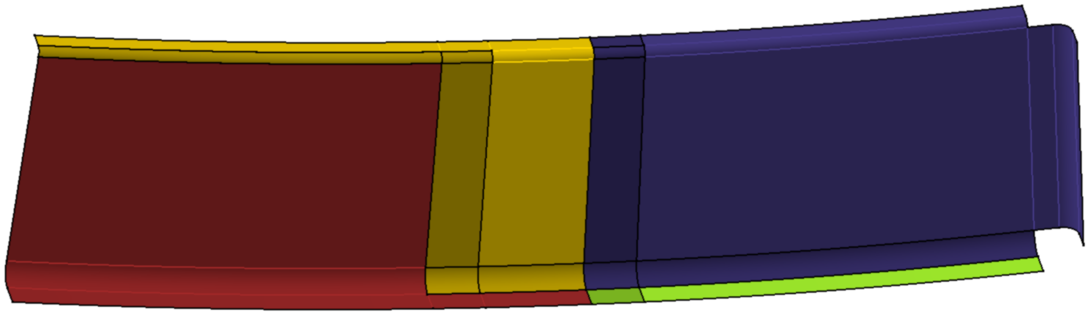

Figure 5: Manufactured frame segment

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To prove the feasibility of the UD process, a fairly complex frame segment was manufactured. The different colours as seen in figure 5 shall represent different thicknesses and stacking sequences. Toho Tenax TPUD PEEK-HTS40 CFRP, Ticona Celstran CFR-TP PPS CF60-01 and Cytec APC (PEKK-CF) /AS4D 12K tapes are cut manually and stacked using ultrasonic welding. The laminates were quasi isotropic $[-45/0/45/90/0]_s$ with various number of layers. A number of laminated featured unidirectional strengtheners to achieve the desired thicknesses according to the zones shown in figure 4.

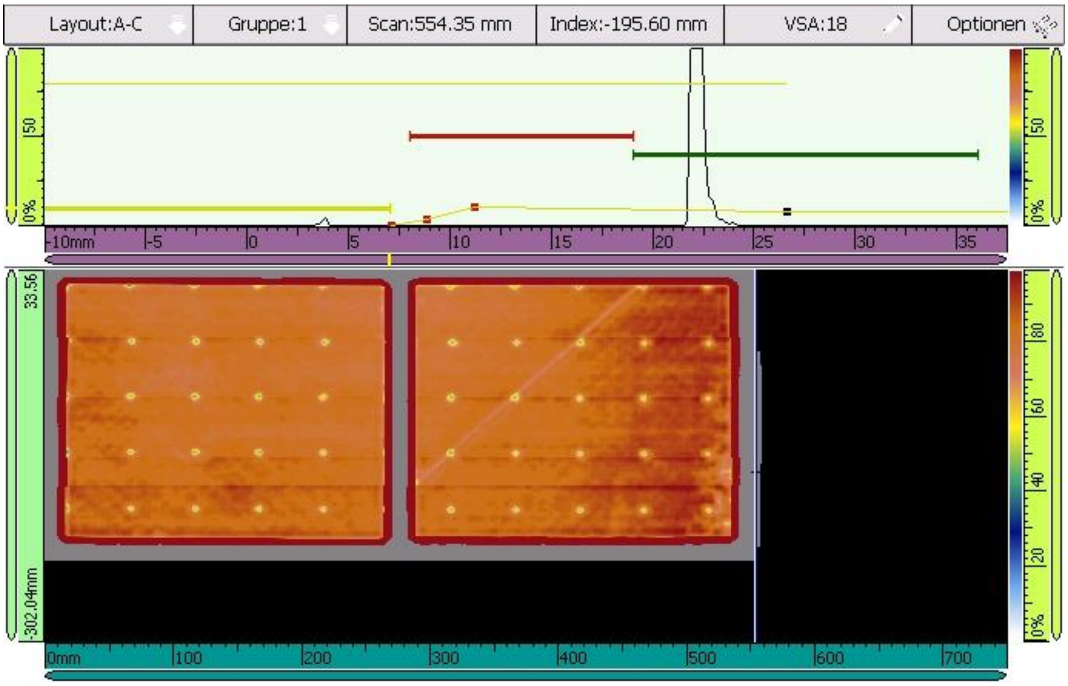
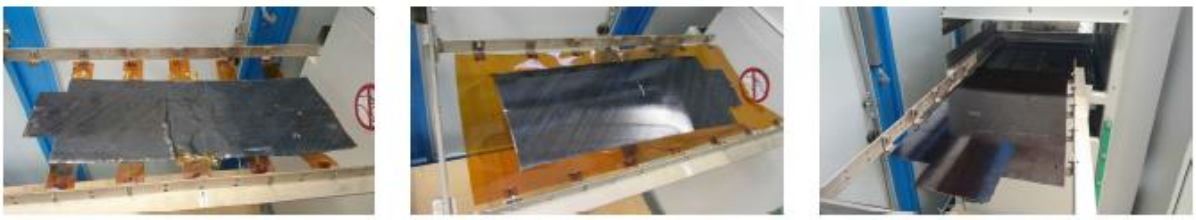


Figure 6: C-Scan of manufactured blank

The C-Scan of the produced blank (Figure 6) shows the homogeneous result achieved through vacuum bag heating . The consolidation was carried out using an oven and a vacuum setup according to Airbus regulations. Concessions to the hold time inside the oven had to be made in order to compensate heat sink effects caused by the tool. Laminates with up to 40 layers thick have been successful consolidated in distinguished quality.



(a) (b) (c)

Figure 7: Three concepts for mounting the blank

Three different concepts for mounting the blank in the handling system have been looked into (see Figure 7):

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a) Using thin foil strips to suspend the blank, which is either taped to the strips or held by self-adhesive tape
b) Using foil as first layer and thus creating a hammock-like suspension
c) Increasing the size of the blank to fit the mounting pins

Concept (c) proves to be the best solution although more material has to be used. Positioning the blank can be done more accurately and, most important of all, with a repeatable quality in contrast to using concepts (a) or (b). The biggest disadvantage of concepts (a) and (b) is that the foil will be pressed as well, making it hard to detach it from the part afterwards. Also, the foil tends to crumble and functions as a barrier in the infrared oven, that results in an increase of heating time and a massive temperature difference between the upper and the lower side of the blank.

Different part geometries have been tested. Omega and Z-Profiles as well as parts with joggles, and stiffened openings have been thermoformed as shown in Figure 8. All special features were reproduced according to the design specifications and in every detail.

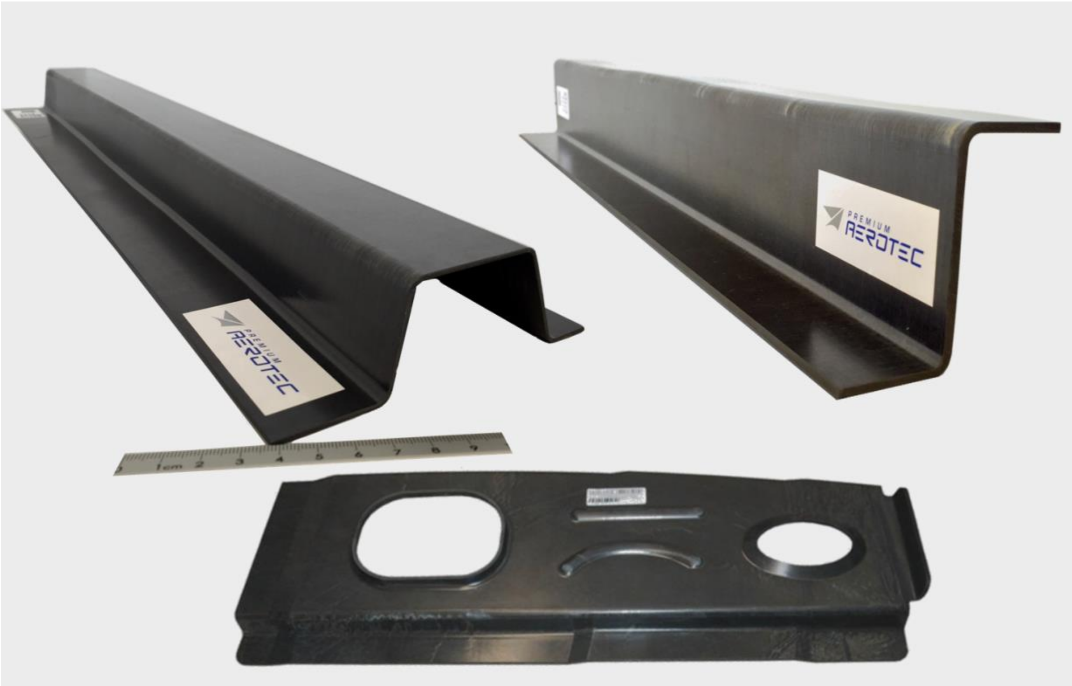

Figure 8: UD-Tape reinforced thermoplastic parts

Parts with variable thickness that were almost impossible to produce using woven reinforced laminates have been proven to be feasible by using tailored UD-Thermoplastic blanks. The alignment of the tapered blank with the mould was very accurate resulting in repeatable tight thickness tolerances.

After forming, the quality of the produced parts was examined by means of ultrasonic inspection. Further microscopy examinations were performed in order to confirm the results. They all showed porosity levels way under 0,5 % volume fraction. The attenuation of the ultrasonic signal did not in any case exceed the 6dB margin. The tapered areas of the parts appeared as white line in the C-Scans. Nevertheless an A-scan in this Area have shown no signal attenuation. Figure 9 illustrates the results of the quality tests performed on parts with tapered thickness.

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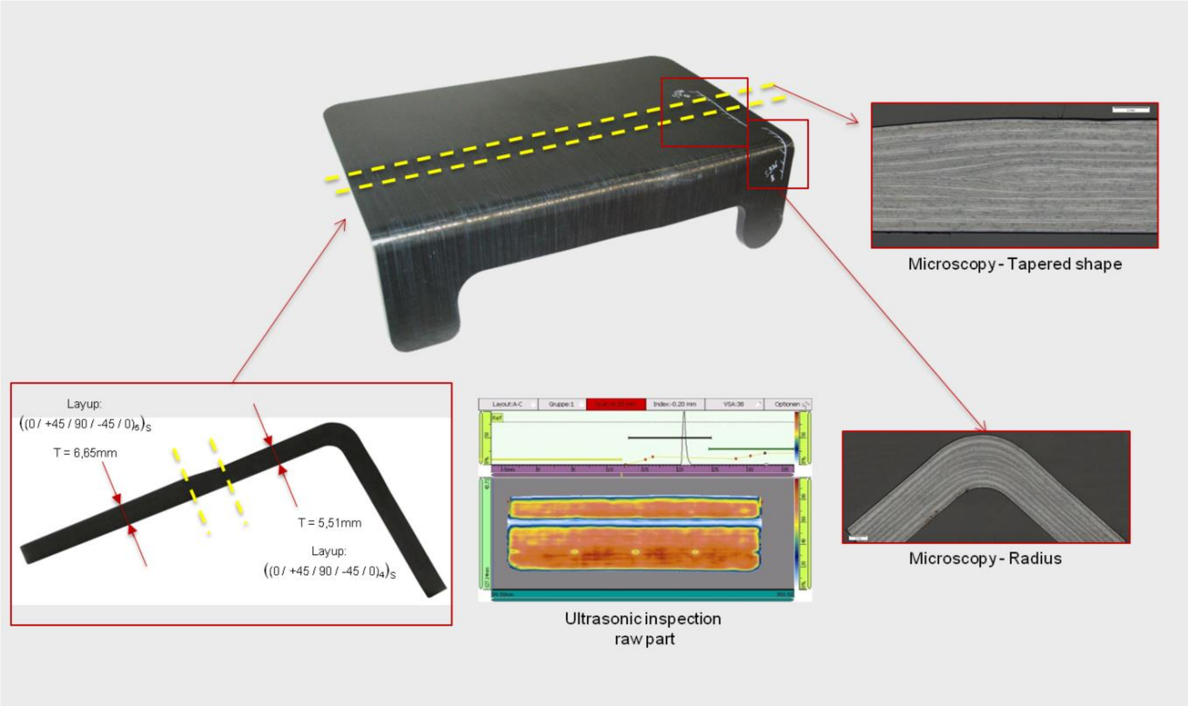

Figure 9: UD-Tape reinformed thermoplastic parts with thickness variations

3. Conclusion

Premium AEROTEC has developed from scratch a process for the production of complex detailed parts reinforced with unidirectional thermoplastic tapes. Various tapes with different matrix systems have been successfully tested. The developed process meets all requirements concerning production stability, part inner quality and dimensional tolerances. The trials that were performed in an industrial environment have revealed the potential of the process for high production rates under very attractive commercial conditions. The complexity of the manufactured parts will allow new design principles making thermoplastic composite parts suitable for even higher load applications with advanced lightweight potential.

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