Explore and develop methods of the welding process to create closed components using over-moulded thermoplastic composites.

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Topic or Subject: To design a closed overmoulded thermoplastic composite component and develop a production process to answer the objective.

Background

The ThermoPlastic composites Research Center (www.tprc.nl) is an open research centre for fibre reinforced thermoplastic composites. The TPRC performs research in co-operation with national and international partners, such as GKN-Fokker, Toray Advance Composites and Boeing, on the processing and performance of thermoplastic composites.

Thermoplastic composites (TC) are becoming more popular due to their recyclability and processibility when compared to thermoset composites. Two new technologies which have seen recent development is over-moulding and welding. These processes allow stiffer lighter panels with complex geometries to be formed. Combining these two technologies provides many possibilities, especially joining over-moulded composite panels to create closed shelled structures. This results in a component where the overmoulded ribs are sandwiched between two TC panels.

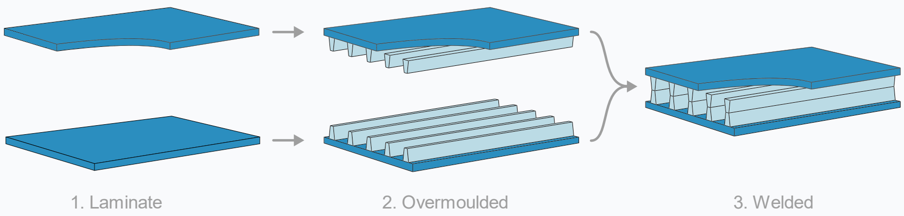

Figure 1: Process to Produce a closed overmoulded thermoplastic component.

By creating these closed overmoulded components the composite panels are moved from the neutral axis, increasing the second moment of area. This in turn dramatically increases the stiffness of the component while keeping the same weight, making these closed overmoulded components ideal for aviation applications such as aircraft wings, winglets, and rotor blades, where reducing small amounts of weight can have massive implications on sustainability and economy for aircraft companies.

Objective

This technology is in the very early stages, and so to develop more of an understanding of the technology and its future potential, the aim of the bachelor theses was to explore “how can two over moulded structures be easily and successfully welded to create a closed component?”

Approach

To answers this question a PACT (People, Activities, Context & Technologies) analysis was conducted to understand the current maturity of the market and the challenges associated with this technology. This PACT analysis highlighted the challenges of the welding methods, such as the high pressures required to prevent deconsolidation of the TC laminate and the weld penetration depth. It became apparent that there were many variables which contributed to the ease and success of welding to create closed components; therefore, a tailored design approach was developed to provide focus for ideation and conceptualisation.

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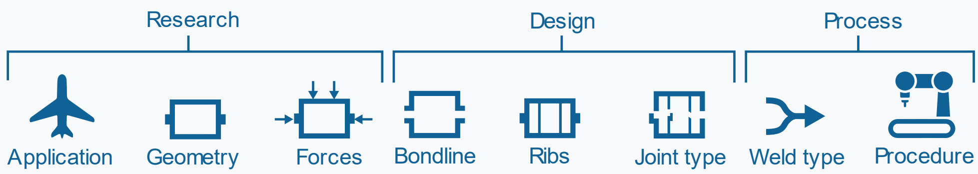
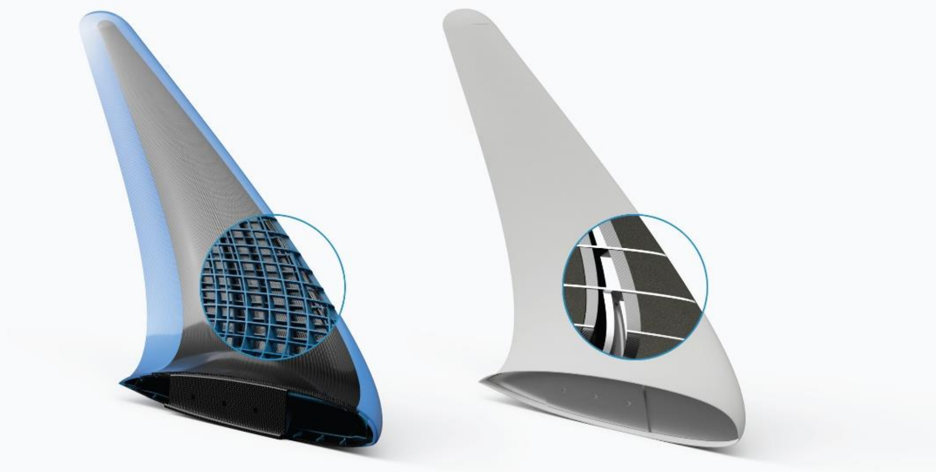


Figure 2: Design process framework used to produce the closed overmoulded component.

This framework was tested by applying it to re-design an aircraft winglet. During the design phase this systematic approach helped break down different variables into manageable independent sections. Taking a systematic approach and conducting a comparative evaluation, the most feasible designs were selected and repeated until a final concept was developed further into a 3D model. In the final stages of the approach the production process was developed, consisting of 7 stages, this demonstrated how the complex geometries could be manufactured using current technologies.

Results



New Design: Materials	g cm^{-3}	Original: Materials	g cm^{-3}
[1] Continious fibre laminate (TECAPEEK CF30)	1.38	[3] Continious fibre laminate	1.43
[2] Short fibre overmoulded Polymer (PEEK90HMF40)	1.45	[4] Aluminium 7075	2.81
		[5] Rohacell Foam	0.032

	New Design: Quantity	New Design: Thickness (mm)	New Design: Additional Information	Original: Quantity	Original: Thickness (mm)	Original: Additional Information
External Skin	4	3.16	[1] 24 Plys	1	3.16	[4] 24 Plys
Spar	11	3.00	[2]	2	4.16	[3] 32 Plys
Horizontal ribs	24	3.00	[2]	9	5.00	[4]
Void Fill	**	**	No void Fill	2	**	[5] Lead & Trailing Edge
Total Weight	6.082 Kg			7.927 Kg		

Figure 3: Final Design comparison to the original winglet

Overall, the design approach helped provide structure and focus to each aspect of the component, resulting in a final design that showed how complex closed components can be welded and produced. There is huge potential for this technology, which was highlighted in the final design with a total weight reduction of 23% and a component that is completely monolithic and fully recyclable. The biggest drawback with the model is that it depicts the process as linear. The challenge is that, especially within the design phase, each aspect is dependent. To overcome this each feature was ideated independently before being combined into designs where there was no contradiction between the elements e.g. ensuring that the rib direction was perpendicular to the bondline. Despite not being a linear process, this approach is ideal for the early stage of the design process to derive new manufacturing approaches and designs of overmoulded components.

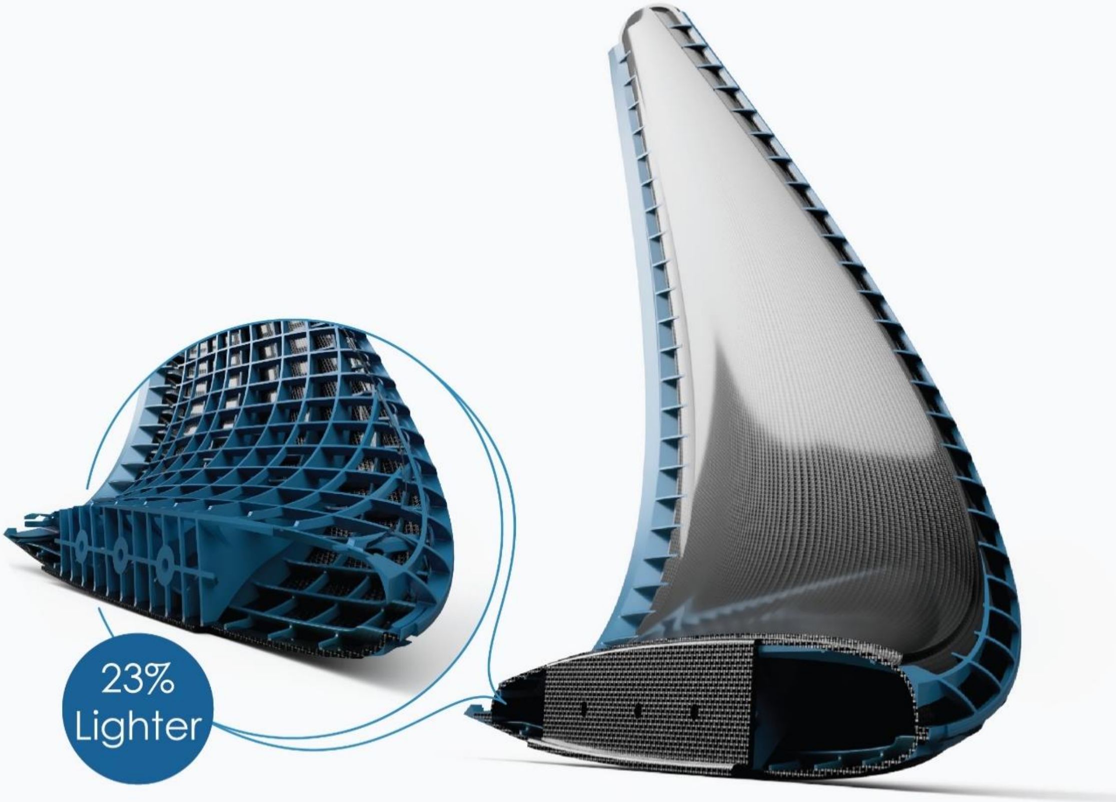


Figure 4: Final Design with the ribs excluding the leading and trailing edge.

Conclusion

In conclusion the main objective has been answered on a theoretical level. A design approach and a tangible final design and production procedure demonstrates how closed components can be produced and the benefit they with have compared to existing technologies. To answer this question a series of requirements were deduced which can be used as a guideline, along with the design approach to create an optimised solution to easily join and create other closed components, whether that be in the automotive or aviation industry: the possibilities and application are endless. The next stage continuing this research would be to test the welding methods and joint geometries, to determine their shear strength to support the theoretical data.