OBTAINING A THROUGHT THE THICKNESS REINFORCED COMPOSITE JOINT

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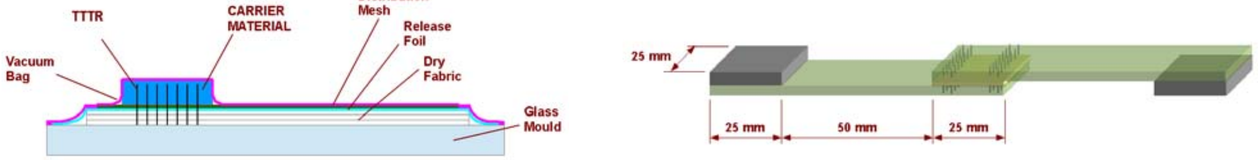
1. INTRODUCTION

The use of fibre-reinforced polymers continues to grow in aeronautical and automotive industry, due to their superior strength to weight and stiffness to weight ratio. The replacement of aluminium and steel with composite materials promises lighter transportation vehicles, meaning less fuel consumption. The same replacement in the wind-energy industry means easier assembly of extremely large parts and greater energy efficiency. Thanks to the aid of composite technology and integral design it is possible to produce large size components made out of a single component. As a consequence the need of structural coupling is reduced. However, joints between composites still exist, due to size and design limitations as well as for operation, maintenance and for handling requirements [1].
There are a number of procedures available for joining of composites, which are generally grouped in three categories: (i) adhesive bonding, (ii) fusion bonding (only applicable for thermoplastic matrices) and (iii) mechanical fastening [2].
However, the main problem of all these techniques is that the strength of the bond is always inferior to the in-plane strength of the composite laminate. In the case of adhesive bonding, this is confirmed by the issue in certifying bolt-free bonded joints for primary composite aircraft structures [1]. To overcome this issue, solutions are sought in combining adhesive bonding or welding, with mechanical fasteners such as rivets or bolts [2], the so-called hybrid bonding. Although the mode-I and mode-II fracture toughness is increases by adding this hybrid bonding, the problem of inducing damage by drilling holes, the increase of weight and the extra preparation time still exists.
With Z-pinning [3], the same goal can be achieved. The problem, however, is that the Z-fibres are inserted in the bond prior to consolidation of the entire part. As a consequence, two separate composite parts, which have been already cured, cannot be joined together with Z-pins in the joint area. Furthermore, this technique has only been used in combination with prepreg material, so resin infusion and resin transfer moulding have not been considered yet [3].
The main objective of this research is to develop a through the thickness reinforced (TTTR) bond between two already manufactured composite parts with better mechanical properties than the corresponding unreinforced bond, with limited or negligible damage or distortion to the fibre or fabric orientation. This means that some sort of insert needs to be developed which can be implemented in composed parts in the areas which are meant to be joined, prior to manufacturing these parts. The next section will discuss the used materials and methods and then, some preliminary results will be discussed.

2. MATERIALS AND METHODS

The material under study is a glass/epoxy composite. The glass reinforcement is a unidirectional E-glass fabric (Roviglas R17/475) with 475 g/m² reinforcement in the fibre direction e_{11}, while in the direction e_{22}, the reinforcement was 17 g/m2. The epoxy matrix was RIM 135 and a $[0°/90°]_{2s}$ stacking sequence was considered.
The composite plates are produced using vacuum assisted resin transfer moulding. However, some extra precautions need to be taken since the TTTR will also be present within the stacking sequence. A cross section of the setup is depicted in Figure 1 (a), which illustrates the use of a carrier material. The latter is supposed to (i) maintain correct positioning of the 3D-reinforcements, (ii) prevent 3D-reinforcements from puncturing the vacuum bag and (iii) avoid the epoxy from settling around the 3D-reinforcements. Furthermore, it should also be easily removable after resin infusion and curing. For the TTTR, the first trails were done with galvanized steel cord, consisting of two filaments with a diameter of 0.2mm.



(a) Schematic view of the carrier material (b) Schematic view of a lap shear sample

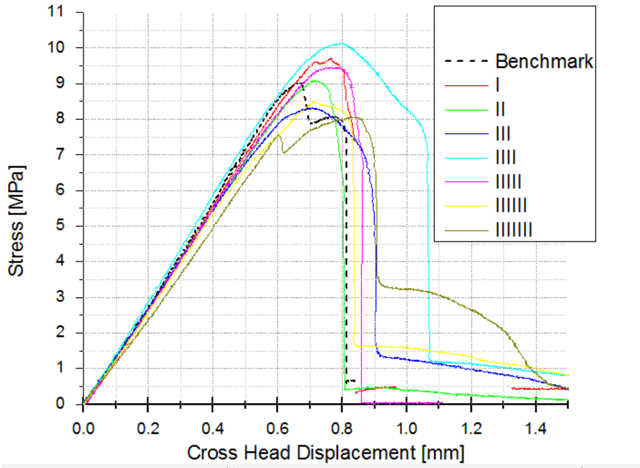
Figure 1. Production and sample geometry

For the mechanical characterization of the joint, the lap shear test was chosen, because of its simplicity. Figure 1 (b) illustrates the geometry, which is according to the ASTM D5868 standard. The lap-shear tensile test involves axial pulling of the bonded specimen until failure at a constant displacement speed of 0.5mm/min. It was performed on a servo-hydraulic INSTRON 8801 tensile testing machine with a FastTrack 8800 digital controller and a load cell of ±100kN.

3. RESULTS AND DISCUSSION

Although the resin infusion process is fairly simple, it proved to be quite difficult to obtain high quality composite plates without voids and with constant thickness, especially underneath the TTTR. Especially the TTTR in combination with the carrier material had a significant influence on the resin flow during infusion, causing a variety of problems. However, after some trial and error, successful plates (and joints) were manufactured. Figure 2 (a) provides a detailed view of the steel cord TTTR, after curing and removal of the carrier material.

(a) illustration of steel cord embedded as TTTR in a composite plate



(b) TTTR steel cord 2Xd0.2mm, stitching and cutting, 1 lines in the edge, 1 mm adhesive thickness

Figure 2: Overview of some preliminary results

A first series of lap shear experiments has been performed with galvanized steel cord, made with two wires of 0.2 mm of diameter twisted together. The thickness of the adhesive was 1 mm. 7 samples were realized in order to assess the reproducibility of the process. However, not all specimens had a homogeneous distribution of the adhesive, because of the presence of the steel wire and the high viscosity of the adhesive (ARALDITE 2015). Nevertheless, the results are already fairly reproducible, as can be seen in Figure 2 (b) which illustrates the averaged shear stress as function of the displacement. To be able to compare these specimens, composite joints without TTTR, but with the same manufacturing and bonding process, were also tested. Although these results were very reproducible, the one with the highest failure stress was chosen as benchmark and is also depicted in Figure 2 (b). It can be noted that most of the TTTR joints show a higher failure stress compared to the benchmark and that the behaviour after reaching the maximum stress is different, in a way that a less brittle failure occurs.

It can be concluded that these first results are already quite promising, given the fact that a large number of parameters, such as (i) material for the TTTR, (ii) insertion method of the TTTR, (iii) distribution of the TTTR over the joint-area, can still be optimized.

4. ACKNOWLEDGEMENTS

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