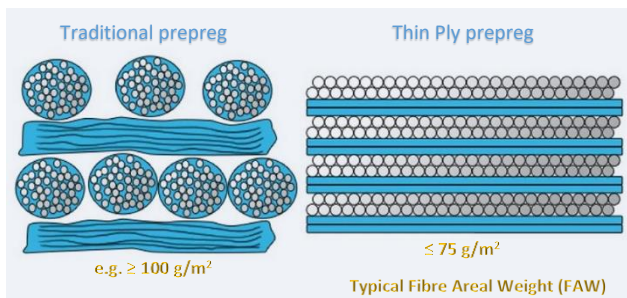


Country: Switzerland
Status: Completed

In a constant need of cost / weight optimisation, the use of fibre reinforced polymers in space industry has been growing since the late 1960's. With their high strength to weight ratio, Carbon Fibre Reinforced Polymer (CFRP) composites enable combining high mechanical performance while ensuring high freedom in designing complex structures or shapes. Through a fibre spreading process enabling improved fibre distribution, Thin Ply Technology (TPT) allows greater optimisation of modulus, strength and weight, building a more homogeneous laminate. In addition, by combining TPT with an Automated Tape Layering (ATL), a very cost efficient solution can be achieved, thanks to the reduction of time consuming manual compactions and inspections required with classical CFRP materials. This technology is currently flourishing within automotive, marine and sports industries. In that context, the GSTP project presented here aimed at evaluating the advantages of TPT CFRP and its potential in space applications, over traditional CFRP composites.



Thin Ply Technology schematic overview

The first phase of the project consisted in identifying, developing and characterising a TPT CFRP material for space applications, to assess its benefits over traditional CFRP in terms of thermo-mechanical properties. While mechanical performance is mainly required at the beginning of satellite life (ground and launch phases), in orbit mechanical solicitations mostly derive from thermoelastic phenomena. In that sense, the focus was put on stiffness driven (e.g. central tubes) and stability driven (e.g. optical bench sandwich panels) applications.

The consortium converged towards a system of materials already studied in previous space projects, offering a good trade-off between tensile modulus, strength, Fibre Areal Weight (FAW) and Thermal Expansion (CTE) properties: YSH-60A-60S (6K) fibres and ThinPreg™ 380CE resin (cyanate ester). Iterative improvement works were performed to ensure compatibility of these materials with TPT and ATL processes. A full scale characterisation campaign was then launched, including ageing and thermal-vacuum cycling, on test coupons in order to identify the benefits and limitations of this novel TPT CFRP (35 g/m²) compared to a traditional (TRADI) CFRP (105 g/m²).

The difficulties encountered in the manufacturing of the prepreg, resulting in unexpectedly high porosity rates of TPT laminate test coupons, underline the improvement works needed to make this manufacturing process more reliable, reproducible and robust. Despite this, the test campaign gave promising results, highlighting two main material characteristics that can be considered as benefits given by Thin Plies and their smoother layup pattern:

- Improved isotropy of Quasi-Isotropic (QI) layups: Thin Ply CFRP isotropy ratio (Min strength/Max strength, between 0° and 90° directions) for laminate tensile test was 20% higher than traditional CFRP's one, showing 25% higher strength in the direction perpendicular to 0° fibres. In compression, TPT CFRP's isotropy ratio was also 30% higher, despite underwhelming results when estimating its compression strength through a 3 points bending test.
- Increased edgewise compression strength of sandwiches: TPT sandwich specimens yielded 10% higher strength values than TRADI ones.

For quite thin skins like the ones used in space applications (0.3 mm being commonly used), it is usually impossible to build a symmetrical layup with traditional CFRP and this results in pre-existing internal bending-moment related stresses, which decrease the capability of the whole sandwich to withstand external loads. Thin Ply Technology allows building thin but symmetrical skins with a progressive layup (0°/20°/40°/60°/80°/-80°/-60°/-40°/-20° for tested samples) with less angle variation between two adjacent plies, reducing this bending effect. From the test results, it also appears to confer a more quasi-isotropic behaviour, providing a smoother load distribution within the laminate and reducing interlaminar strain between plies.



Phase 1 – Edgewise compression test coupons

The second phase of the GSTP project was dedicated to the evaluation of the industrial benefits of Thin Ply Technology, in terms of production time and costs, in the manufacturing of a Space-grade CFRP sandwich panels. Previously encountered difficulties prevented the consortium from using newly developed TPT material in that stage. Alternatively, a commonly used TPT material with a stable prepreg ATL process was selected: HR40 fibres and TP402 resin (epoxy). After having defined the design of the demonstrators and reviewed the critical process parameters needed to ensure the best possible performance, two sandwich panels were manufactured:

- Demonstrator 1 was produced in a classical curing process (“two shots” with skin curing and sandwich bonding done consecutively)
- Demonstrator 2 was produced in a co-curing process (“one shot” with skin curing and sandwich bonding done simultaneously)

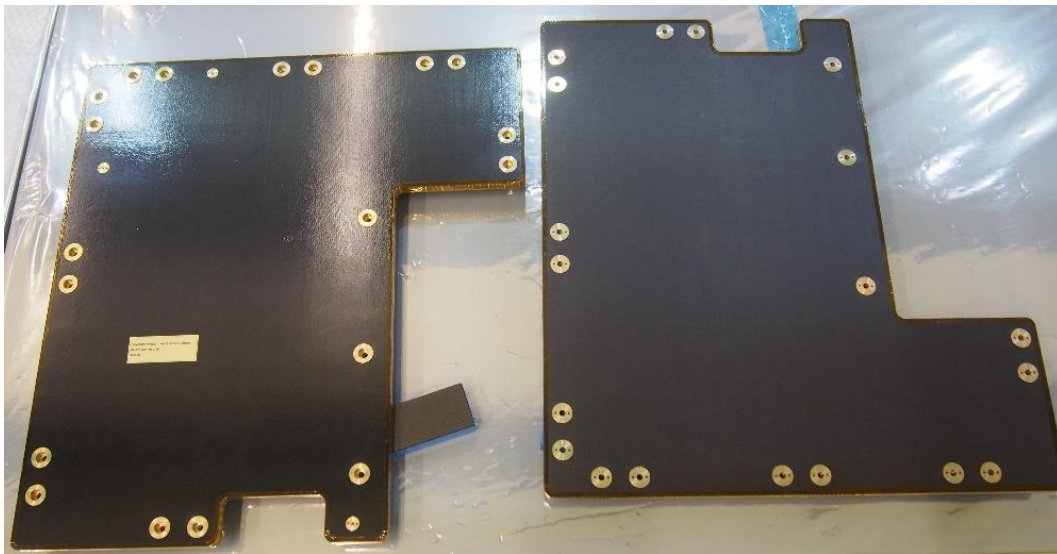
Both Demonstrators met skins’ and sandwich panel’s health and mechanical performance expectations. The panel manufactured with TPT material in combination with a co-curing process presented a very good quality level, with almost invisible telegraphing on its surfaces (common effect after co-curing process with standard CFRP). Despite its higher surface roughness, it seemed to be much less prone to small delaminations, e.g. during machining

operations. Most importantly, its flatwise tensile strength was 17% higher than the one of classically cured panel. It was assumed that the use of raw preforms in the co-curing process might enable increasing the available volume of adhesive for skin to core bonding, which may lead to enhancing the formation of well-shaped and bigger menisci, resulting in the increase of flatwise tensile strength of the sandwich.

The time/cost purely related to manufacturing activities was estimated to be cut by 15% for “two shots” curing and by 25% for “one shot” co-curing process, when using TPT preforms laid by ATL. Another key point to stressout as an advantage of TPT was the procurement lead-time, which was 3 to 4 times shorter than what it would have been with a classical CFRP.

In light of these findings, the advantage of using TPT preforms laid by ATL is clear, the interest being even higher in combination with a co-curing process.

To increase the TRL further, a practical use case shall be defined for the latter HR40/TP402 system within Space applications, going along with the identification of its critical functions and a full characterisation in relevant environment.



Phase 2 – Demo 1 and Demo 2 sandwich panels