**HiTape®**

# A new efficient composite technology for Primary Aircraft Structures

HiTape®

Over the past 30 years, high performance composites have been successfully developed and used increasingly widely in the aircraft industry due to their superior overall performance characteristics (i.e weight, corrosion, fatigue..) compared to metal solutions prepreg has gradually become the technology of choice in composites for secondary and primary structures. This technology, which guarantees composite performance, quality and reliability, supports current production rates and key OEMS requirements on csot and performances.

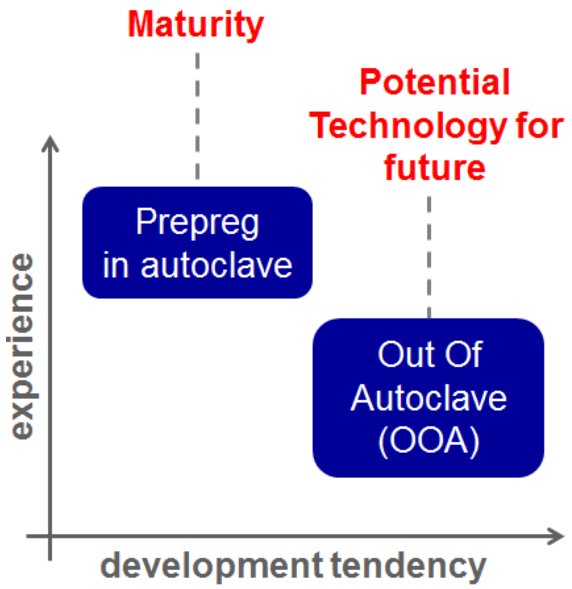
Faced with increasing demand from airlines & increasing production rates, the cost of composites (materials and processing) is becoming an ever greater challenge in the development of parts for next generation aircrafts. In particular with increasing production rates, some of the composites solutions adopted so far are challenged by other processes and solutions

Other composite technologies, such as **Liquid Composites Moulding** have been successfully developed for aircraft structures such as beams, corners, attachments, flaps, ailerons. The type of reinforcements used were so far mainly based on woven technologies which do not meet the requirements of primary aircraft structures.

Nevertheless, there is a global understanding that such Out of Autoclave technologies could be a candidate for primary structures if both the performance levels and process industrialisation were achieved. The main limitations were the relative lower performance of materials, including impact resistance requirements for such structures, and the lack of automation in preforming - a key manufacturing step in RTM or vacuum infusion processes (liquid composites moulding).

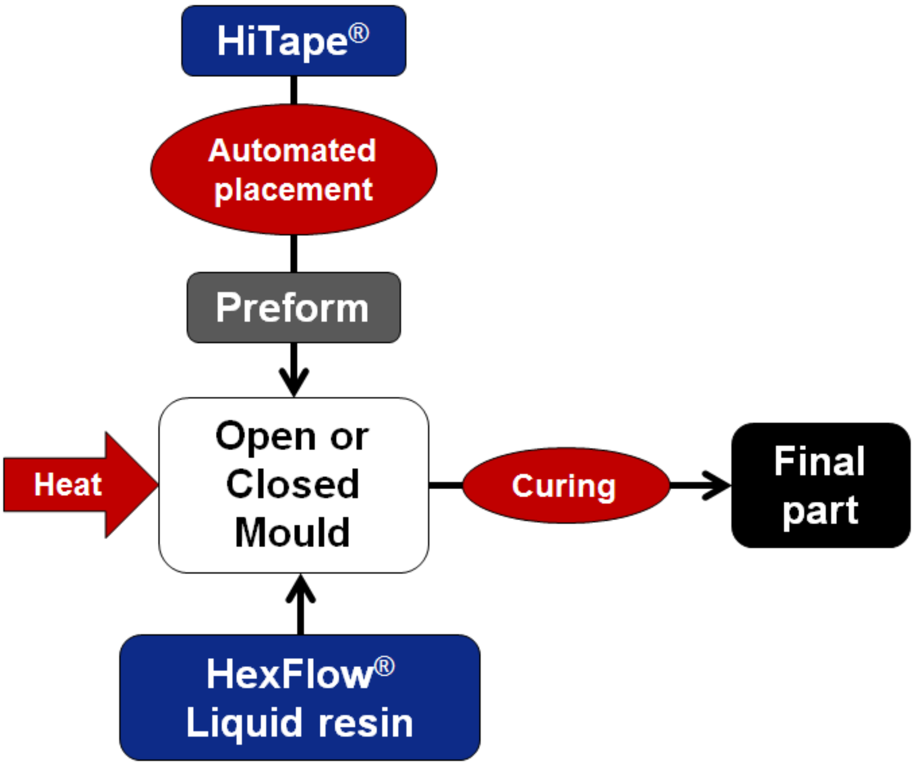
Based on its long experience and widely achieved qualifications in injection technologies for Aircraft secondary structures with HexForce® carbon woven reinforcements and HexFlow® RTM6 resin, Hexcel has developped a next generation of reinforcements named HiTape® for Primary Structures fully meeting the challenges of Liquid composites Moulding achieveing adequate cost, performances of the latest prepreg generaytion aw well as allowing to meet high production rates.

Maturity of Composite processes for Primary Aircraft Structures




Out of autoclave technology is currently less mature than prepregs but the drive to reduce costs presents growth potential for the future aircraft programs.

Dry OOA with HiTape



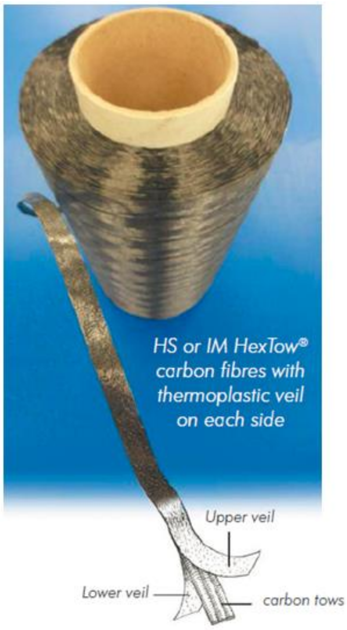

An overview of part manufacture using the HiTape® process

Material definition and key features

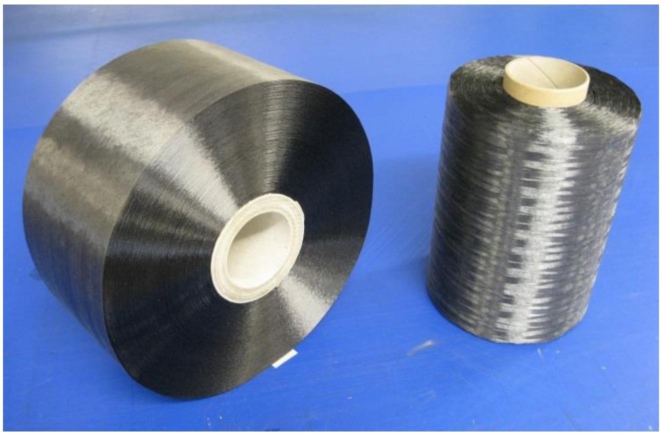
HiTape® has been developed to be used on automated machines already in place for the manufacture of primary aircraft structures using slit tape prepreg, such as AFP and ATL.

HiTape® is a dry Unidirectionnal tape made with Hexcel Hewtow® carbon fibers, that are co-bonded with thin thermoplastic veils on 2 sides.

The veil used on HiTape® has a functionalized role. First, it holds the fibers together for width control during the manufacturing of HiTape®; this provides HiTape® with an optimal calibrated width (the tows are not cut avoiding issues such as fuzz during process). During lay-up the veil activation by local heating literally acts as binder adding a key feature to this solution (not having to use a powder binder brings also a benefit in optimizing process efficiency on AFP machines); and finally it improves drastically the damage tolerance of the final cured part after vacuum infusion or injection.




HiTape® can be used in several width and weights along with a choice of Hewtow® carbon fiber. Typical widths of ¼", ½'' have been originally used and larger width such as 1.5 and even 2'' for higher deposition rates for flat surfaces are also available.



Dry Preform Manufacturing by Automated Placement

As the UD reinforcement is dry with no resin there is no need for cold room storage which is a positive greener solution for OEMs and also provides cheaper storage. HiTape® can be stored at room temperature for months, with no need for defrosting, and the AFP/ATL machines do not require refrigerated creels either.

The reinforcing tow filaments being never cut during the HiTape® manufacturing process, no fuzz is generated when it is used for automated placement despite friction from direction rollers and machine surfaces.

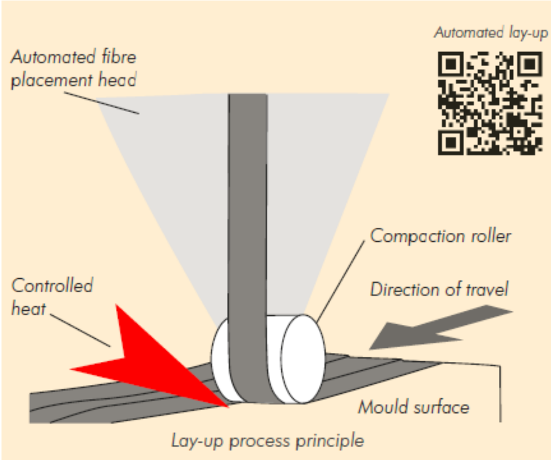
HiTape® is also free of splice, as the bobbins are delivered as one single length of tape.

As there is no fuzz and no splicing, there is no tape breakage and no rings appear over AFP/ATL machine rollers during lay-up.

Furthermore, as the UD reinforcement is dry, HiTape® does not require any backing paper or films, simplifying the lay-up heads and making the preform manufacturing process more simple and robust.

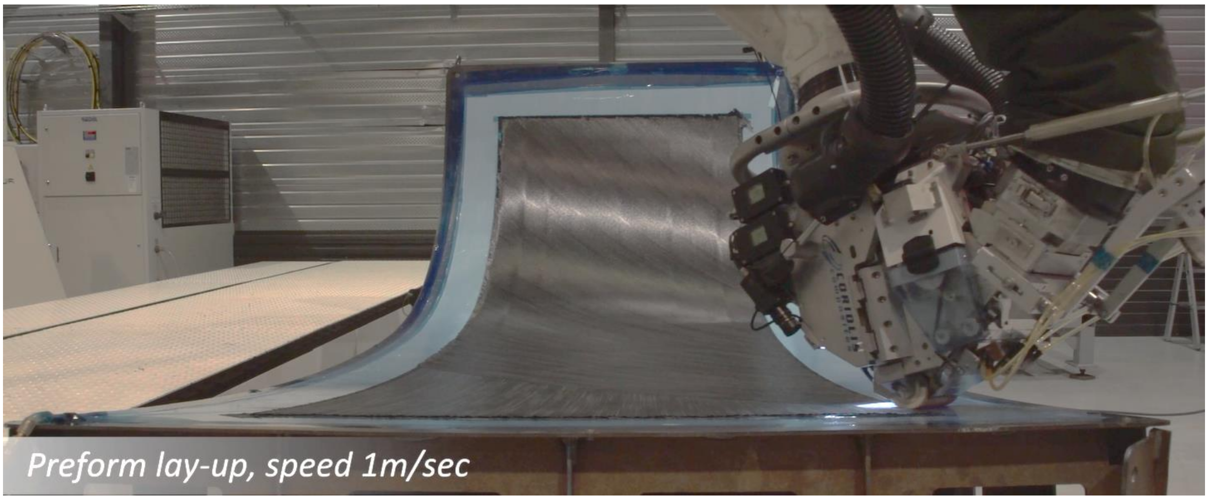
All of these advantages are essential for a product that is used for large volume production.

The preforming is done by automated lay-up using heat at the location where the tape is laid-down (see drawing). Controlled heating is necessary; the heat source can be Infra Red or LASER, both of which have pros and cons. Infra Red is well suited for low curvatures and large parts such as wing skins, whereas LASER is adapted to more complex shapes such as frames and spars. The use of LASER is also constrained by safety regulations, in particular the need to close the robotic cell to avoid any eye contact with the source, or to make sure anybody entering the building is equipped with appropriate protective safety glasses.



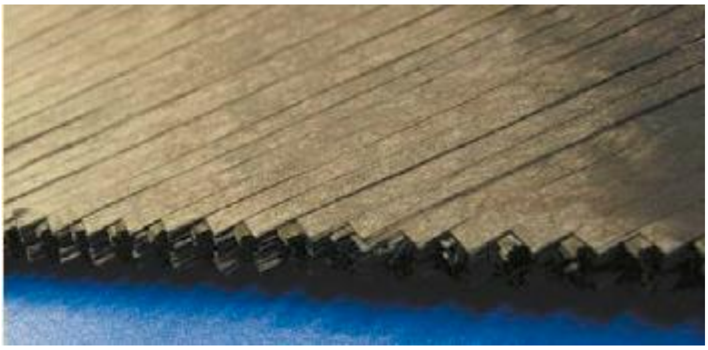

Several machine manufacturers have successfully used HiTape® for different customer programs, among them Coriolis Composites (France), MTorres (Spain), and Ingersoll (USA). ElectroImpact (USA)

HiTape® lay-up speeds of up to 1m/s have been achieved (see 3), illustrating high efficiency and output of the material.




Single curvature preform manufacturing by Coriolis Composites AFP machine

using ¼" HiTape® and LASER placement

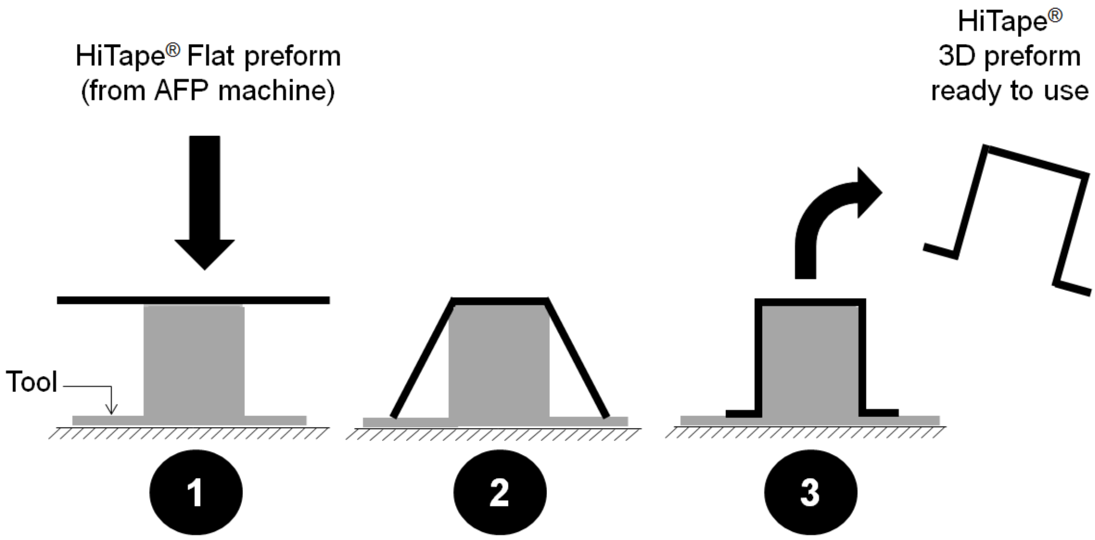


Edge of thick HiTape® AFP preform

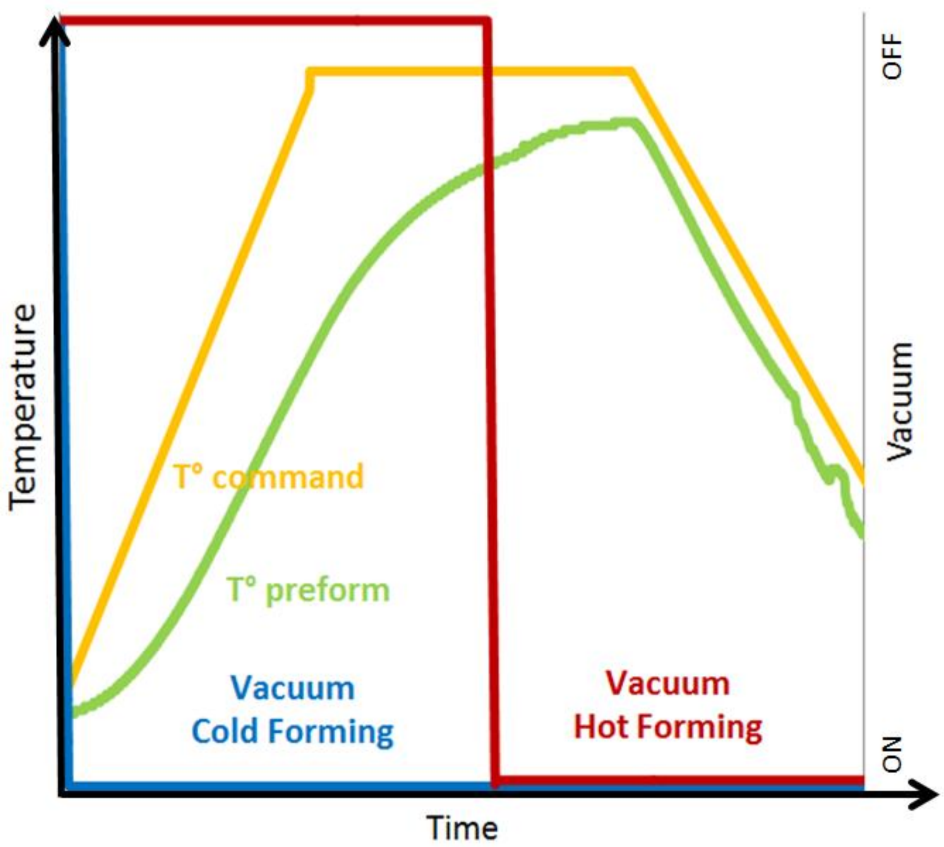
Preforms achieved by AFP using HiTape® have a low bulk factor.

Experience with prepreg has shown that the lay-up of complex parts is time consuming and therefore has a low output. An interesting route for preform manufacturing is Forming.

Forming is a well-known technique used to shape a flat material to a 3D shape. This has been used for many years with dry reinforcements, especially with woven or Non Crimp fabrics that are bonded with epoxy binders. This is also widely used in current aircraft manufacturing with prepreg.

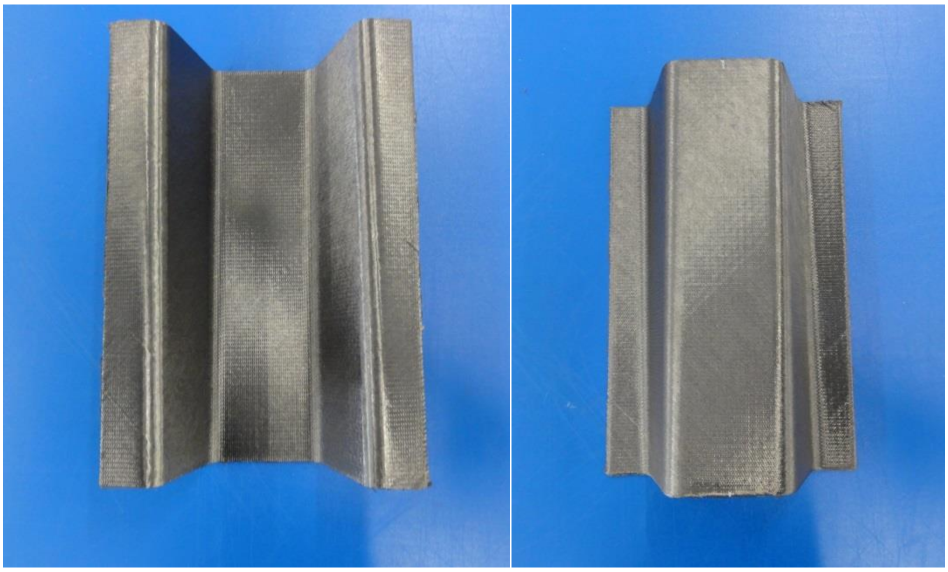



Forming process principle



With HiTape®, we can use the same dry forming technique while keeping the advantage of automation. This is done by laying-up HiTape® flat, with high speed placement, and then forming the flat preform onto a mandrel or mold that is shaped for the final part. Forming can be done either hot or cool, and if the latter is chosen, consolidation to allow the preform to retain its shape is done with heat. In both cases a cooling step is necessary before removing the preform from the mandrel or mold. Different techniques are possible, from diaphragm forming using membranes to press forming using activators.

Recent studies have shown promising results in terms of Fiber Volume Content management as well as preform quality. U shape and Omega shaped stringers have been manufactured this way, then successfully vacuum infused at 60% +/-3%FVC.



Example of Cold Formed Omega shape HiTape® AFP preform (which is then heated/cooled to retain the shape)

Once manufactured, HiTape® preforms can be stored for months at room temperature if necessary, and can be re-worked before being vacuum infused or injected.

One of the most interesting and useful properties of dry preforms is the ability to assemble skins, stringers, etc, prior to infusion, in the dry state, with no use of additional materials (such as local adhesives). This function integration can save a big part of the time consuming materials assembly stage currently required with today's prepreg technology.

<u>Permeability</u>

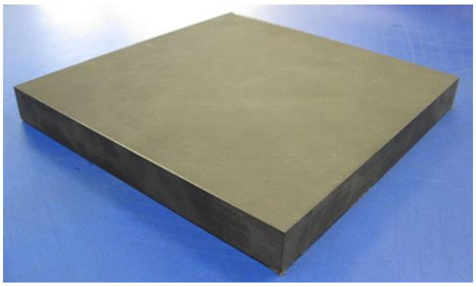
Dry reinforcements need to be filled with liquid resin prior to curing and trimming to achieve the finished part. Standard dry reinforcements such as woven fabrics are widely used for secondary aircraft structures, either using high pressure closed molds (RTM) or 1 bar pressure (open mold Vacuum Infusion). Non Crimp Fabrics are also now being used, for secondary as well as for primary structures. Hexcel has also developed a range NCF solutions with its HiMAx™ range which meet primary structure requirements

Both reinforcement types have relatively high permeability that can allow fast/secured resin infiltration. The high permeability is explained by fiber undulation (crimp) or stitching that helps keep spaces in between some tows and allows the liquid resin to permeate during the infiltration phase. The flip side of this is lower mechanical performance (due to crimp and waviness), and lower Fiber Volume Content, the latter especially when using the Vacuum Infusion method.

Hexcel has spent a long time working on permeability (ref 1, 2), and is able to measure different permeability levels (X,Y,Z) in house using specifically designed equipment.

In order to match the performance of latest generation prepregs used for primary structures in today's aircraft, HiTape® is made from carbon fibers, that are 5 microns (Intermediate Modulus) to 8 microns (High Strength) diameter. As the material is pure unidirectional, there is little space for resin to infiltrate in between tows / filaments, and permeability (X,Y,Z) can be seen as lower than standard woven, braided or stitched reinforcements.

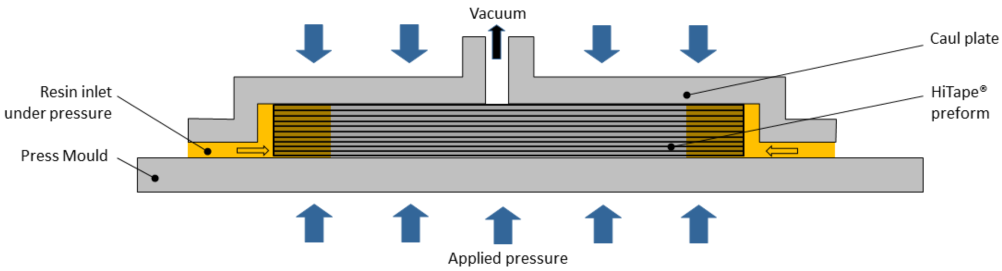
To deal with this low permeability, HiTape® has been tailored to allow the resin infiltration of thick parts (1 inch and above with vacuum infusion) while maintaining state of the art Fiber Volume Content (60% +/-3%). This work has been done on both AFP materials and wider tapes for ATL or Hand Lay-up.



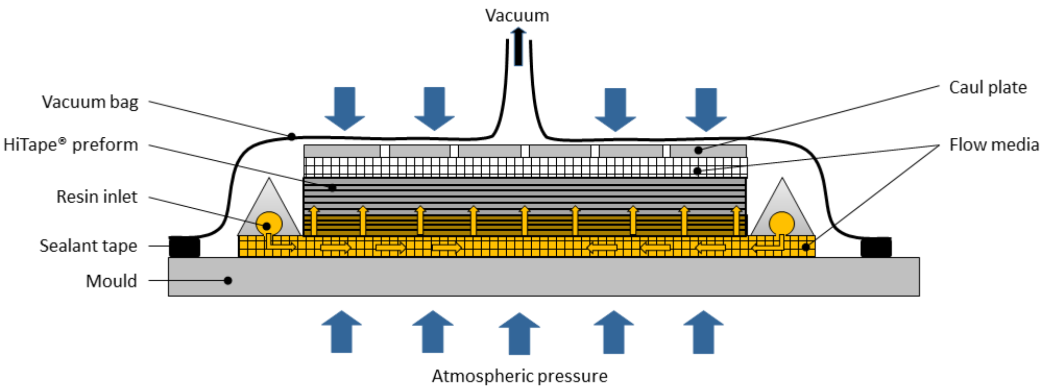
30mm thick vacuum infused HiTape® / RTM6 AFP panel - 58% FVC

Liquid Composite Molding – Vacuum Infusion or RTM injection

Resin Transfer Molding (or Injection Molding) uses a closed mold. This is particularly suitable for complex and small to medium size parts (frames, spars…). The preform is put into the mold and resin is injected with pressure applied (typically 3 to 5 bars).



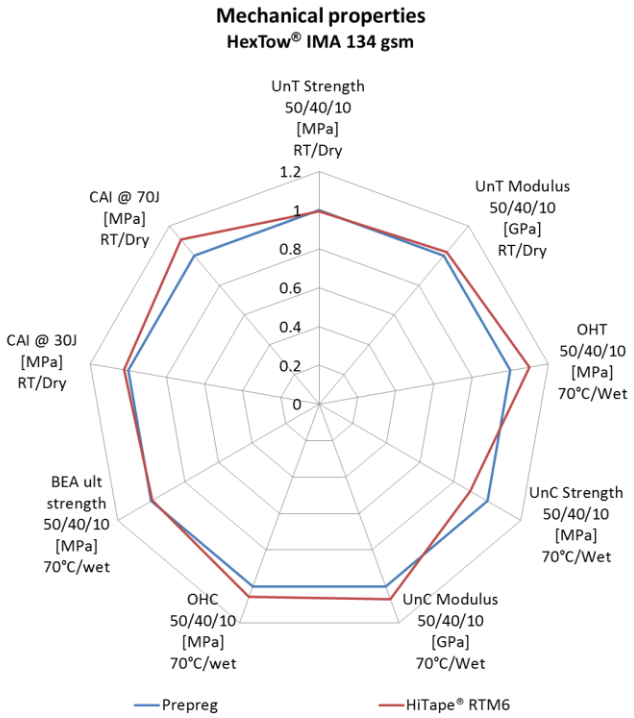

Vacuum Infusion and all the variants use an open mold. These methods are better suited to large parts where perfect geometrical control is necessary only on one side (for example wing skins). The preform is placed on to the mold before being vacuum infused.



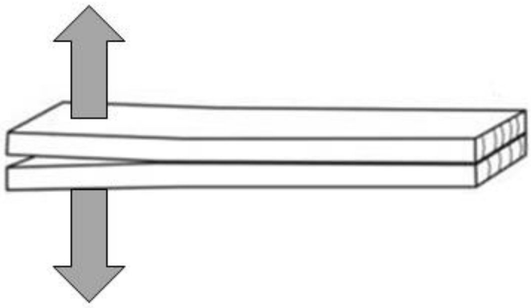

Both of these methods have been used to make demonstrator parts using HiTape® with HexFlow® resin system, achieving a very low porosity content (less than 0.5% in volume) and high Fiber Volume Content (60% +/-3%).

Mechanical properties

The mechanical properties of laminates made from HiTape® and HexFlow® resin systems are as high as those currently only achieved with the latest generation prepregs.




A further benefit of the function integration mentioned previously is that because skin and stringer preforms may be co-infused or injected, the interlaminar properties of all skin plies are equivalent to those between skin and stringer. In addition, thanks to its excellent Mode I Interlaminar Fracture Toughness (G1c) property, HiTape® preforms once infused or injected and cured can advantageously replace the assembly of cured, or uncured prepreg elements and remove the need for adhesives and shimming of these parts.

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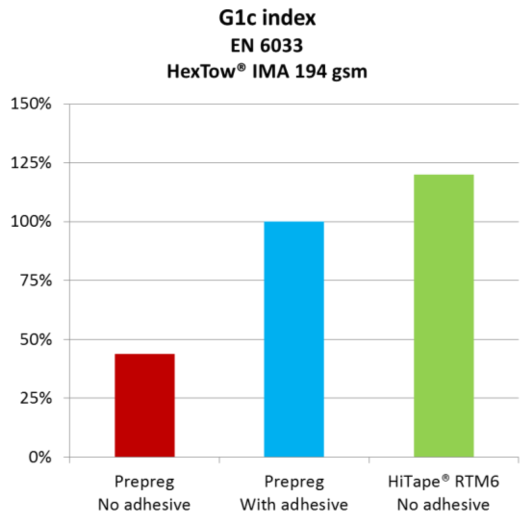
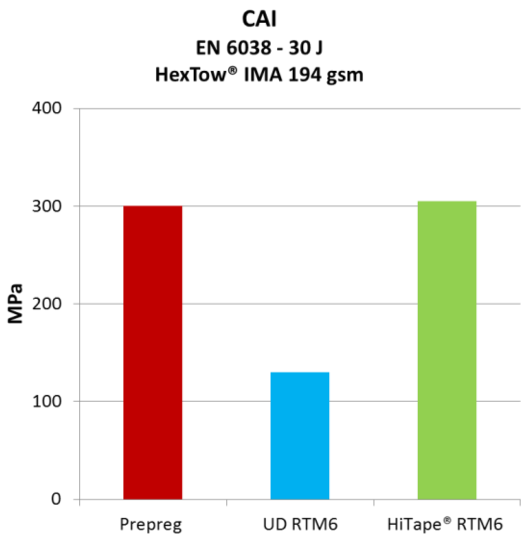
<u>G1C Test principle</u>




As mentioned above, HiTape® has a high G1C value, allowing function integration, but also very good impact resistance and low delaminated area after impact.



Hexcel is currently working on several aerospace projects to prove both the technological feasibility and the cost benefits of HiTape® for next generation Aircraft structures.


(1) Composites Part A: Applied Science and Manufacturing, Volume 42, Issue 9, September 2011, Pages 1157–1168 - Experimental determination of the permeability of textiles: A benchmark exercise

(2) Composites Part A: Applied Science and Manufacturing, Volume 61, June 2014, Pages 172–184 - Experimental determination of the permeability of engineering textiles: Benchmark II

(3) http://www.hexcel.com/products/aerospace/ahitape