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Automated preform manufacture at an affordable price

FEATURE

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Higher production rates and improved part quality at lower cost are key objectives for all composites manufacturers. A new generation of automated tape laying (ATL) machines from North Thin Ply Technology (NTPT) offers a versatile and efficient automation solution accessible to smaller manufacturers, enabling them to reduce labor costs and materials wastage, whilst enhancing part quality and retaining full design freedom. Thomas Ricard, NTPT Technical Director – Materials & Automation, discusses the benefits of the company's ATL technology and outlines some of its possible applications.

Automated tape laying (ATL), a process using computer-guided robotics to deposit prepreg tapes onto a flat or curved tool, originated in the military aerospace industry in the 1960s. Its use has since expanded to the commercial aircraft sector and today it is widely used to create high quality carbon fiber composite parts such as wing skins and fuselages. The automated process enables the manufacture of large structures in one shot, with increased accuracy, repeatability and quality, and reduced cycle time. However, this heavyweight CNC-based equipment has a high capital cost which has been prohibitive to many composites manufacturers. North Thin Ply Technology (NTPT)'s ATL equipment was developed via a different route – the marine industry – and is lightweight, less complex and lower cost, making it accessible to small and medium sized composites companies operating in a variety of markets (Fig. 1).

From sail making to composites

As a sister company to North Technology Group (NTG), a collection of companies with a strong marine heritage, NTPT operates alongside North Sails, the sail maker of choice for the majority of America's Cup, Grand Prix, ocean race boats and superyachts. In the pursuit of stronger, lightweight carbon fiber sails, NTPT started to investigate techniques for spreading carbon fiber tows around 15 years ago. The technology it developed resulted in the capability to produce extremely thin, lightweight tape pre-impregnated with thermoset adhesive. However, it would require many thousands of these individual, difficult-to-handle tapes (in some cases more than 30,000!) to manufacture a sail. It was clear that to enable a practical and economic sail making process the deposition of these tapes onto the mold had to be automated. Therefore, in parallel with its spread tow research NTPT began to develop its first ATL equipment. Following a three-year R&D program the technology was transferred to North Sails where it was scaled up

FIGURE 1

Multiplast, the builder of Groupama Team France's America's Cup yachts, employs NTPT's ATL technology to optimize lay-ups and fiber orientations in the aft wing flaps, removing critical weight high up in the yacht's wing rig.

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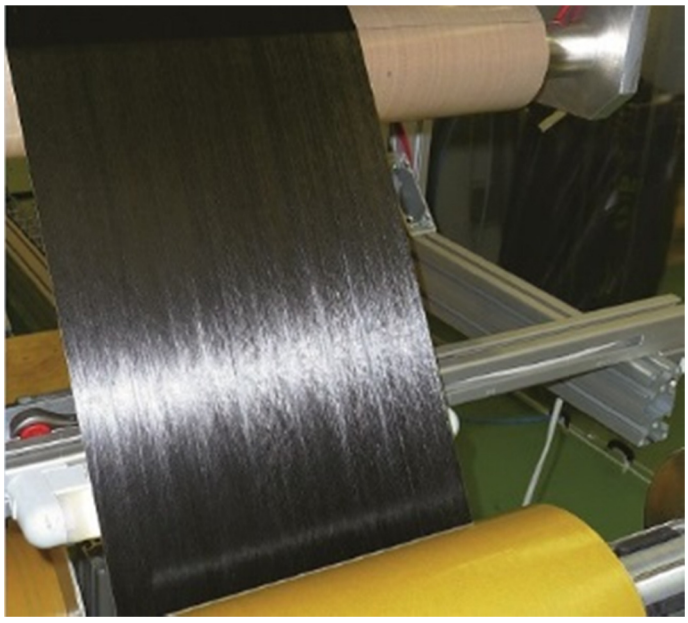

FIGURE 2
NTPT is a leading manufacturer of lightweight prepreg materials.

into an industrial process, now known as 3Di™. This patented sail making technology produces the world's fastest and most durable sails.

Spurred on by this success NTPT then considered the potential of using its spread tow technology to create a composite prepreg using epoxy resin. The extremely lightweight, thin prepreg tape produced was just as difficult to handle by hand and a second generation ATL technology was developed. Further iterations of the machinery followed as NTPT continued to develop its thin ply prepreg range, today branded Thin Ply Technology® prepreg (Fig. 2). During this development phase NTPT determined to make its ATL machine simple, lightweight and low cost, and this meant focusing on the creation of flat (2D) preforms rather than 3D preforms in order to keep the price and complexity of the equipment down. The resulting ATL machine lays down plies of unidirectional (UD) prepreg tapes to create 2D multiaxial prepreg preforms designed to be assembled on a 3D mold. Up to eight plies can be placed in each preform, with any angle of orientation (0–360° in increments of 1°). NTPT uses its ATL technology in-house for the manufacture of preforms using its own thin ply prepregs, but also designs and manufactures machinery packages for clients. The equipment can be used with NTPT's prepregs or any other prepreg tapes (thin ply or conventional) available on the market.

Flexible, adaptable equipment

Whilst NTPT works with customers to design a bespoke ATL solution that will best fit their requirements, machines are built from a set of customizable standard components (Fig. 3).

The equipment consists of:

1. The ATL gantry and head. The computer-controlled ATL head applies each tape on a specified axis and cuts it to a specified length. The layers of tape are built up to produce a multiaxial stack of plies to provide the required performance in the final part.

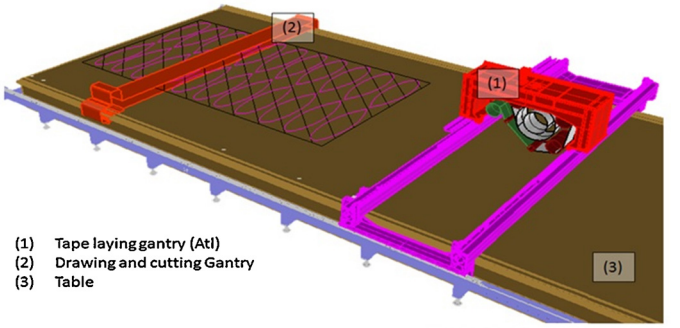

FIGURE 3
The standard components of NTPT's ATL machine, also known as a 'prepreg plotter'.

2. The cutting and drawing gantry. This is equipped with a drag knife and a rotating cutter and nesting software cuts the preforms to the required shape for the mold. Cut accuracy is ±1 mm and the cutting speed is approximately 1 m/s, depending on the material type, the preform area weight and the size and radius of the cuts. The maximum preform areal weight for cutting is 1200 g/m^2.
3. The table. This is a standard cutting table equipped with up to three volumetric pumps, positioned below the table, that generate suction to hold the prepreg paper (or release film) on the table when the tapes are laid. The table is made up of aluminum profiles and vacuum panels and is separated into three zones in which suction can be switched on or off as required.

NTPT offers three standard ATL products with plotting surfaces (defined as the area on which tapes can be laid in any direction and cut at any angle) ranging from 9 m^2 up to 63 m^2. A 20 m table is standard, but longer lengths are available on request.

The ATL equipment is offered with a full selection of design, kitting, and draping software, including:

- TPTDesigner, a user interface for defining multiply preforms on a given geometry;
- TPTNester, a program to organize the preforms on the ATL table and to generate the CNC files for the ATL;
- TPTTracker, which controls and archives the work done by the ATL in real time; and
- TPTStockMaster, a data-based program to control, visualize, organize and edit the stock of composite components, such as rolls of prepreg. The remaining shelf life for each item is recorded.

A typical machine specification is shown in Table 1.

To ensure the best integration within the client's production facilities a dedicated NTPT project manager is assigned to each individual ATL installation project. Following the installation, NTPT will train the client's employees in use of the equipment and software. The ATL technology package is in constant development and customers acquiring ATL technology packages enjoy a close working relationship with NTPT.

Reduced costs, increased quality

The use of NTPT's ATL equipment to produce multi-layer, near net shape preforms (Fig. 4) has a number of advantages over manual lay-up of UD tape:

TABLE 1

Outline ATL machine specification.

Machine size	Typically 12 m long × 4 m wide. Width can be 2–4 m with length <20 m off the shelf, longer lengths on demand
Deposition rate	200–300 linear m/hour depending on material and component
Aerial weight range	Suitable for thin ply prepregs of 15–300 g/m^2
Raw material width	Maximum prepreg width 300 mm
Overlap/gap tolerance	±0.5 mm
Cutting tolerance	±0.5 mm
Tape cutting angles	Includes angle cutting to minimize waste of angle plies at preform edge
Software supplied	Suite including TPT® Designer, TPT® Nester, TPT® Tracker, and Stock Manager

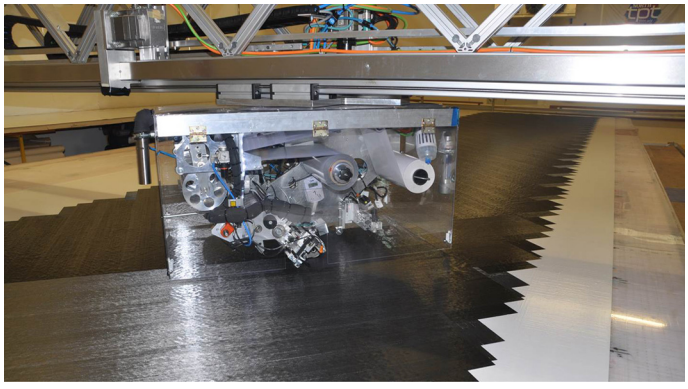

FIGURE 4

The ATL machine lays down plies of UD prepreg tapes to create 2D multiaxial prepreg preforms.

- the preforms are accurately reproduced every time, assuring quality;
- the integrated software provides evidence and tracking of the plies in each preform, easily satisfying the requirements of the most rigorous quality management systems;
- the part design can be as complex as the designer requires and is no longer limited by the low precision of manual lay-up;
- draping time of preforms in the mold is shorter than draping of numerous pieces of UD tape, leading to a reduction in the overall molding cycle and improved mold utilization;
- significant and consistent labor cost reduction is achievable, especially in higher labor cost countries;
- the versatility and ease of use of the equipment allows savings on small projects as well as high volume production runs;
- reduced capital cost and lead time (compared with heavier, more expensive CNC-based ATL technologies) can streamline the business case justification by allowing equipment payback within an individual project cycle.

Because NTPT's ATL can 'angle cut,' a near net shape preform can be made, reducing materials wastage. In addition, multiple shapes can be nested within one larger preform, maximizing material yield.

NTPT estimates that a single ATL can handle the work of eight to ten composite laminators, with full traceability, and no possibility of prepreg backers being left within the laminate. Production rates of up to 300 lm per hour are achievable. The number of parts per day the ATL can produce is dependent on the part size, part complexity, production management, and type of prepreg material.

NTPT's ATL technology is ideal for custom and small- to mid-series parts of average-to-high quality. Efficiency is driven by nesting a large number of small parts on a large table. For example, if the table is 4 m wide by 15 m long and the preform is 1 m^2, several tens of these preforms can be produced at one time. If the part consists of, say, four preforms, after 2–3 hours of plotting and cutting preforms for perhaps 30 parts have been produced. The preforms, cut to the right dimensions and with guide marks, are then easy to place into the mold. For parts with some curvature a composite technology equivalent to the cold seaming technique common in sail making, but using scarf joints rather than seams, is used to drape the 2D preform in the 3D mold.

Although a table length 20 m length is considered practical, in theory there is no limit to part size since a part of any size can be made by joining preforms together.

This flexible and adaptable ATL technology can be used efficiently for custom parts as well large series production runs, as illustrated in the following applications.

Quality assurance for the boat builder

Boatyards processing carbon fiber prepregs are typically not manufacturing larger series production runs. However, a major justification for an ATL machine is its versatility and ease of programming which allows a multitude of components, even complex one-offs, to be manufactured with reduced labor. Components suitable for ATL production include bowsprits, bulkheads and hulls.

To simplify the production process and free up laminating resource, pre-made bulkhead kits can be manufactured as a single preform, ready for easy application to the sandwich core. A typical base laminate, such as a lay-up of eight plies of 300 g/m^2 UD prepreg, will often feature large cut outs and additional reinforcement around penetrations and inserts. These design features can be easily incorporated by the ATL machine with reduced labor, minimized material usage and consistent high quality.

A high performance prepreg yacht hull, typically laid up using large rolls of UD prepreg as well as multiaxial and woven materials, can also be produced as a set of ATL preforms for rapid placement in the mold. The hull laminate sections can be produced incorporating all additional patching, reinforcement tapes and with highly accurate scarf joints ready to align with the neighboring section.

Multiplast, a market-leading builder of high performance yachts and structures renowned for its collaborations with Volvo Ocean Race, Vendée Globe and America's Cup competitors, has installed an NTPT ATL machine at its facility in Vannes, France, and is considering investing in another. The technology is used to produce carbon prepreg laminates optimized for light weight and fiber orientation. In the case of the wing and some reinforcements of the AC50 (Fig. 1), for example, the company was looking for increased mechanical properties and ply sequence optimization. For other projects, the goal is to obtain accurate cuts of the finished preforms in order to precisely control sandwich skin thicknesses. Multiplast also appreciates the speed at which thin ply prepreg

can be draped to create thick monolithic pieces, which saves valuable time.

The ATL machine is a vital tool for Multiplast's highly technical projects and brings a competitive advantage in terms of production of large composite parts. The equipment guarantees the quality of the lay-up, which is crucial to satisfy the company's demanding clients which require the most rigorous quality control and state-of-the-art tracking capabilities.

Another company appreciating the quality assurance the ATL provides is Southern Spars, a specialist in the design and construction of carbon fiber spars, components and rigging. The company has a long history of building rigs for the America's Cup and its products have been fitted on several Superyacht of the Year award winners.

Southern Spars has a meticulous quality control system refined over 25 years and uses LEAN manufacture to ensure organization, traceability and consistency. NTPL's ATL equipment is a key component of the company's quality methodology as it makes it possible to accurately place every ply according to the structural design and produce the documentation to demonstrate this to its customers. The more efficient use of material and the labor savings seen in pre-stacking plies are further valuable benefits.

Rapid preform production for automotive applications

Vehicle manufacturers are looking to carbon fiber composites as part of their lightweighting strategy, but they need processes to enable series production at acceptable cost. NTPT's ATL equipment offers new opportunities for manufacturers of medium volume production runs as the following example illustrates.

For the 2 m^2 bonnet outlined in Table 2 an NTPT ATL machine designed around a 12 m × 4 m table could lay prepreg tapes for a set of 18 parts at one time. A complete production cycle time for the table – including initial set-up, prepreg lay down, roll changes, cutting, labeling and picking of the finished preforms – could be as short as 3 hours.

TABLE 2

Example automotive part.

Part	Automotive bonnet – 2 m^2
Preform lay-up	5 plies of 200 g/m^2 UD carbon prepreg
Production run rate	10,000 parts/year
Composite process	UD prepreg laid up and cut to shape with NTPT ATL machine, transfer to compression molding press

Including adjustments for overall equipment effectiveness (OEE) produces a time per part of under 13 min could be obtained, with a material yield of 88%. The annual production of 10,000 preforms could be achieved with a single shift (8.3 hr/day for a 250 day working year) while the ATL equipment guarantees the quality of the lay-up.

Rapid, consistent and traceable carbon fiber preform production for this project could be delivered by an ATL machine costing approximately €800,000.

A competitive advantage

As these examples demonstrate NTPT's new generation of ATL machines make automated preform production a more accessible option. The initial equipment investment is paid back in savings in both materials and labor costs, higher production rates and improved quality and traceability. The equipment's versatility and ease of use enables savings on small projects as well as high volume production runs. The possibility of significant labor cost reduction opens up new opportunities for companies operating in higher labor cost countries to compete with those in lower cost regions. With this combination of benefits it is no surprise that NTPT's automation solutions are finding more and more applications in the marine, automotive and a host of other markets.

North Thin Ply Technology (NTPT); www.thinplytechnology.com