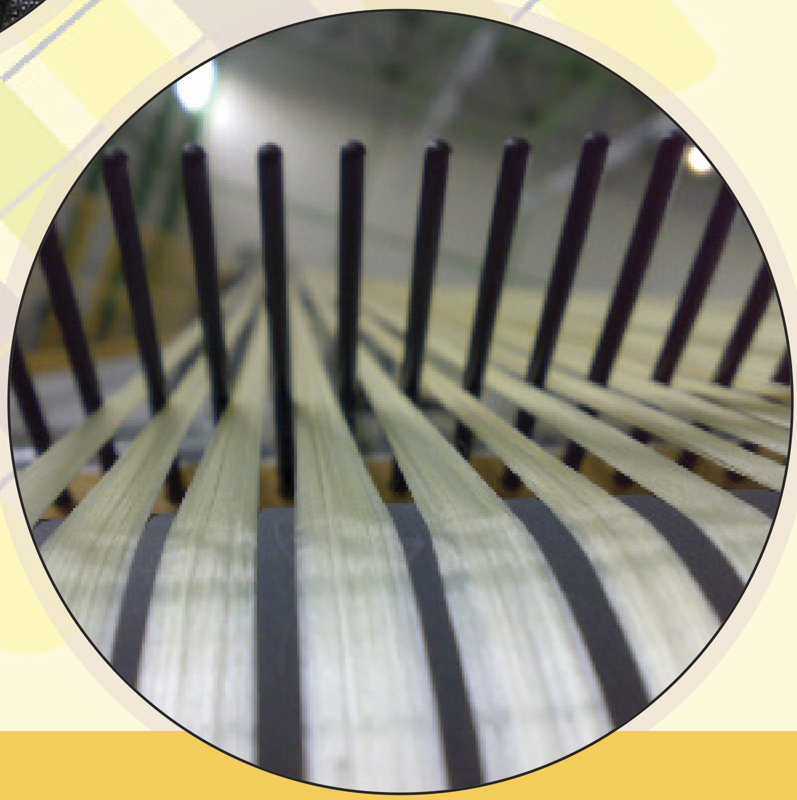
Technical TEXTILES international

Summer 2020
Volume 29, Number 2

Informing the industry worldwide

The industry's life-saving response to the global pandemic

Cygnet Texkimp's secret to success: a focus on fibres



INSIDE:

The fibreglass industry booms

Groundbreaking uses of warp-knitting technology

Producing nearly pure spider silk with silkworms

A focus on the integrity of fibres pays dividends for Cygnet Texkimp

Custom machinery builder Cygnet Texkimp has built a global business around fibre. Technical Manager Andy Whitham explains why fibre integrity is the essential design element in every piece of machinery Cygnet Texkimp engineers. He shares the company's approach to fibre handling, and the technical considerations that ensure the integrity of valuable fibres is protected during processing to deliver materials and end-products of the highest quality.

Cygnet Texkimp's 3D Winder is a robotic machine designed to produce complex non-linear parts that vary in cross-section (see also, page 33).

Cygnet Texkimp was founded in the early 1970s to manufacture fibre-unwinding creels, initially for the traditional textile industry in the UK, and then for the emerging technical textiles market around the world. The company from Northwich, UK, was one of the first manufacturers to focus on the way machines deliver reinforcement fibres into processes for making composites and created some of the first-ever creels specifically designed for carbon fibre materials to be used in high-value applications such as military and aerospace.

Today, we design and build some of the largest and most sophisticated creels in the world, together with equipment for downstream conversion and automation, targeting high-performance textiles and composites markets. Fibre-unwinding creels make-up around one-third of the machinery portfolio.

Our guiding philosophy is to engineer everything we can to protect the fibre at every point in the process. In practice, this means causing the least damage possible to the fibre, because any touching or handling will damage it in some way. This is especially important in the case of technical fibres, which are typically fragile in their raw forms and yet are often used in applications where their strength is an essential feature.

The key principles of fibre care developed in the 1970s still hold true, namely:

- the need to minimise the fibre's deviation throughout the process;
- the application of the correct surface finish for the material;
- the desire to keep tension constant and as low as possible;

One of Cygnet Texkimp's creels for three-dimensional weaving.

- the avoidance of the build-up of foreign-object debris (FOD) and stray filaments;
- the absence of twist in the fibre (unless it is desirable);
- the design of equipment around the principles of ease of operation and maintenance, and reliability.

As a result, our creels now boast much tighter control mechanisms, including in-process tension adjustors and data collectors, developed to provide the best treatment for each material and process.

Three-dimensional weaving

An example is the 3000-position three-dimensional (3D) weaving creel we recently supplied to the Composites Centre at the University of Sheffield's Advanced Manufacturing Research Centre (AMRC) [(1)] in the UK. The high-capacity creel is being used alongside AMRC's 3D jacquard loom to weave structures from dry fibres such as carbon and ceramic for automotive and aerospace applications.

Offering manufacturers a novel way of creating strong, lightweight and structural composites in complex forms, 3D weaving is used to help make parts for many end-uses, including automotive and aerospace. The way in which the fibres are handled and fed into the process is fundamental to the quality and performance of the finished product, making the design of the creel important.

With a footprint of less than 40 m^2, the AMRC creel has an intelligent control system to maintain a low and consistent running tension of the fibre into the downstream weaving process, and enable operators to adjust the tension of individual positions or zones according to the fibre weight and position in the woven structure. A bespoke guide system accommodates varied fibre counts (k-counts) and tow widths, and a tension recuperation mechanism offsets the effects of the shedding motion of the loom.

Eliminating fibre damage and controlling tension

With thousands of tows needed to weave a single component, the opportunities for damage caused by fibres crossing and touching are magnified. The guide system is central to reducing fibre damage by maintaining the separation of each tow from package to process and keeping contact points to a minimum. Where fibre contact is necessary, its impact is mitigated by, for instance, incorporating highly polished, low-friction ceramic guides and smooth surface- finishes throughout (see also, page 3).

Unlike traditional weaving, which demands constant fibre speeds and equal running tension for all warp fibres to produce a uniform sheet, for 3D weaving it is necessary to vary the tension of individual fibres or banks of fibres according to their position in the structure and the type of fibre, in order to produce the desired shape.

Filament winding

In filament winding, fibres under tension are wrapped around a rotating mandrel to build-up a shape. Cygnet Texkimp has also used its knowledge of fibre handling and machine control to improve the speed and

An array of Cygnet Texkimps's creels feeding the looms at a weaving plant.

production capacity of this technique, with the goal of making it a viable method of manufacturing components in high volumes for the automotive market.

In 2016, Cygnet Texkimp launched a large-scale research and development (R&D) project with the University of Manchester, UK, to develop a series of technologies and explore what can be achieved using filament winding by applying robotics and automation. In addition to increasing the rates of production, the work seeks to expand the scope of filament winding into areas where conventional methods are too slow or impractical.

The first technology to emerge from this work was the 3D Winder[2]—a robotic machine designed to produce complex non-linear parts that vary in cross-section. It is based on the nine-axis robotic winding concept first developed by the University's Professor Prasad Potluri[3].

The 3D Winder (see also, page 31) is a high-speed machine combining rotation and fibre-feed in one mechanism that is robotically moved around a static mandrel, winding as it goes. Multiple heads, each carrying a single package of fibre, are mounted onto a rotating ring. The size of the ring and the number of heads it incorporates are changeable, and dependent on the size of the part being manufactured.

By mounting multiple fibre feeds, we are able to speed-up what has typically been a relatively slow process. The 3D Winder is capable of winding carbon fibre at a rate of 1 $kg.min^{-1}$, which means it can wind an aircraft spar in just a few minutes or create a 150-mm part by laying-down roughly 7.5 m of fibre in every revolution.

Other parts that can be made on the 3D Winder include aerospace fuel lines, crash beams for automobiles, hydrogen fuel cells, oil and gas pipes, wind-turbine blades and aircraft fuselages.

A key feature of the 3D Winder is its ability to create complex and curved shapes with a high degree of precision. The inspiration for its development came from the design of an inlet duct for a fighter aircraft (F-35 jet), which measures around 3 m long and has a large, circular cross-section at one end and a smaller, square one at the other. The 3D Winder can cope with this complexity because of the travelling winding mechanism's degree of freedom.

Polyacrylonitrile fibres fed from a creel using an angled guide system.

It was originally thought that the 3D Winder would be more akin to a braider, because its large-scale ring, loaded with rotating packages of fibre, has a similar appearance. In practice, however, the machine produces a low-crimp material that contains less shear than a braid, and so can be strong, thin and lightweight. Nevertheless, the mechanical interlocking of fibres in a braid is known to confer desirable properties, such as good impact-resistance, and so we designed the 3D Winder to impart some of the mechanical linking together with its winding action. (Together with the University of Manchester, we are continuing to compare the performance of braids with our wound materials.)[4]

In addition, the mechanism by which fibre is taken from the package to the part, using a compressed version of the guide system typically found on a prepreg machine, is far more gentle than that on a typical braider.

Not only does the guide system reduce the build-up of FOD, but the 3D Winder can also accommodate fullsize packages of fibre. This reduces the need to re-spool the 3D Winder and so boosts productivity.

The work undertaken to develop the 3D Winder was so wide-ranging that it has left us with a body of knowledge that has so far enabled the development of three other filament winders, each less complex, but equally useful to the market.

More conventional

The first is a robotic filament winder with a conventional winding set-up, in which the mandrel rotates in a fixed position while the feed is positioned on a robotic arm to supply fibre using multiple axes of motion. This version can incorporate a driven creel mounted onto the robot, which allows fibre at each position or axis to be tensioned individually to control the feed and deliver a high level of accuracy and consistency. This also means the speed of each feed can be varied to deliver high resolution and create small-scale features or complex geometries.

A four-axis filament winder based on this design was installed by composites company Solvay at its Application Centre in Heanor, UK, in late 2019[5]. Solvay uses the winder to produce large sheets of composite (blanks) for its Double Diaphragm Forming (DDF) technology. After winding, the material is slit automatically to leave the blanks, which can be moulded to create exterior parts, including bonnets and boot-lids for the automotive industry.

This blank is produced by filament winding and then slit to produce a 1 × 1-m preform.

The winder takes dry fibres, or tows, from an integrated, four-position driven creel and feeds them onto an application head. The driven creel controls the tension, which ensures consistent spreading despite the variations in fibre speed that occur throughout winding. The four tows are spread within the application head to create a 50-mm-wide consolidated sheet or tape, onto which Solvay's resin system is applied immediately before it is laid onto a mandrel.

We designed the filament winder to incorporate a resin-metering system that can mix Solvay's advanced resins at the point of application. As a result, there is no curing of the pre-mixed resin before its application or any need for it to be stored under special conditions.

The winder is capable of running at a speed of up to 100 $m.min^{-1}$ and has been built to accommodate a mandrel spanning 2.2 m in length by 0.6 m in diameter, which means it can produce 2-m^2 preforms. For the automotive market in particular, this is a compelling alternative way to make high-performance composite parts in medium volumes.

High tension

Launched at *JEC World* in Paris, France, on 12–14 March 2019, the second development is a four-axis winder. This simpler, more conventional machine is cheaper and so more accessible to a wider cross-section of the market, but is still designed to minimise the deviation of the fibres (and so the stress applied to them) and keep the number of contact points small, as well as providing high-quality surface-finishes. This winder is particularly useful in applications where high fibre tensions are required, up to and exceeding 1 kN when running at 120 $m.min^{-1}$. Winding at high tension allows the user to make the parts stronger without adding weight, which is particularly important when fabricating products such as pressure vessels.

High-speed continuous processing

Finally, the most recent innovation of the three is the Multi-Axis Winder (MAW), which uses the rotating-ring mechanism of the 3D Winder, but simplifies the overall system by mounting the fibre-delivery head onto a sliding rail, rather than a robotic arm, making it suitable for applications where speed and continuous processing are important.

Cygnet Texkimp's collaborative robot is mounted on an automatically guided vehicle (see also, page 36).

The MAW is optimised for the high-rate production of linear structures, such as tubes and masts, but is not capable of the more complex, curved shapes allowed by the 3D Winder.

The MAW allows manufacturers to run dry fibres as well as pre-impregnated tapes at fast speeds with a high level of control and accuracy. It is already being used by JRM Group of Daventry, UK, as part of a confidential research project for an automotive brand investigating the use of carbon fibre composites in structural automotive parts.

Automation and handling

In the last decade, the size of the fibre packages being used in the technical textiles market has grown considerably. Bobbins of fibre weighing up to 350 kg and measuring one metre in diameter are now commonly used by manufacturers as a way of increasing production capacity and speed, as well as reducing downtime. In addition, there is an increased focus on operator wellbeing and product traceability.

To address these needs, we now offer a portfolio of automated systems alongside our fibre-processing and converting technologies to help manipulate large bobbins for use on our customer's machines. Examples of these technologies include: automatic loading and unloading of creels; systems to wrap, pack and palletise bobbins of fibre; radiofrequency identification (RFID), barcoding and vision systems; automatically guided vehicles (AGV).

Each technology is designed to enhance the quality of the fibre or product, either by reducing physical handling or improving traceability and in-process checking.

Our automated packing and palletising system, for instance, is designed to process bobbins efficiently without workers touching the fibre. This helps customers eliminate damage to fibre caused by oils and acids on our skin, and bumps and scrapes on package edges.

From the time they enter the process, the bobbins are untouched by human hand. A bellows-type gripper, which touches only the core of the bobbin, is used to transport them through each stage in the process. At the end of the process, they are transferred in the same way to an automatic checking and wrapping system, which encloses the bobbins completely in shrink-wrap to protect them during transport and storage.

Finally, the packages are labelled with their unique identifier before being boxed by robots and palletised ready for shipping.

Collaborative robotics

We are also developing automated systems based on collaborative robots.

Collaborative robots work with the customer's staff to make the manufacturing process safer, faster and more productive. Conventional robots can only operate in contained spaces, because they cannot sense or respond to the presence of a worker. Collaborative robots, in contrast, sense pressure and stop when a person or object is detected.

In 2019, we launched an AGV-mounted handling system using a collaborative robot capable of lifting packages of fibre weighing up to 35 kg (see also, page 35). Until recently, collaborative robots were only been capable of handling packages weighing up to 2 kg. The increased payload capacity, together with advances in AGV technology, have enabled us to develop a system that can lift and load large packages more easily and safely, including those high-up from the ground.

Our system can be used for loading and unloading creels, winders, cabling and twisting machines, and shelving and racking structures. It can be programmed to follow a pre-determined route, which can be changed easily and cheaply, according to the task it needs to perform. With no infrastructure needed to navigate around the factory, the technology is completely mobile.

References

(1) https://www.amrc.co.uk/news/3d-creel-helps-amrc-take-weaving-to-new-level

(2) *Technical Textiles International*, May 2017, *Winding machine for making curved composite parts*, page 72; https://www.technical-textiles.net/node/73218; and: *Advanced Composites Bulletin*, April 2017, *Winding machine is capable of making curved composite parts*, page 5.

(3) *Technical Textiles International*, February 2019, *Graphene-coated jute fibres for reinforcing composites*, page 42; https://www.technical-textiles.net/node/74540; and: *Advanced Composites Bulletin*, January 2019, *Graphene-coated jute fibres for reinforcing composites*, page 1.

(4) *Comparative Evaluation of Braiding and 3D Complex Winding for Automotive Chassis Frames*, Yan Liu *et al.*, *Proceedings of the 18th European Conference on Composite Materials (ECCM)*, Athens, Greece, 24–28 June 2018. https://az659834.vo.msecnd.net/eventsairwesteuprod/production-pcoconvin-public/4e4f075b0bad4322bfe9f6f7a015a238

(5) *Advanced Composites Bulletin*, February 2020, *Solvay reveals demonstrator line for the high-volume manufacture of composites*; https://www.technical-textiles.net/node/75379

Further information

David Barker, Sales Manager, Cygnet Texkimp.
Tel: +44 (1606) 338748.
Email: david.barker@cygnet-texkimp.com

Mike Urey, Sales Manager, Cygnet Texkimp.
Tel: +44 (1606) 338748.
Email: mike.urey@cygnet-texkimp.com;
https://cygnet-texkimp.com

Advanced Manufacturing Research Centre.
https://www.amrc.co.uk

Yan Liu, School of Materials, University of Manchester.
Email: yan.liu@cygnet-texkimp.com

Prasad Potluri, School of Materials, University of Manchester.
Email: prasad.potluri@manchester.ac.uk;
http://www.materials.manchester.ac.uk/our-research/research-groupings/robotics-and-textilecomposites

JRM Group.
https://www.jrm-group.com