whitepaper

Automated Stringer Manufacturing

AUTOMATED STRINGER MANUFACTURING – GFM CONCEPTS AND TURN-KEY SOLUTIONS

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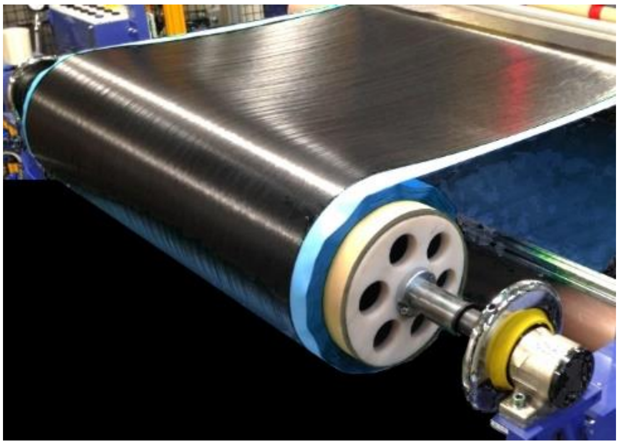
Fuselage stringers are one of the few structural components of an aircraft that can be considered for mass production. Such stringers, which are responsible for the stiffness of an aircraft's fuselage skin, are needed in such large numbers that intensive research to invent and realize new production and automation methods is justified. Similar techniques can also be used for the production of wing, stabilizer or flap stringers.

RAW MATERIALS FOR CARBON STRINGERS

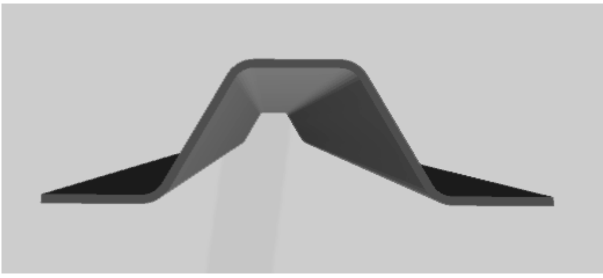
Carbon fiber stringers consist of many thin layers of carbon fiber fabrics with specific properties that ultimately define the stiffness, flexibility, strength, weight and many other requirements to make them an optimized part of an aircraft.



According to the designed lay-up sequence, unidirectional and/or woven prepregs are stacked as cut plies in predetermined angular directions or built up by a lay-up system. Such prepregs are either laid as single layers or processed as pre-laid multi-angle unidirectional layups. Often a thin glass fiber prepreg layer is placed in areas where the stringer is in contact with metallic parts to avoid corrosion.

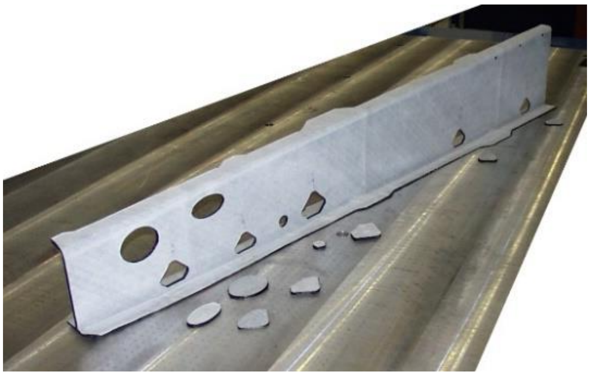
An alternative to using prepregs are dry unidirectional and multiaxial carbon fiber materials to make stringer preforms. Such preforms are finally filled with resin by processes such as resin transfer molding or vacuum infusion processes.

Ω - STRINGER SHAPES



The typical shape of a fuselage skin stringer has a trapezoidal profile with 2 bases, similar to the Greek omega, which is where the name comes from. This shape allows the use of relatively thin stringers, which give the so reinforced skin the highest stiffening properties. Firmly attached to the skin, it forms a wide, stiff structure. Cold and hot forming techniques to form the shape from a flat layup benefit from the fact that no movement between the plies in the hat and between the plies in the bases is necessary during forming - the two radii on each side, to the hat and to the base, automatically equalize their length per ply and movement between the plies is thus limited to the flanges and the radii.

Other stringer shapes such as J-stringers, which have thicker walls and also larger cross-sections, are used to stiffen wing skins and other structural parts. Many alternative profiles and corresponding manufacturing techniques can be found in the relevant literature and in various patents.



STRAIGHT AND CURVED STRINGERS

In addition to straight stringers in the center fuselage sections, curved or highly curved and twisted stringers are also required for a complete fuselage. Mass production of straight stringers can be realized relatively easily by selecting the right technologies and equipment for automation to achieve the production of enough stringers for the required rate of aircraft per month. Curved stringers require more complex production steps and techniques, but can also be produced today by automated manufacturing cells offered by GFM.

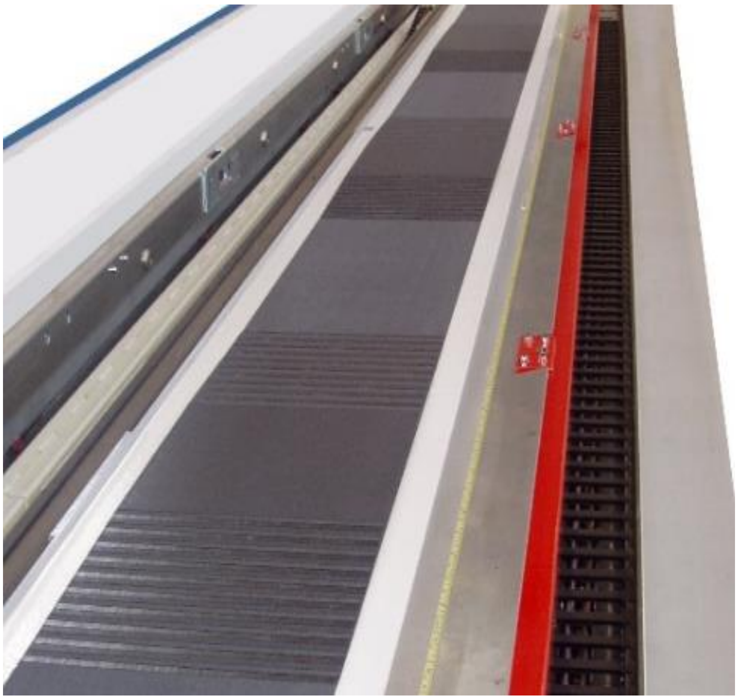
LAYUP OF STRINGER MATERIALS

Flat layups, which are finally shaped by a forming process, are often the basis for the mass production of straight fuselage stringers.

Such layups can be made with unidirectional prepreg laid at angles and with ramps according to the ply book of the single stringer. If the layup is produced as a nest of several stringers, care must be taken to ensure that these stringers have the same layer angle sequence and that the ramps can be properly organized in the nesting. Depending on the layer sequence, the production of large layups can be very economical as the laying times are minimized. After the laying sequence, the individual stringers are typically cut on the same machine into the correct shape for the subsequent forming process.

A very efficient alternative is to lay material that already contains the desired fiber directions, e.g. woven ±45° prepreg, lengthwise. For this purpose, we offer a laying system with several laying heads. This has the advantage, that the relevant head is simply activated at the programmed length position for laying. Ideally, the laying heads are stationary and the laying surface performs the laying movements. Such laying is done one stringer at a time and thus the required sequence of stringers can be produced without large storage areas.

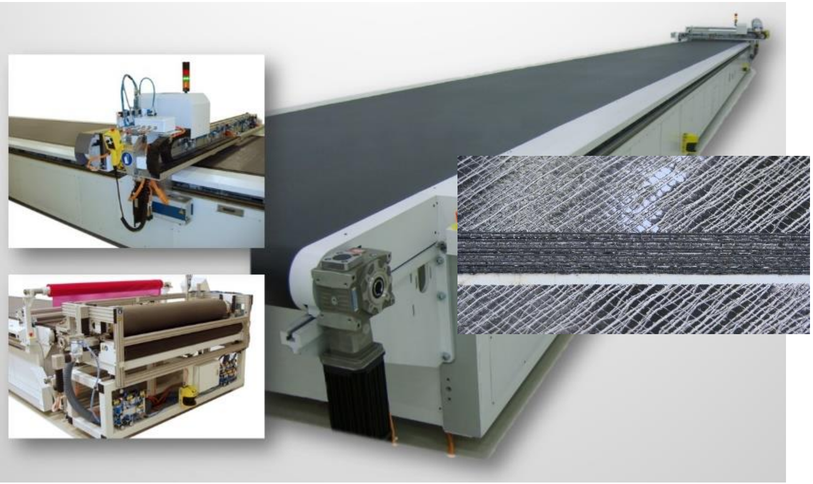
Alternatively, a combined system may be the right solution. In such a system, the unidirectional prepreg is laid lengthwise by a laying head and the angular strips are cut just in time by a cutting machine and placed at the programmed position by a pick & place system.



Another possibility is to lay up sequences of layers that are repeated in the stringers as a large layup, followed by cutting, picking and placing the thin layups thus produced at the right places in a set of stringers. A similar solution is to continuously produce, for example, ± 45° or ± 90° strips as a pre-layup, cut them to length and place these strips by a pick & place system.

A combination of the above laying techniques can also be used for the pre-production of layups for curved and twisted stringers.

For stringers produced using the RTM process, single or multi-layer dry material strips are prepared, cut into the correct shape and laid automatically according to the ply book.



Pre-compaction steps are typical, which locally bond the individual layers together prior to preforming.

GFM solutions for layup production

GFM is a manufacturer of laying systems with single or multiple laying heads as well as laying systems with cassette changing system.

Combined systems for laying, ultrasonic cutting, pick & place are available for all required process steps to have the right solution for the desired stringer layup production system.

Such systems can either operate as standalone units or be integrated into automated production cells by our experienced team.

FORMING

The forming of flat layups into the final stringer shape is carried out today with different techniques, whereby a common technique is still hot drape forming. Alternatively, forming can be done by special presses, by roll forming systems and combinations. The choice of the right forming process depends on the layer structure of the stringer and very often also on the required productivity. It is important to choose the right forming process that ensures the required flow between layers within the specified times and produces a precisely formed stringer.

GFM solutions for stringer forming

As part of a stringer manufacturing cell, GFM implements the customer's preferred forming solution or individually industrializes new customer processes. Furthermore, we can especially recommend the recently developed new GFM technology, namely the GFM DrapeForging process, an excellent solution for the automatic and stress-free forming of prepreg layers.

ULTRASONIC CUTTING OF STRINGER FLANGE ANGLE AND STRINGER ENDS

Ultrasonic cutting was originally developed for cutting prepreg materials by Design Technologies Limited, which became GFM in the mid-1980s. Today, ultrasonic cutting is used around the globe and is widely used for cutting prepregs, prepreg layups, dry technical textiles, honeycomb materials and many other materials.

For stringer flange low angle cutting and for stringer end trimming, ultrasonic cutting opens up unique possibilities due to the high quality of the cut edge. Stringer edges that are ultrasonically cut to net shape usually do not require further processing after curing.

GFM Ultrasonic Cutting solutions

GFM offers a wide range of 2D and 3D ultrasonic cutting machines. For ultrasonic cutting of the stringer flange angles and stringer ends, a GFM US-50 3D ultrasonic cutting machine is typically used. The US-50 can be configured in a variety of ways to suit actual cutting requirements to create an optimized overall system. It typically comes with a flat vacuum table, with single or double shuttles for maximum productivity, or with tables for placing fixtures used for cutting curved and twisted stringers, for example.

BLADDER OR FIXTURE FOR COMPLETION

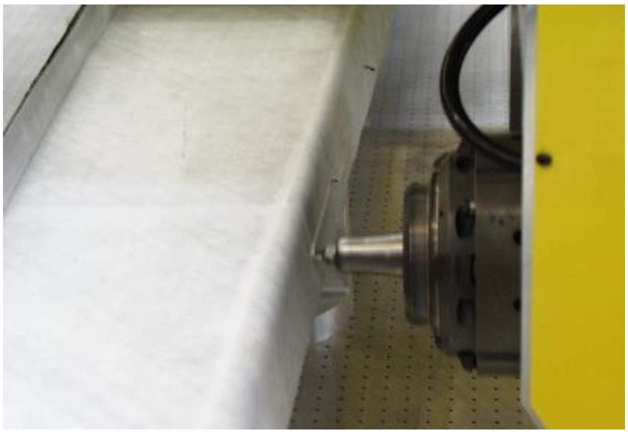
To cure the fuselage skin together with the stringers in an autoclave cycle, bladders are used to hold the stringer in shape.

If a stringer is processed on a fixture, such fixture is often already used at the forming stage, then for 3D-cutting and further goes together with the trimmed stringer into the autoclave.

GFM solutions

If the bladder is pre-assembled to the stringer prior to insertion into the mandrel for fiber placement, the preparation and insertion process can be supported or performed by GFM pre-assembly and handling equipment.

For stringers being processed on a fixture, a typical GFM task is 3D ultrasonic cutting of the stringer flange angle, stringer ends and recesses on some stringer types.



FILLER OR NOODLES

Many stringers require the use of fillers or noodles to close radius areas of the cross-section in order to optimize stress behavior or avoid resin-rich areas.

GFM solutions

Layups for fillers or noodles can be processed with GFM tape laying machines or with 2D ultrasonic cutting and pick & place solutions. 3D ultrasonic cutting of such fillers or noodles can easily be performed on a GFM US 50.

PRE-COMPACTING

Some types of stringer manufacturing processes involve pre-compaction after a certain number of layers or before the stringer is inserted into the mandrel for completion by fiber placement or before the curing cycle in an autoclave.

GFM solutions

As part of automated cells, GFM offers integrated and automated pre-compaction systems.

HANDLING

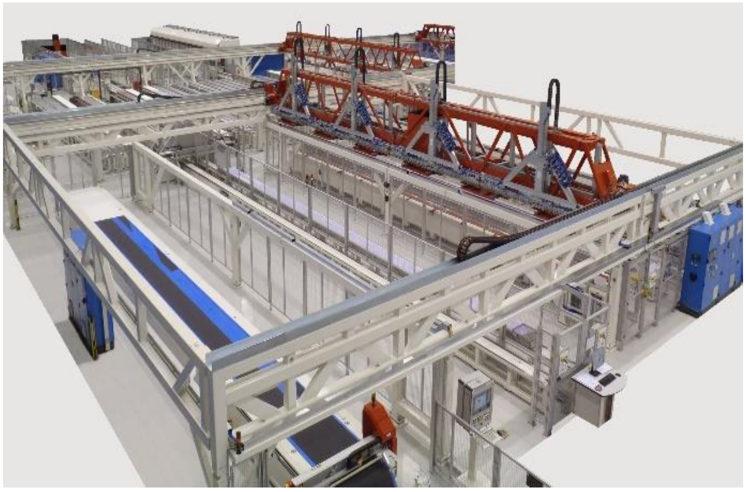
Optimized handling solutions are important for proper serving the various stations in an automated stringer manufacturing cell. Handling starts when raw materials enter the cell and is required for the transfer of semi-finished products from one manufacturing station to the next or finished stringers to storage or output stations. An optimized handling system also provides the right tools at the right time at the different stations, serves buffer or tool stations and performs process-related pick-and-place tasks in the meantime. Handling systems can either be integrated and equipment-specific or universal to perform multiple tasks.

It is important to take a comprehensive view of all tasks to be performed within an automated stringer manufacturing cell at the time of cell planning to ensure smooth operation and high performance of the cell.

Since adjusting one parameter or making a change at one end of the cell can lead to necessary adjustments in other parts of the cell, it is very beneficial to have a company that has a holistic view of all the details involved in planning and implementing an automated cell.

GFM solutions

GFM supplies various equipment with its own dedicated handling system and knows how to optimally combine such individual units with central universal handling systems, including the operation of tool storage units, parts storage stations and auxiliary, infeed and outfeed stations. GFM has the know-how and the possibilities to realize the individual process steps with dedicated process- and productivity-optimized systems as well as to combine the units into a complete, smoothly running, integrated manufacturing cell.



SOFTWARE

The main scopes of software for an automated cell can be defined as a) machine-related control, PLC and process-related quality inspection systems, b) programming software for the individual machines, c) cell control software for coordinating, optimizing and controlling tasks within the cell, such as transferring a part from one machine to the next using the central handling system and d) plant implementation software for receiving work orders, providing status reports per machine, cell status and production status to the plant management software.

GFM solutions

For the product range of ultrasonic cutting machines and tape laying machines, GFM uses its own highly developed CNC 6000 control system, which has been optimized for GFM technologies and offers unique advantages to the user. For additional processes that are customized or implemented in the cell, as well as for the main handling systems, GFM uses commercial control systems. The software for quality inspection is adapted and implemented by GFM according to the individual task. The software for cell control and plant implementation is typically developed by GFM, including customization and integration to interface with customer-specific systems. Programming systems for the various processes are either developed by GFM, such as for 2D ultrasonic cutting or tape laying, or selected programming software can be supplied.

SAMPLE DATA OF A CELL SUPPLIED BY GFM

Cell size	approx. 60 x 60 meters
Stringer length	max. 18 meters
Stringer shapes	up to 6
Productivity	stringers for up to 30 barrels per month
Automation grade	>95%
Operators	2

Applied Technologies and Equipment realized by GFM:

Laying, forming, 3D cutting, 2D cutting, pick & place, pre-assembly, pre-compaction, stringer storage stations, tool storage stations, handling between all stations, material inspection, process inspection, cell control system, programming systems, overall system integration.

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