Automated composite ply kitting and preforming

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White paper

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Executive summary

Automating the kitting process brings many advantages. It not only replaces manual labour by automation and significantly reduces material waste, automated kitting also unlocks many other opportunities to maximise ply cutting and lamination output whilst reducing production costs.

In combination with advanced nesting software it opens the way to more efficient nesting, or even dynamic nesting, which significantly reduces material waste.

In this paper we take a look at the challenges for the industry, the traditional kitting process and the opportunities for and advantages of automating the kitting process.

And, as a next step, we discuss how the automated kitting process could be extended to include preforming as well.

Glossary of terms

Nesting

In the manufacturing industry, nesting refers to the process of laying out cutting patterns to minimize raw material waste.

Plies

Plies are the individually cut pieces of composite material that are used to manufacture a composite part or structure.

Kitting

Kitting is the process of gathering the cut plies in the groups and order needed for the lamination of a particular part or product.

Sorting

Sorting is the process of picking the plies and arranging them in groups on the trays (according to the sorting algorithm).

Sequencing

Sequencing is the process of arranging the pre-grouped plies in the order required for layup.

The Industrial Internet of Things (IIoT)/ Industry 4.0 (I4.0)

The IIoT/I4.0 is a vision of fully connected factories where machines, employees, raw materials, processes and finished products use a digital backbone to share all data in real-time, allowing managers to constantly optimize and improve operations.

Introduction

The composite parts manufacturing industry is constantly challenged to produce increasingly higher volumes at ever lower costs. This trend is particularly marked in high growth industries such as aerospace, automotive and marine. In part, this trend is driven by global economic growth and the increasing desire to use lightweight materials for reducing energy consumption. A second aspect is the opportunities opening up by the latest advances in the Industrial Internet of Things (IIoT) and Industry 4.0 (I4.0). This makes it possible to increase throughput and efficiency by automating and optimizing processes such as composite material cutting and kitting – and ultimately forming.

Increasing volumes while reducing costs is particularly challenging for manufacturers of composite parts. These are the most highly engineered components in industry, used in applications with an uncompromised demand for quality and tolerances. More so than other manufacturing industries, the composite parts industry is still strongly reliant on manual labour due to the complexity of the production processes. Yet the human factor comes with challenges such as material waste, human error and the cost of manual labour.

Automated solutions are becoming increasingly available for composite parts manufacturers to reduce costs and save time. For example, automated cutting of composite plies is already widely used in the industry, while other activities such as kitting are mostly still done manually. Cutting and kitting is the traditional job of cutting composite plies, compiling them per part and, preferably, sequencing them in the right order for lamination. The lamination operator can then take the plies from the kit stack and place them, one by one, into the mould.

Figure 1. Cell overview

Kitting has always been a highly important and labour-intensive job, but it has a risk of human errors in the process. Automating the kitting process brings many advantages. It not only replaces manual labour by automation and significantly reduces material waste, automated kitting also unlocks many other opportunities to maximize ply cutting and production output whilst reducing production costs. In combination with advanced nesting software it opens the way to more efficient nesting, or even dynamic nesting, which significantly reduces material waste.

In this paper we take a look at the challenges for the industry, the traditional kitting process and the opportunities for and advantages of automating the kitting process. And, as a next step, we discuss how the automated kitting process could be extended to include preforming as well.

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Industry challenges

The composite parts manufacturing industry faces three main challenges in its production processes:

- Raw material cost
- Human error
- Cost of manual labour

Raw material waste

Raw material waste is one of the biggest challenges in composites manufacturing. Using sequential cutting or simple nesting of plies per part can mean up to 50% of the material is discarded. Ideally, a highly efficient cutting plan would be designed, mixing nests from different parts and making optimal use of the material roll to minimize waste. But in reality this is not always possible. Also, workers have to keep track of all of the different plies and sort them into kits for a variety of different parts. Simpler cutting plans are often required to minimize the risk of errors, resulting in excessive materials waste, even though composite materials are one of their largest costs.

Human error

Manual kitting of cut composite plies is a complex process. Operators have to keep track of all multiple plies coming from the cutting table and ensure these end up in kits in the right order. This is not only labour-intensive, but also prone to human error. Plies may accidentally get mixed up in different kits and be transferred along the production line, ultimately ending up in the wrong product. Missing plies at the lamination stage might require recuts to be made, leading to more waste, but can also lead to full scrapping of the laminated part at serious costs.

Cost of manual labour

The composite parts industry is very reliant on manual labour due to the difficulties associated with working with composite materials. For example, most prepreg composite materials must be freezer-stored and, once removed, have a limited time to be used in the manufacturing process before they must either be cured in an autoclave or returned to the freezer. Such complexities have inevitably led to a more manual manufacturing process where humans are readily available to respond to unexpected situations and problems. This high reliance on manual labour can make it very difficult for composite parts manufacturers to meet their customers' demand for continual cost reductions.

A look at a traditionally manual process

In order to describe the possibilities of automation, we should first take a look at the process flow and the different elements of the traditional kitting process, including nesting, cutting and kitting.

Process flow

The process flow for kitting follows a basic series of subsequent steps:

- Warehouse materials storage (prepreg freezer)
- Transfer of material roll from warehouse to cutting table, followed by acclimatization of prepreg (to warm up to ambient conditions)
- Nesting of plies, by dividing plies over the material roll by fitting ply shapes next to each other, to maximize material usage
- Cutting of plies, based on the nest, on the cutting table
- Kitting of plies per part
- Transfer of the kits to the lamination area
- Lamination of the part

Cutting

In manual composites manufacturing, the lamination operator hand-cuts the plies needed for lamination. Plies would be cut in the desired order, be stacked and then put together as a part. Material losses are generally significant at around 50%. As production volumes increase, efficiency of the process can be increased by investing in a cutting machine and separate cutting from the lamination. The operator now oversees the automated cutting process, collects the plies in the right order and sends them to the lamination operator. Cutting tables are also used for identification of the plies by adding stickers or printed labels for traceability and ply identification for the lamination operators.

Nesting

Instead of cutting the plies sequentially, modern cutting tables and nesting software open up the possibility of nesting plies per part by matching the ply geometries. Once all plies are cut, the operator needs to sequence those plies into the desired kit. This process, known as back-to-back part nesting, is then repeated by cutting new part plies and sequencing those into a kit. Typical material usage rate goes up to 80% compared to sequential nests. As production volumes increase, material waste can be reduced even more by enabling the nesting of multiple parts per material roll. Mixed order nesting, requiring the use of fully automated nesting software, will raise the material usage rates to over 90%.

Kitting

In the kitting process the plies belonging to one part are compiled together and put into the desired lamination sequence. In doing so the kitting operator also tracks the ply numbers and documents these for quality compliance. Modern day kitting for back-to-back nesting is done on large kitting tables by hand. This is extended for mixed order nesting into rows of tables, as the plies are sorted per part first and then sequenced per part. This requires significant space (mostly in expensive cleanroom environment) and operator handling. Once the kit is ready it is put into trolley carts, to be moved to the lamination area. Where lamination is now a matter of ply-by-ply positioning and again documenting the flow.

Automated kitting

The kitting process can be fully automated by integrating the nesting, cutting, labelling and kitting processes inside of a single automated and digitalized cell. The automated kitting system is a high-end robot-based system with extensive automated programming to meet the requirements of ever-changing ply geometries, locations and orientations. The cell includes a conveyorized cutting machine, robot with dedicated end-effector and buffer station for plies.

Automated equipment and sensors enable a digital thread of information to be created to optimize entire processes. All steps in the process are joined by a digital backbone communicating back and forth. This is a key element to eliminate waste out of the full production process from warehouse to cutting and kit supply for lamination. Inside of the cell, all information including the location, orientation and identification of the individual plies are fully known to the cutter, robot and buffer station. There is no need for physical labelling of the plies, unless when this would be required for possible downstream manual processes.

"The automated kitting system can optimise both material utilisation and laminating throughput, with just in time delivery of fully ordered kits to the operator."

Changing from manual to automated kitting does not alter the basic steps of the process flow. Within the manufacturing process, the cell is situated in between the freezer with prepreg material rolls and the laminating cells. A digital work order will initiate all the different manufacturing activities in the right order. This starts with a signal to the warehouse for the desired material roll transfer to the cell for acclimatization. Nesting software is activated to create the cutting files or upload earlier run nesting information to the kitting cell. After that, cutting will be initiated. The cutting machine has a conveyor belt with an extension for moving the plies after cutting into the offloading area of the robot. There, the robot will automatically pick-up the plies and place them on a tray in the buffer station.

Automated kitting does change the way in which the kits are formed. Traditionally the kits are ordered per part and sequenced in the right order for lamination by the cutting table operators or by operators added to the cutting table dedicated to kitting. Depending on the nest quality and efficiency this can be laboriously or not at all. Therefore, automation of this process can be very beneficial. The automated kitting system can optimize both material utilization and laminating throughput, with just in time delivery of fully ordered kits to the operator. It can fast-track certain kits, or material streams due to expiry dates or shelf life and laminating cell availability

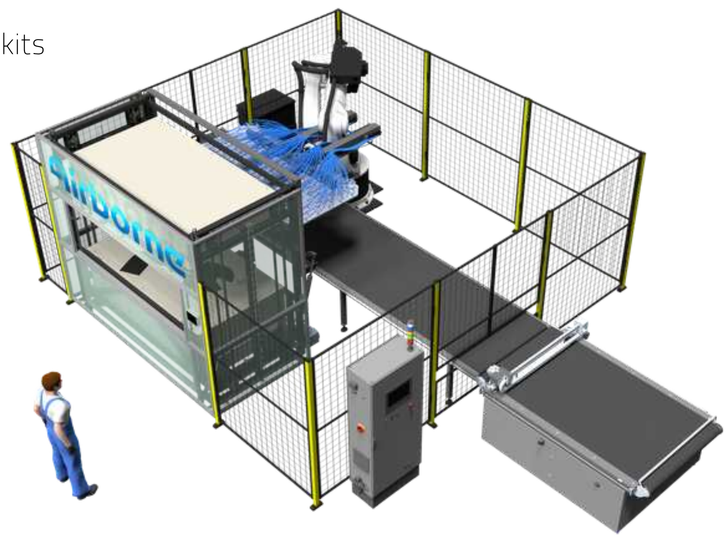

Figure 2.
Automated kitting cell with conveyorized cutter layout

The following sections zoom in on the main actions that take place inside of the cell.

Automated programming for ply pick-up and placement

The automated programming is essential to have full flexibility to cope with many different parts or even projects. Using the information of the ply – including location, orientation, material and geometry – the robot and end-effector are automatically programmed to move to the desired pick-up location and activate the desired grippers that match to the ply geometry and orientation. Handling of the plies is typically done by suction cup grippers for most prepreg materials and other non-porous materials as adhesive films, vinyl, etc. When porous materials are used, flow grippers are required to handle the material.

Ply placement in buffer

The information of the ply includes kit identification and kit ply sequence. This information will tell the buffer station to present the desired tray assigned to the kit and the robot automatically deposits the ply on that tray. The buffer stations can hold any number of trays, which are vertically stacked and move up and down to be presented upon request. The size of the buffer station is based on the ply sizes and the amount of trays on the number of kits to be stored and sequenced. Kits with a very large number of plies are subdivided into sub-kits to fit on a single tray in order to maintain a good sequencing efficiency.

Ply sequencing in buffer

With the plies collected in the buffer, the buffer station will do the sequencing of the plies per kit. As all ply locations are known the sequencing algorithm is straightforward and will determine the most efficient sequencing steps, before commencing the physical sequencing. When any intermediate changes happen, this can automatically be re-run in an instant. The buffer makes use of a sequencing tray and multiple tray locations for temporarily storing plies before putting them back at the desired sequence.

Figure 3. Airborne's Automated Kitting setup

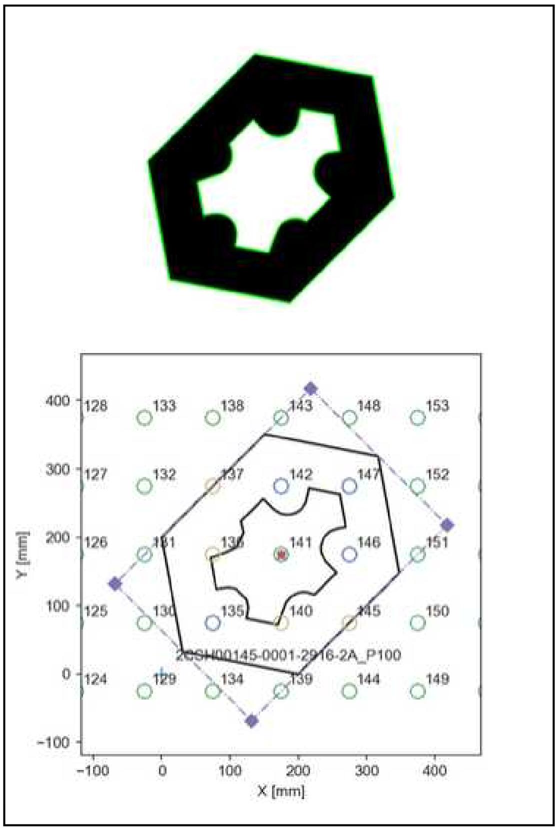

Figure 4. Ply geometry overlay on gripper pattern to identify gripper activation

Benefits of automated kitting

Automated kitting brings a number of important benefits for the composite parts manufacturing process. It not only replaces manual labour by automation and reduces material waste, it also unlocks many other opportunities to maximize ply cutting and kitting production output and limit production costs. Key element is the digital thread and exchange of information that comes with the automated equipment and sensors to provide the data. This enables well-informed decision making to eliminate waste out of the full production process from warehouse to cutting and kit supply for lamination.

Automated kitting brings the following advantages for manufacturers:

- Upscale your production
- Assured product quality
- Radically improved clean room efficiency
- Reduce production and engineering costs
- Shorter time-to-market
- Manufacture more diverse products simultaneously
- Reduce material waste
- Adapt your pace to your product
- Reduce paperwork
- Opens the way for more efficient nesting

Unlocking full potential of automation

Next to the traditional reasons for automating production, automated kitting can unlock significant other opportunities. These include:

- Nesting software integration
- ERP/MES integration
- Process flow optimization and project costing
- Complex operation
- Dynamic nesting
- Cost and throughput optimization
- Digital tracking for shelf life, less waste upstream in warehouse
- Cutting table output
- Employee effectiveness, removing dull and uninspiring work in exchange for challenging and rewarding tasks

The potential of these opportunities can be hard to quantify when starting with automation, but it is where the biggest benefits and gains will be realized over time. The first three items will be discussed below.

Nesting software integration

By integrating the nesting software with the kitting, very complex nesting can be made that would normally be impossible to track by human operators. The next step is moving towards dynamic, real-time nesting in combination with cutting, which can be done on demand. When a ply is damaged downstream or when a defect is present in the ply, the ply can be immediately requested to the cell to be re-cut and delivered. By supplying this ply in time, with minimal incursion on other projects, the lamination can be finished without the risk of more plies or even a part that needs to be discarded.

Flow optimisation

The work flow can be optimised using the enhanced control of the output generated by the cutting machines. Decisions can be made knowledge-based on the lamination need, material cost and cutting availability. In cases where there is a big need of lamination and ply cutting is the bottleneck, it is possible to reduce nesting complexity to get cutting and ply kit availability faster to the lamination operator. In line with the flow optimisation in real-time, this will be done in advance as well for process optimisation and project costing for maximal utilisation of production equipment.

ERP/MES integration

Extension of flow optimization is strongly linked to Enterprise Resource Planning (ERP) and the Manufacturing Execution System (MES), which determines what order or part is to be made when. Key is the digital thread connecting all elements and giving full insight in the process steps. With a better insight of the building blocks of the process flow, choices can be made on:

- Oder/part selection & scheduling
- Material/roll selection (freezer – defreeze actions, and expiry dates)
- Cutting table and kitting cell selection
- Nesting, cutting & kitting method

These choices can be quickly simulated to give the information to make the right informed decisions. Also, last minute changes can be simulated before being executed, preventing mistakes or inefficiencies.

Major gains can be realized on:

- Maximization of production yield, minimization of production cost through informed (data driven) decision making
- Improved material utilization (Buy to Fly ratio), better remnant management
- Roll change-over minimization (transport waste streams, freezer in/out)
- Upstream loss minimization
  - Shelf life maximization, in time material roll selection
- Downstream material loss minimization
  - Minimal loss of ply or out-of-sequence
  - In time solution to downstream issue by dynamic nesting
- Reduced errors, improved quality
- Reduced manual labour, elimination of paper trail

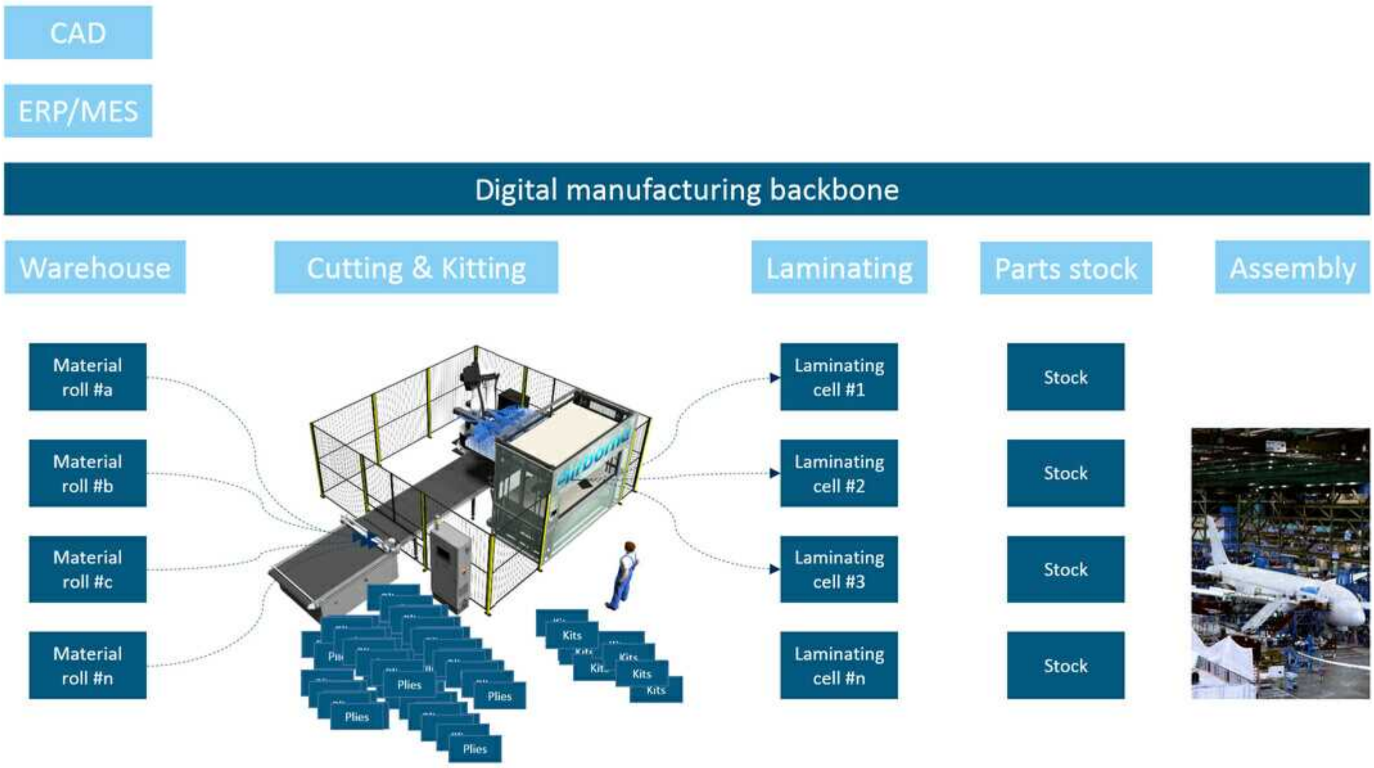

Figure 5. Ply process flow

Preforming as the next step

The flexibility of the robot in the automated kitting cell and having all plies available makes it possible to extend the functionality of the cell to include preforming as well. The same robot and end-effector that are used in the cell can be used to create a preform laminate. This makes use of the ply buffer for maximum material utilization on the cutting table. But rather than only buffering and sequencing the plies into kits, the robot can then automatically place the plies to build the preform.

On a lamination table the plies from the kit can be taken out of the buffer by the same robot and end-effector, creating a preform laminate. For this functionality a foil-removal station is needed and depending on the accuracy need, a vision system is to be added as well, to re-calibrate ply position compared to robot tool centre point, for the accurate positioning of the plies. Depending on the type of materials tacking by heat can be done to fixate the plies in place.

The biggest advantage of the combination of preforming with the buffer is that plies can still be cut with minimal scrap rate through complex nesting and buffering of the plies.

Conclusions

With automated kitting not only manual labour is replaced by automation and material scrap rate is reduced, it also unlocks many other opportunities to maximize ply cutting and kitting production output and limit overall production cost, including lamination. Key element is the digital thread and exchange of information that enables good informed decision making to eliminate waste out of the full production process from warehouse to cutting and kit supply for lamination. This digital thread is only possible with the automated equipment and sensors to provide the data that create the needed information.

The automated kitting system is a high-end robot-based system, with extensive automated programming to meet the requirements of ever-changing ply geometries, locations and orientations. High throughput requirements are met with smart and adaptive algorithms for sorting and sequencing.

About Airborne

At Airborne we believe that innovation in manufacturing through automation, digitalisation and advanced analytics is the catalyst for the significant increase in productivity companies need to stay competitive. We understand the complexity and cost involved in producing composite components for demanding applications in highly regulated industries. Our legacy in advanced composites manufacturing makes us experts in developing and delivering automated solutions that enable our customers to achieve high production rates and radically low conversion costs.

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