

Designing for the Challenges of Automated Aerospace Manufacturing

By *Steven J. Peck, VISTAGY, Inc.*

With an increasing global presence in the commercial aerospace industry, OEMs are faced with an unprecedented level of pressure to be first to market with their state-of-the-art aircraft. Given the volatility in fuel prices coupled with the need to decrease operating and total lifecycle costs, aircraft manufacturers are rapidly adopting the use of advanced composite materials for primary structural components. These components include fuselage skins and substructure, wing skins, ribs, spars, stringers and shear clips along with complete empennage assemblies and pressure bulkheads.

As if the adoption of new advanced materials and global supply chain challenges were not enough, new automated manufacturing processes are being implemented to help reduce touch labor, improve product quality and consistency, and meet demanding throughput requirements. Technologies such as automated fiber placement, tape laying and robotic material deposition are being used on an increasing variety of components.

While material layup is a significant part of the process, it is not where the automation and associated challenges end. In-process and post-cure inspection using new state of the art automated NDI equipment is becoming a necessity to ensure engineering requirements are being met. Automated trim and drill operations using the latest NC driven routing and water jet equipment followed by automated fastener installation and even laser guided assembly are key parts of the process.

While CAD and PLM systems are the primary components of the engineering IT environment, these systems lack the specialization required for effective management of the complex airframe data, the foundation for enabling automated downstream processes.

VISTAGY's AeroSuite™ fills that void. The AeroSuite is comprised of FiberSIM® composites engineering software, SyncroFIT® for designing and manufacturing airframe assemblies and the Quality Planning Environment™ (QPE) to streamline the First Article Inspection process.

FiberSIM is a software suite that addresses the entire composites engineering process, from conception, laminate definition and ply creation through simulation, performance optimization, flat pattern generation, documentation and manufacturing. SyncroFIT is a group of software products for easily authoring and managing the assembly interfaces and the hundreds of thousands of fasteners that are typical in an airframe. With the QPE, engineers are able to generate quality plans and inspection data based on design and manufacturing characteristics created by FiberSIM and SyncroFIT and saved in the CAD model.

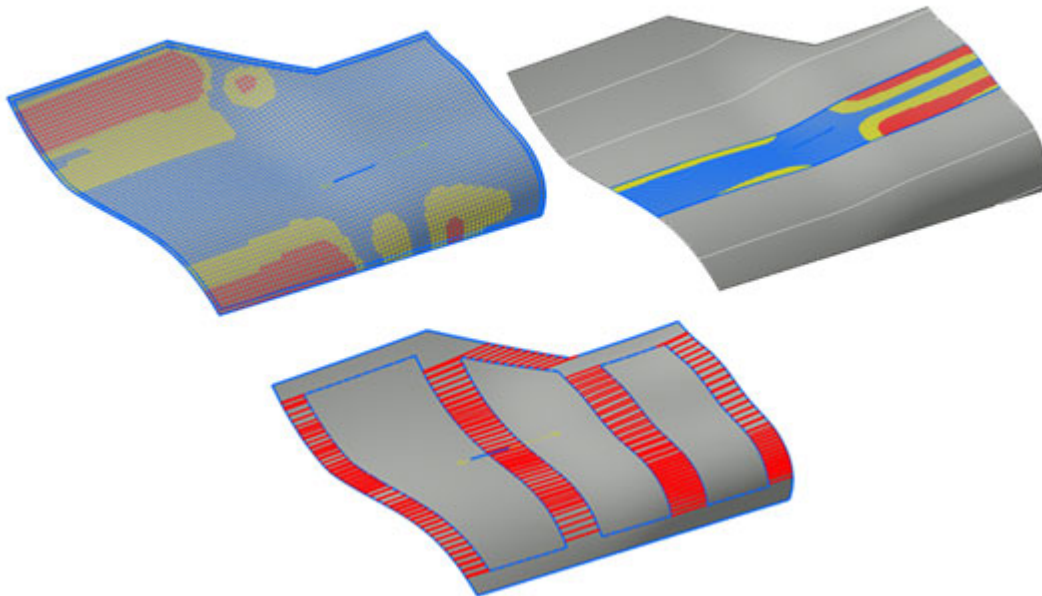
Material and Process Trade Offs

The use of composites introduces a high level of uncertainty and variability contrary to the well understood structural and manufacturing behavior of other materials, such as aluminum. Composites design requires a careful balance between the geometric requirements, the material form, and the manufacturing process.

For example, a monolithic skin panel, a t-shaped stringer and a sandwich panel fairing must be treated differently. Likewise, different material forms, such as woven fabric, unidirectional tape, or a non-crimp fabric, each present unique design and manufacturing implications.

Finally, the manufacturing process, such as hand layup, automated tape laying, automated fiber placement, resin transfer molding (RTM), or forming, needs to be taken into consideration. The specific combination of these variables influences the design approach and, ultimately, the cost and quality of the finished product. Needless to say, balancing all of these elements constitutes a significant challenge. But those who are successful will truly reap the benefits of composites, which ironically can provide the ability to use less to achieve the required performance.

A solution that incorporates simulation capabilities tailored for the specific material and manufacturing process will provide early visibility into the challenges that will occur during the build process.



Illustrated above are simulation results from FiberSIM® based on various materials and manufacturing processes. On the top left, the simulation result for manufacturing producibility of a full coverage 0 degree layer of woven carbon prepreg is shown. The image on the top right illustrates the producibility challenges that will be encountered when this 0 degree strip of unidirectional carbon prepreg is layed up by hand. The image on the bottom shows areas in which an automated fiber placement machine will be unable to deposit material in the narrow strip areas of the picture frame ply due to the minimum course capability of the machine.

Boosting Production

In an effort to increase throughput, cut production costs and improve quality and repeatability, automated deposition processes are quickly becoming the manufacturing method of choice for composite aerospace components. Unlike the NC machining of metals or the injection molding of plastics, manufacturers of automated processing equipment for composites are installing relatively few systems per year as opposed to the thousands per year being installed for the automated manufacture of other materials.

Various analysts estimate that within the next decade, upwards of 75 percent of composite parts will be manufactured with an automated fiber placement, tape laying or robotic deposition process instead of hand layup. These processes may be a single stage in which the material is deposited on an as-flown shaped mandrel or may involve multiple stages, such as the high speed tape laying of a blank followed by a subsequent forming process.

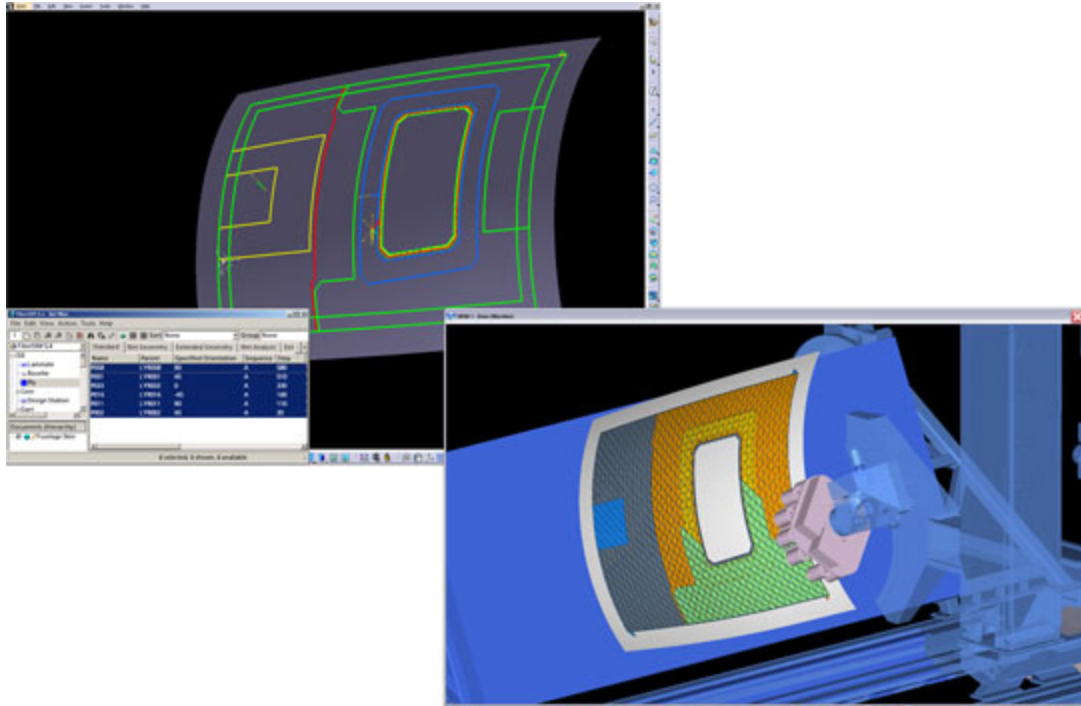
Regardless of the method, it is clear that we are still in the very early stages of a major transformation in the way that composites are manufactured. Cycle times will decrease significantly, part quality will improve, and design-for-manufacturing techniques will evolve to the point where surprises during machine run time will be rare.

To keep pace with this evolution toward automated composite manufacturing, the key capabilities of composite design software must likewise evolve. Just as hand layup requires the ability to manage the complex splicing and staggering requirements imposed with fixed width conventional materials, producibility simulations that mimic hand smoothing techniques and the generation of the appropriate shaped flat patterns, automated processes will require their own set of innovative design for manufacturing capabilities.

For example, a machine limitation, such as a minimum course length, induces a design constraint which can affect ply boundaries, potentially cause interference with mating part footprints and influence part weight. Identification of such constraints must therefore be highlighted and addressed during the design process rather than being left for manufacturing to figure out. Ignoring these critical manufacturing requirements in design—using the traditional throw-it-over-the-wall approach—will inevitably result in costly design iterations, over-design, and situations where as-built does not conform to as-designed, a significant certification risk.

By working closely with the manufacturers of automated deposition systems and CAM software for composites, a set of requirements has emerged that enhances the engineer's environment so that he or she can fully define and optimize the design of composite components for automated manufacturing.

Minimum course length, staggered ply origins, minimum strip width and minimum cut angles are some of the manufacturing requirements that are part of FiberSIM software. And with the composites manufacturing industry leaning toward machine-independent composite part definition, additional functions are likely to become part of the design environment, while a separate category of machine-specific, run-time parameters will still remain part of the offline and machine programming CAM software environment.



The top image shows the ply layout design for a composite fuselage panel generated by VISTAGY's FiberSIM® software during a CATIA V5 CAD modeling session. The design data is rapidly and seamlessly transferred to CGTech's VERICUT Composite Programming & Simulation software (bottom) to generate the manufacturing data for the automated fiber placement machine and verify the process.

Composites Precipitate Assembly Challenges

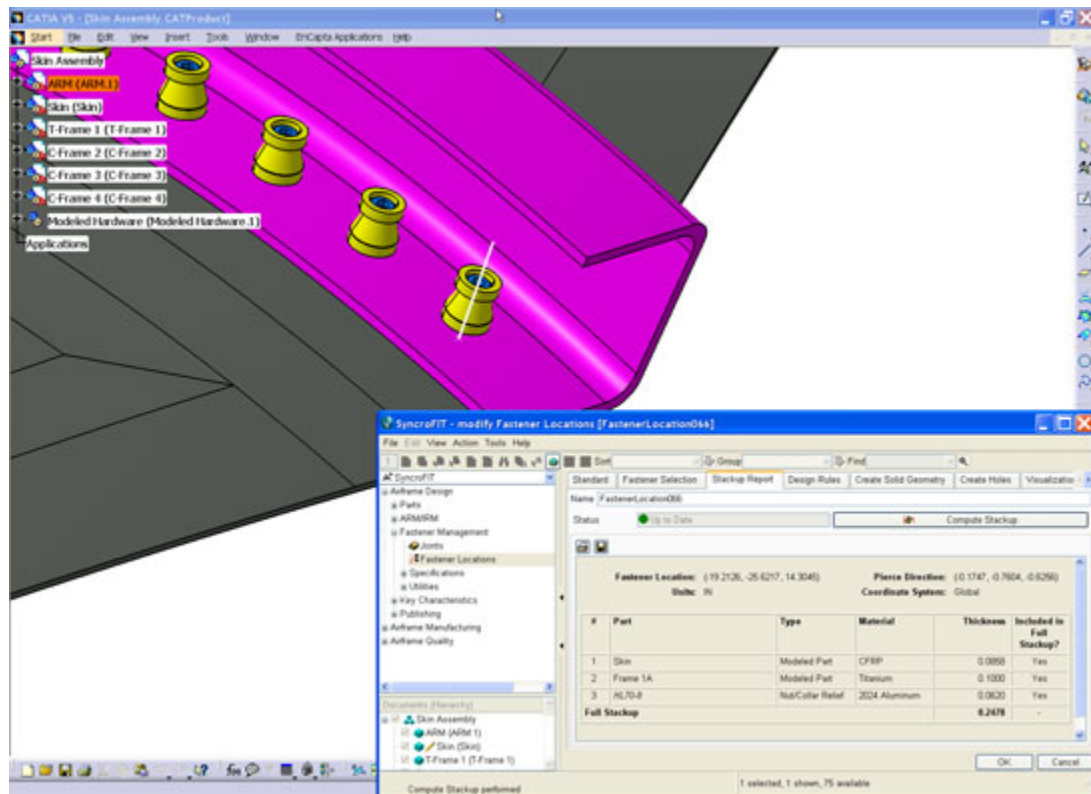
With the increased usage of composites and the ability to tailor thicknesses to support loading conditions, the specification of fasteners is becoming simply unmanageable. A number of issues, such as material compatibility, hole preparation methods, structural requirements, design rule considerations, part specification changes, and cost and lead time implications of the specialized fasteners, are raising the concerns across the industry. It is also generally acknowledged that on average; nearly 15 percent of detail design activity is associated with managing assembly interfaces, fasteners and holes. Likewise, upon review of engineering change orders and non-conformances on the shop floor, industry figures show that more than 50 percent of these problems are associated with assembly definitions.

When you couple these definition issues with the automated drilling and fastener methods being used to improve quality and cut cycle times, you have significant challenges. You need to precisely control feed rates and drill speed through stacks to avoid potential damage to the composite material from drill break through or chip extraction. NC programmers require detailed stack thickness and material information to properly throttle drilling operations. Typically, significant time is required to obtain this information on each fastener location.

As programs progress through the development process and subsequently into sustaining engineering efforts, it will be critical to have a solution that enables the reduction of cycle times to implement changes and eliminate errors that inevitably will occur.

With a clear understanding of these challenges, VISTAGY realizes the importance of having

a solution in place to manage the complexities associated with modern airframes containing numerous joints and fasteners. That's where SyncroFIT comes in.



The automated detection of an edge distance violation is one of the many design rule checks incorporated into SyncroFIT®. Other checks, such as the verification of fastener pitch, angularity, countersink depths, and length-to-diameter ratio, dramatically reduce common errors that result in costly engineering changes and rework on the shop floor.

With the unique capability to capture assembly joint definitions and manage the interactions between both modeled and non-modeled components, SyncroFIT is enabling firms to reduce engineering development times, effectively manage the change process and cut the number of engineering change orders that are typical in an aircraft program. It automates tedious tasks, such as computing grip lengths, loading and positioning hardware or temporarily installing a clearance solid to detect potential collisions upon assembly. Managing the airframe as a series of joint definitions allows the engineer and downstream consumers to navigate the assembly in a logical way. It provides the capability to fully define the part stack up and feed NC programming systems the information required to drive automated drilling and fastening systems.

For more information please visit www.vistagy.com.

Steven J. Peck is the director of product and market strategy for Aerostructures at VISTAGY, Inc. Images provided by VISTAGY, Inc.