Composite Aircraft Need the Right Engineering Tools

Software smoothes the flow from analysis, to design, to manufacturing.

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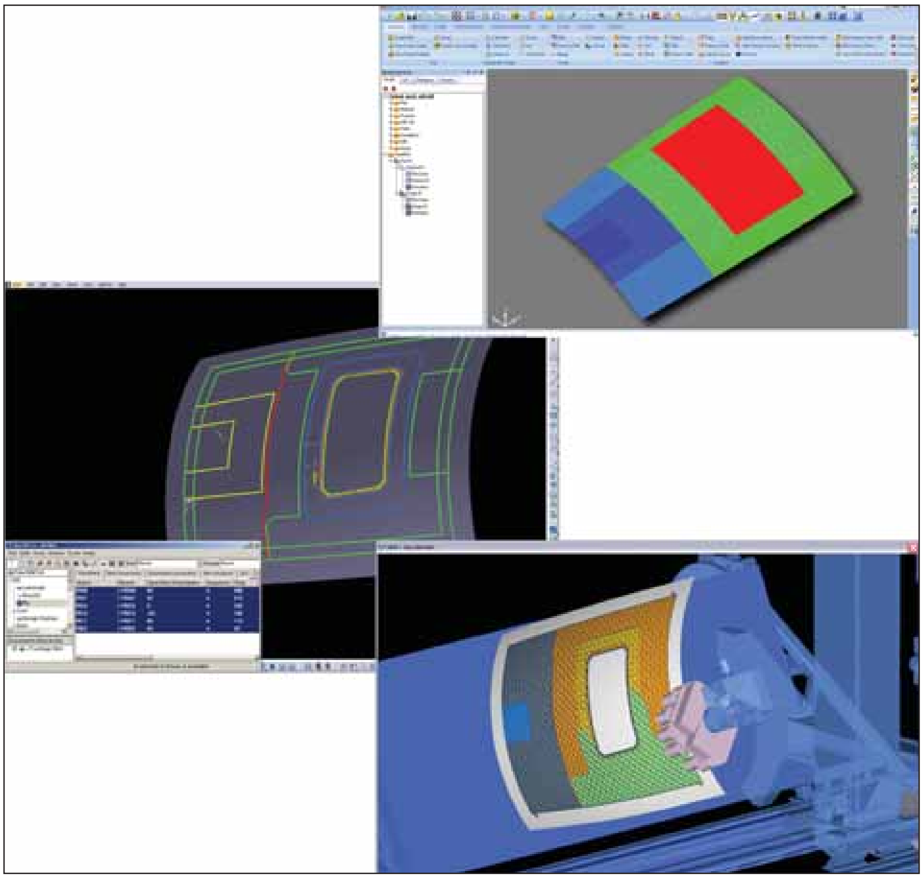
As the aerospace industry transitions to making large assemblies entirely out of composites, there is an obvious need for a more comprehensive engineering approach. These complex composite assemblies include many parts and joints and go through multiple laminating and assembly states, requiring new specialized design and planning tools.

Although the high-performance composites industry is already one of the most dynamic, the level of engineering and manufacturing complexity within that sphere continues to increase dramatically. Interdependencies between design, performance, and manufacturing have expanded and are complicating the design-to-manufacturing process flow.



Ply layup data for a composite fuselage panel is shared seamlessly during a CATIA V5 design session between FiberSIM software (middle), SimXpert FEA (upper), and the Vericut Composite Programming & Simulation session (lower).

There must be a three-fold approach to addressing these issues:

- Engineers must be able to clearly and rapidly assess the impact of design changes and cascade them consistently through the engineering process and supply chain;
- They must not only reduce risks, but also enhance optimization with reliable tools that allow faster design iterations and eliminate non-value-added activities;
- Engineers must be able to fully leverage the latest technologies for composite parts manufacturing.

As the aerospace composites industry expands into a global enterprise, competition grows fiercer. Solving these challenges is critical to maintaining competitiveness. Aerospace composite part and assembly software has been designed to solve these issues and enable firms to compete. Vistagy's software suite is an example.

Conventional CAD and PLM systems alone do not address the unique complexity of composite structures, whether this complexity comes from the product or the process. Trying to force these systems to address the creation and management of the large and complex amount of data pertaining to composites engineering has proven extremely inefficient.

Instead, by constructing a specialized environment atop CAD and PLM systems, risks and costs can be reduced by creating and analyzing the design more efficiently and enabling a better understanding of the impact of design decisions across disciplines.

While 3-D CAD essentially helps create and manage geometry, the specialized application adds the numerous and complex composite characteristics and manages the interdependencies between these characteristics and the geometry.

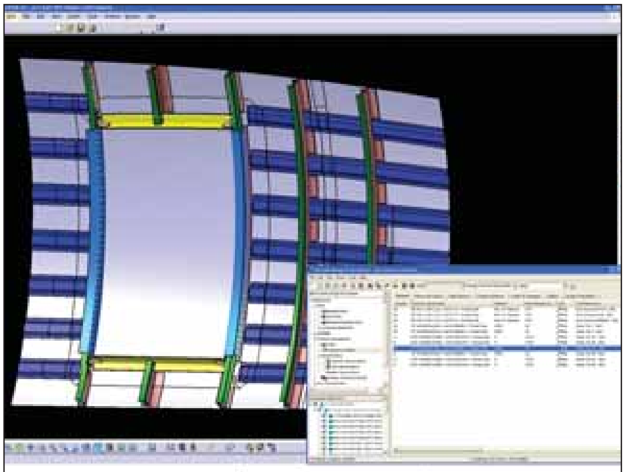
As an example, here are just half a dozen of the hundreds of parameters used by our software to enrich the CAD geometry with all the details specific to a composite assembly:

- Zones,
- Joints,
- Plies,
- Fastener specs,
- Drop-offs,
- Stagger profiles.

Hence, the specialized environment uses the composite engineering vocabulary, helps capture design intent and trace requirements, associates characteristics to geometric features, manages relationships, and enables composite engineers to work the way they think.

One particular aspect of the composites engineering process is the interaction between design and analysis. Traditionally, analysts and designers have worked somewhat separately, focusing on their own domains. Analysts think in terms of material properties, load cases, stress, and strains. Designers work with ply coverage, nonstructural details, and design rules.

So making any change was slow, difficult, and expensive. It was a serial process that did not help achieve the goals of reducing product cycles, diminishing the amount of rework, and staying within budget.



Fuselage panel with 6 x 8 bays	Composite Skin	Assembly, Fasteners and Holes
Relationships	1,360	4,120
Characteristics	11,320	48,300
Detail Geometry	585	710
Reference Geometry	75	84

The table illustrates how engineering complexity can be quantified. The small fuselage panel shown contains thousands of characteristics and links to geometry, most of which are not captured or remain unstructured, and are not managed and validated without the use of a specialized environment.

In order to understand what may constitute a common framework for the design and analysis of composites, one must "tease apart" what tools and processes remain related to each domain. One must also identify what constitutes an overlapping domain and what key touch points may provide the basis for a common framework.

In composites, the first key touch points are "regions" or "zones" built from the loft surface and system lines, typically provided by the systems group, and from the material specifications and sizing data from the analysis group. These key elements are unlikely to change too frequently or drastically, and represent information that can be usefully shared.

While the designer and the analyst typically use different platforms, collaboration between them is greatly enhanced when both are working with shared geometry through native CAD interfaces that expose the geometry and allow an automated response to design changes. The analyst can directly use system lines and zone partitioning to create and control a mesh of shell or membrane elements for a composite skin, or lines of beams or bars for stiffening elements. And he can easily communicate zone and laminate requirements back to the designer.

The assignment of physical properties is another touch point for collaboration. The ability to seamlessly share detailed layup specifications enhances the analyst's efficiency and productivity and significantly improves the accuracy and fidelity of the part design validation.

Therefore, it is possible to find higher level information that enables faster and easier iterations abstracted from the geometry, which leads to a truly parallel process, as exemplified by the integration between Vistagy's FiberSIM composites software and MSC.Software's SimXpert for analysis. Indeed, MSC.Software, which has expertise in enterprise simulation solutions, and Vistagy have established a strategic partnership in order to enable even greater collaboration between composites design and analysis.

In the high-performance composites industry, automated manufacturing processes are becoming prevalent in all new commercial aircraft programs. And while the notion of designing for the manufacturing process is not new, its application to composites manufacturing is changing rapidly.

Until recently, specialized composite design software was largely used for components manufactured using the hand layup process, so all that was needed was a ply-based design methodology, a reliable draping and flattening simulation, and the ability to create the manufacturing output and drawings.

With manufacturing automation, the key capabilities of the composite design software are changing. The content of the detailed engineering model, the handoff between engineering and manufacturing must be redefined. Some aspects of the manufacturing process may impact part or assembly producibility and must be integrated in the design environment. Some other process and machine-specific details can be determined separately and independently by manufacturing software.

For example, a machine limitation, such as minimum course deposition, induces a design constraint which can impact ply contour and stagger layout, or interfere with a mating part footprint and modify part weight. Such constraints must therefore be made an integral part of the design parameters and cannot be left to manufacturing to deal with due to the risk of unforeseen and costly iterations or uncontrolled overdesign.

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

Minimum course length, staggered ply origin, minimum strip width, and minimum cut angle are some of these manufacturing requirements that are made part of our design software.

And with the composites manufacturing industry leaning toward machine-independent composite part definition, additional functions will likely become part of the design environment, while machine-specific parameters will remain part of the offline and machine programming software.

It is interesting to note that "engineering complexity" can be attributed a somewhat specific meaning in design and can be quantified to some extent.

Indeed, we attempted to quantify the level of complexity of large aero structure panels made of composites. For example, for a fuselage panel typical of a commercial aircraft counting 6 by 8 bays separated by stringers and frames, we found that beyond geometric data, there are 11,320 nongeometric characteristics for the composite skin and 48,300 nongeometric characteristics for the assembly, fasteners, and holes. These are not part of the 3-D CAD model or in PLM and are not structured. In addition, the relationships are typically not captured in 3-D CAD or PLM, nor are the specialized design intent. In all, over 90% of the data is not captured and managed effectively by the CAD and PLM systems.

With our software for composites aircraft development, 100% of the product definition is captured and managed effectively, 85% of the geometry is automatically created, and 100% of the critical characteristics are automatically validated.

Design changes are ubiquitous and inherent to the engineering process. Consider the cascading impact of a skin thickness change and a substructure shift in the fuselage panel.

In design, such a change may affect laminate stack-up, ply drop-off locations and shapes, the skin inner tool surface, the substructure mating surfaces, fastener specifications, and, ultimately, weight and balance. In manufacturing, the change may affect the fiber placement programs, the composite flat patterns, the automated drilling and fastening program, the laser projection files and the process plans. In tooling manufacturing, the skin IML tooling and the substructure tooling may change. Finally, the First Article Inspection plan and other QA documents might change as well.

The key issue is that it takes only a couple of inconsistencies or missteps in the change process to derail a whole development program with extremely detrimental consequences. Getting the change process right requires a combination of expertise in design, analysis, manufacturing, and process planning, all within the context of a composite material.

The aerospace composites industry is changing rapidly under pressure from globalization, the emerging markets, and the current economic downturn. In particular, manufacturing automation is becoming pervasive in aerospace composites, with the production of ever larger and more complex composite aero structures.

As a result, aerospace firms need to take a more comprehensive approach to the design and manufacture of composite parts and assemblies. Efficient composites engineering tools extend beyond CAD, PDM, and CAE to encompass a composites engineering specific view of the ontology, process, and product details. Ultimately, the foremost challenge facing designers and manufacturing engineers is the need to recognize and rapidly accommodate the inevitable changes that occur throughout the development process without errors and costly delays.

As the role of composites continues to evolve, software developers, including Vistagy and its partners, are committed to delivering solutions that will empower aerospace firms to continuously optimize the design-to-manufacture process. ✈

Manufacturing ENGINEERING
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