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Enhancing Collaboration Between Aerospace Designers and Analysts is Key to Developing Robust Composite Parts

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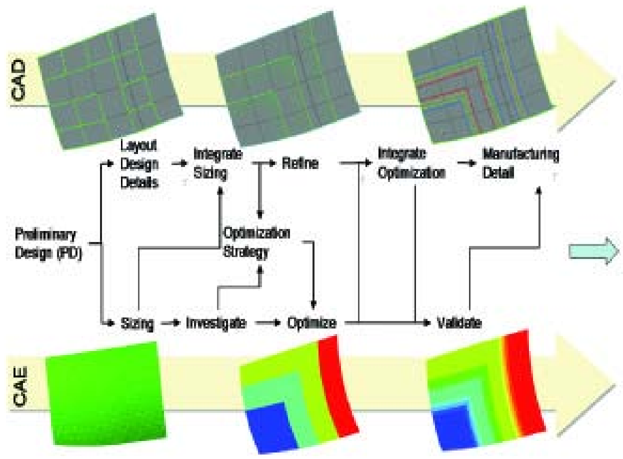
With the coming of age of large and highly complex aerospace composite structures, designers and analysts are faced with extraordinary challenges. Due to a variety of factors, including a highly competitive global environment, the necessity to work with a worldwide supply chain and uncertain energy costs, there is substantial pressure to design, analyze and optimize parts and assemblies that enhance performance and quality, cut weight and reduce time and cost.

Traditionally, analysts and designers have worked somewhat separately, focusing on their own domains rather than seeing the project from a more comprehensive viewpoint. This is understandable because analysts would do their work and hand it off to the designer. However, making changes after the first iteration was slow, difficult and expensive. It was largely a serial process that did not help achieve the goals of reducing product cycles, diminishing the amount of rework and staying within budget.

By proposing an abstracted data representation common to both composites design and analysis, VISTAGY works directly with a variety of CAE solution providers, such as MSC.Software, to take the next step in meeting the challenge of improving the integration of these two disciplines at every step in the engineering process. This integration enables a concurrent process; from preliminary sizing with grid-based and zone-based design methodologies to optimization and validation of the as-manufactured representation with a detailed ply-based definition of the parts. Further, details pertinent to various manufacturing processes are taken into account, including hand layup, resin infusion, forming and automated deposition.



VISTAGY's FiberSIM composite design software works directly with a variety of CAE packages, including MSC. Software's SimXpert FEA package. The top image shows the FiberSIM® model of a fuselage panel and the bottom image shows the corresponding SimXpert model. FEA mesh information created in SimXpert can be communicated to FiberSIM with the click of a button, creating a common data representation and design tool for composite layup. This allows products to be designed, validated, and optimized without having to translate volumes of data between different software tools, resulting in faster design iterations and better product optimization and validation.

Designing composite parts is complicated, with many design and manufacturing decisions being "baked" into the part when it is laminated and cured. Because there are many more unknowns and interdependencies in manufacturing composite parts than metallic parts, the quality and performance of the final part may not meet expectations.

It is difficult to efficiently iterate over the design and propagate even small design changes during the composite engineering process due to the high interdependencies between geometry, design and process. As a consequence, changes are often delayed and eventually result in more rework than anticipated.

In order to make the overall process more manageable, companies have typically resorted to using a serial process for design, analysis and manufacturing engineering. But in addition to lengthening the development cycle, a serial process effectively eliminates the possibility of making any complex adjustments, which negates the design benefits specific to composites, such as material directionality. It has also become a standard practice to increase design allowances and safety factors, effectively treating composites as black aluminium and forgoing the benefits offered by designing the material itself.

Eventually, these processes bring a disappointing outcome because the expected benefits in weight savings, increased stiffness or strength are not realized. As a result, the use of composites end up being justified based on other benefits, such as its resistance to corrosion, durability and low maintenance requirements.

Integrating the major disciplines

While structural composites have been used in aerospace for well over three decades, volume production of large and complex assemblies is a recent development. The ability to just make the part, with its associated challenges, has been replaced with the demand for ever better performance and quality. Concerns for manufacturing issues ¬— including drapability, fiber deviations, residual stresses and strains and voids forming — have been replaced with a demand for structural and design optimization.

So now the challenge is to devise process improvements and new tools that integrate the two major disciplines of composite part engineering, Design (CAD) and Analysis (CAE).

There are many obstacles to developing effective collaboration between designers and analysts due to different domain knowledge, special techniques and language. Analysts think in terms of material properties, load cases, stress and strains. Designers work with ply coverage, non-structural details, and design rules.

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, allowing each discipline to contribute in an unobtrusive way.

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 logical information that can be used as the basis for shared concepts. Instead of using unreliable parametrics or fragile links to geometry, 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.

Eliminating the need for translation

In the new development process, the part is designed, refined and verified based on initial specification of the laminate thickness for each zone. Then iterations take place that entail exchange of data between CAD and CAE.

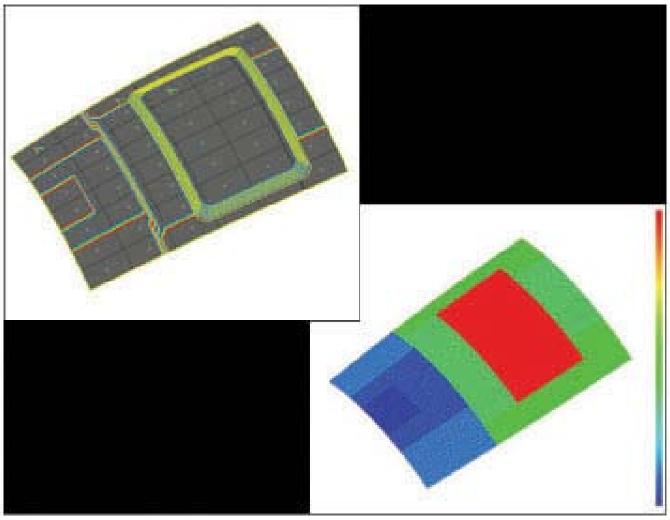
Preliminary design consists of defining the laminates and zones. The analyst typically provides an estimate as a starting point from which both CAD and CAE can begin. The designer and the analyst collaborate on an initial optimization. At this point, the designer provides the analyst with a definition based on the initial geometry, laminate specifications and zone information so that it can be mapped onto the initial finite element mesh of the part. And the concurrent process can now begin.

The designer moves on to integrating non-structural pad-ups, laying out transitions and doing detailed design of drop off areas, preparing fasteners and inserts, and designing added parts, including stringers and shear ties.

The analyst begins the actual sizing of the part by meshing the geometry with elements. He or she applies physical properties (a critical consideration with composites), loads and boundary conditions. Optimization may also occur in order to improve the design.

Geometry access with no translation or re-creation is a key element of collaboration. The collaboration of the designer and analyst 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, such as stringers or frames in a fuselage section. Native geometry access also exposes named attributes from CAD, which can be used for process automation.

The assignment of physical properties is another touch point for collaboration. The ability to seamlessly share detailed layup specifications is a major help to the analyst’s efficiency and productivity and has a significant impact on accuracy and fidelity. This way a number of analysis types will be performed with better accuracy, from simple linear static, dynamic, to non-linear buckling, progressive failure and fracture.



The image at the top shows VISTAGY's FiberSIM® model of a fuselage panel and the corresponding MSC. Software SimXpert model at bottom. FEA mesh information created in SimXpert can be communicated to FiberSIM with the click of a button, creating a common data representation and design tool for composite layup. This allows products to be designed, validated, and optimized without having to translate volumes of data between different software tools, resulting in faster design iterations and better product optimization and validation.

Seamless exchange of optimized layup data

Optimization should be multi disciplinary in order to account for all the performance requirements of the composite structure. Typically, there is more to a layup than just achieving lower weight. Multiple manufacturing constraints and other design rules and requirements must be met.

This is where sharing composite concepts across disciplines enable the seamless exchange of optimized layup data. This is also where a dependence on minimal system geometry allows minimization of complicated dependency failures while the logical relationship between CAD and CAE removes the need for frequent, complicated refreshes. All changes flow from a constrained set of sources and enable easy automated re-mesh in analysis and automated translation and update of transitions in design. New specifications are automatically assigned to zones. Increasing ply counts or altering zone thicknesses result in automatic updates with the addition of new ply drop-offs. Transition definitions, material choices and detailed geometry all remain valid.

With the detailed design almost finalized, shared native geometry enables a key collaboration: design validation. The analyst is getting access to the mesh control curves that enable him or her to include the effects of ply drop offs for precision meshing. Meanwhile, the correct layup is mapped onto each finite element for detailed analysis.

Applying thermal loads that simulate the curing cycle will give information on possible laminate spring back “potato chip” effects. That may impact the final part shape and require tooling correction to be integrated into the CAD model for manufacturability of the part design. The feedback loop is now fully closed between design, analysis and manufacturing.

Reducing the risks of using new materials

Multiple benefits are realized by bringing together the design and analysis of composite structures: First, modifications can be made earlier in the development process as well as to accommodate changes late in the process to enhance optimization; secondly, accurate analysis can be performed on the as-designed part definition using the true material properties.

Such concurrent engineering results in shorter lead times and a parallel workflow with increased opportunity for more and faster iterations. Each discipline can continue working while synchronizing on significant changes. The risks due to the complexity associated with the use of new materials and novel technologies are reduced as are program costs and potential liabilities. Finally, efficient communication is achieved between Design and Analysis for the benefit of the overall product development process.

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