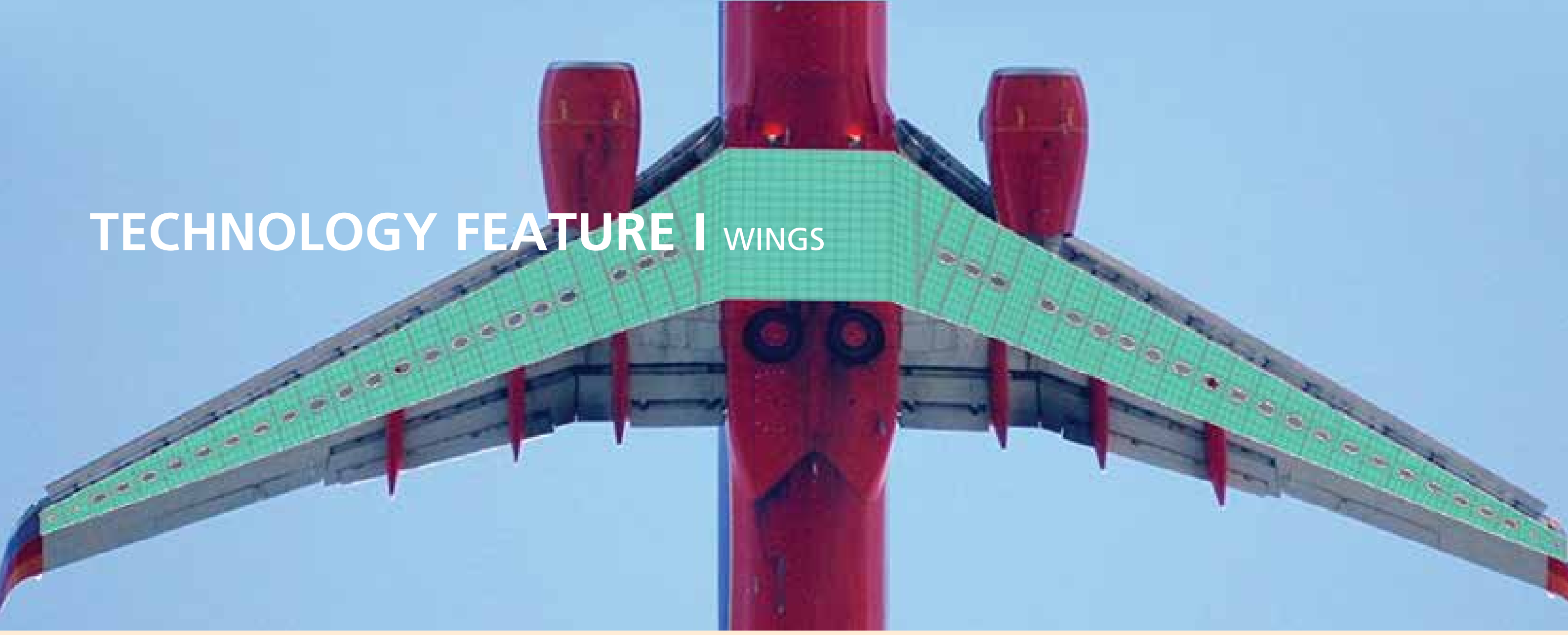


This finite element model highlights the load carrying wing box structure (the section of the fuselage between the wing roots) for a commercial aircraft

THINKING OUTSIDE THE WING BOX

According to Collier Research Corporation's president, **Craig Collier**, robust optimisation of airframe structures is essential from preliminary design through final analysis.

Engineers tasked with designing more efficient airframe wing boxes are confronted with a host of challenges. As we explore fuel efficient designs, weight reduction is a primary concern. We must cope with optimising all aspects of the entire structure whilst managing extensive engineering data and resolving a number of manufacturability issues - especially where composites and hybrid laminates are concerned. Even with sophisticated CAD and finite element analysis (FEA) software, it's my experience that barriers to innovation still exist throughout the industry.

This is due to significant limitations built into many of today's standard industry processes. For one, unnecessary weight is consistently added on, since engineers have only a partial view of options and are forced to overdesign to be 'safe' within the fast-paced design cycle schedule. Optimisation tools are also not as integrated with a customer's process as they should be, leaving this significant task for engineers to do manually.

The very nature of design is iterative. This necessitates the swapping of critical data back and forth, often from multiple engineering groups. Given the growing adoption of complex composites in wing box and other airframe structures, analysis is now a highly complicated exercise involving layups in some areas that are nearly a hundred plies thick.

Global optimisation

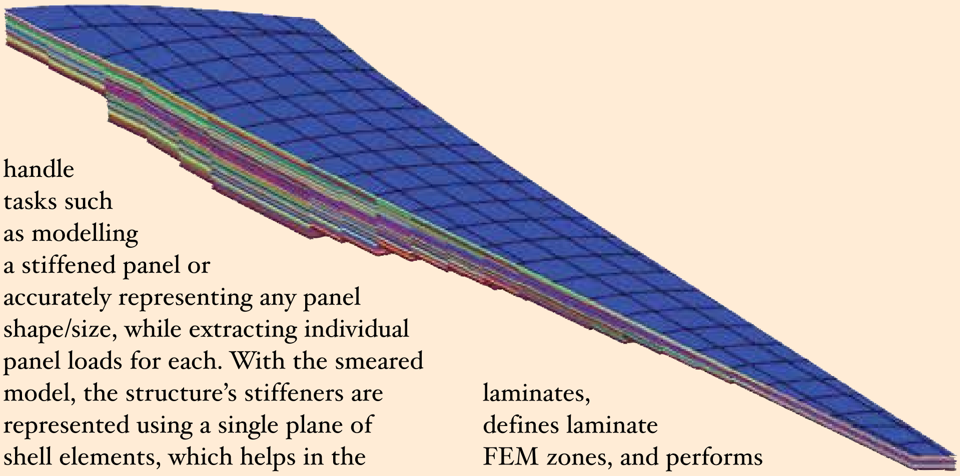
Some specialised CAD-based composite software packages offer partial solutions to these problems. These tools can be used with FEA on the analysis side to provide a degree of efficiency and process integrity. They are able to simulate and graphically represent details - such as ply drape and rosette angle changes across a part's curved surface - and can pass cutting pattern data directly to fabrication equipment on the factory floor. But while they're useful on the manufacturing side, none of these tools can explore composite structures in an integrated design and analysis way to provide the extensive trade-off studies and weight reduction calculations necessary to win today's competitive battles for the best ideas. What are needed are more global optimisation procedures that provide a faster design cycle.

Addressing many of the current limitations in airframe design, HyperSizer, a software tool I helped develop at NASA and at Collier Research Corporation, offers design, analysis, and optimisation solutions for both composites and metals. Used on NASA's current Space Launch System (SLS) heavy launch vehicle, and in higher volume by a variety of tier 1 and tier 2 aircraft manufacturers, the software can be deployed from one end of the design process to the other. It serves as an independent and neutral hub for industry-accepted CAD, FEA, and composite software, automating data exchanges without loss of information or extra engineering effort. With our HyperFEA, it automatically iterates in a continuous loop with FEA solvers, searching for lightweight structurally sound options and visualising structural details to the ply level. It also complements the various composite codes, while doing things like defining laminate zones, determining sequencing and interleaving, and minimising ply drops/adds - all of which improve manufacturability.

The standard industry practice is to use two types of finite element models (FEMs) in the design of metallic and composite wing boxes and their associated stringer/stiffener, spar, rib, and skin components. The process generally begins with a smeared model in the preliminary design phase, during which all sizing variables are optimised concurrently. Having decided on stiffener location - and 'frozen' tooling specifications - analysts may then transition their 2D smeared models to 3D discrete stiffener models (DSM). In this stage, engineering teams typically perform detailed structural analyses for all key panel segment components. As the design progresses, other cross-sectional dimensions are locked down, too. Laminate specifications are finalised, and margins of safety calculated, with failure analyses documented for all parts required for flight certification. But these accepted practices can - and should - be enhanced further.

Using our company's software during preliminary design, engineering teams can explore a more wide-open conceptual space and perform trade studies involving thousands of alternatives. This enables the calculation of robust and minimal weights for each option, an approach that leads to the greatest overall weight savings and to multiple alternatives for considerations such as cost. HyperSizer also determines initial sizing based on fibre orientation and thickness and can handle tasks such as modelling a stiffened panel or accurately representing any panel shape/size, while extracting individual panel loads for each. With the smeared model, the structure's stiffeners are represented using a single plane of shell elements, which helps in the optimisation of stiffener spacing. This is a significant time-saver: by optimising placement early in design, the team can effectively eliminate the need to come back later and remake the model.

HyperSizer optimises wing skin composite laminates to be more manufacturable by finding the ply coverage that minimises the number of individual plies and ply cuts



Workflow automation

During structural analysis, our software provides additional automation of workflows. All material, loading, and sizing data can be automatically transferred intact from the smeared to the discrete stiffener model. Once in the DSM, the stringers are represented individually by beam or shell elements, or a combination of the two. Engineers can then identify each stiffener as a separate panel segment, select failure analyses, and determine unique margins of safety for each. With this added flexibility, they can create panel bays with stringers of varying dimensions and materials, and capture the strength and weight benefits of non-uniform spacing and termination. Other advantages include interpreting how the stringers and skins fit together to form a stiffened panel, calculating stiffener spacing and heights automatically, and mapping the loads for crippling and buckling analyses.

In addition, a six-step process included in our software generates effective laminates, defines laminate FEM zones, and performs ply-count compatibility. It also helps the design team produce discrete laminates, create the most effective sequencing, and finalise layup specifications. These steps lead to a reduction in ply drops and fabrication steps, such as fewer layer applications on the tool and fewer ply cuts. Working with a number of airframe customers, we have consistently helped them cut as much as 20% from the weight of their structures.

As the aerospace industry continues to embrace composites and other advanced materials in search of lightweight structures, I see new and difficult challenges on the horizon. But I also see solutions. The most innovative will emerge from robust optimisation that tackles every variable, identifies substantial weight savings, and generates a number of alternative designs. Doing all of this seamlessly and without disrupting existing engineering processes will help you achieve the best design results possible. In an ideal airframe design process, there will be wide-open design space exploration leading to lightweight, structurally sound designs that are easily manufacturable and certifiable to fly. I

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