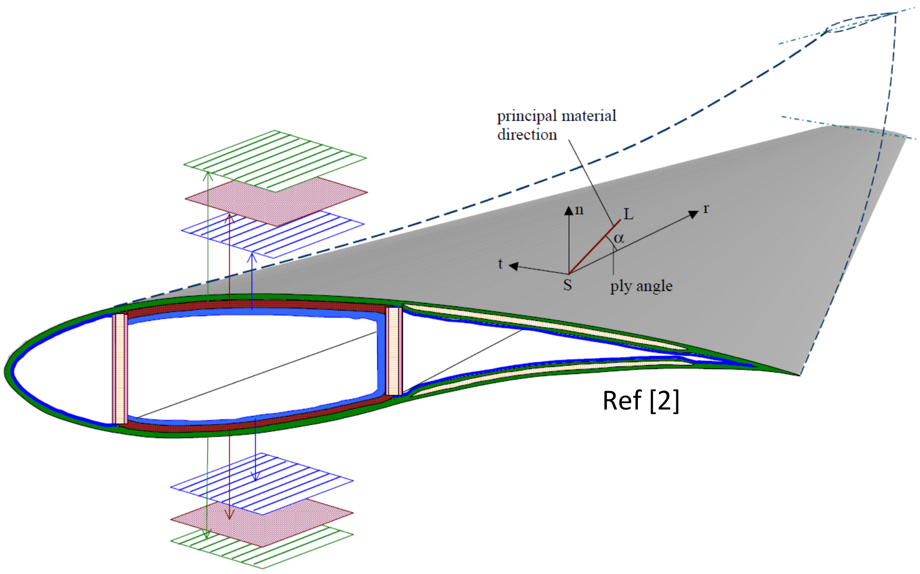
HyperSizer®

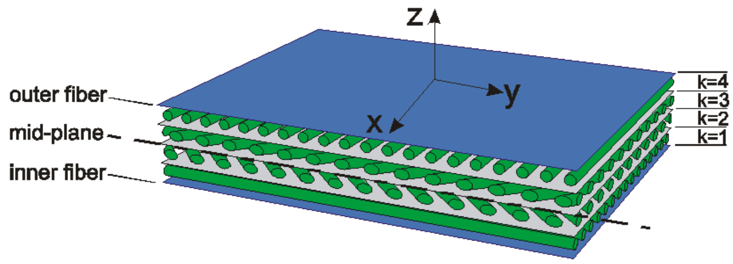
Composite Wind Blade Software

Wind Blade Design Challenge

As the wind industry continues to explore new technologies, the blade is a key aspect to better designs. Harnessing greater wind power requires larger swept areas. Increasing the length of blades increases the swept area of a wind turbine, thereby improving the production of wind energy; however, larger blades add significant weight to the turbine. Since weight is a key factor in the efficiency of operating a wind turbine, reducing the weight of wind structures through composite materials is essential to achieving overall efficiency. If a blade is doubled in length to achieve greater swept area, the unit weight of the larger blade increases by over **100%**--creating a significant need to reduce weight through optimization and rapid trade studies.



Ref [2]



HyperSizer® Structural Sizing Software is an essential tool for engineers optimizing and analyzing composite material wind blade s.

"Blades are source of all energy and loads

- *Typically 10-15% of system cost*
- *Even a small system improvement offsets a large increase in blade cost*
- *Perhaps we should be thinking of more expensive blades [higher graphite fiber volume content] instead of lowering blade cost! " (Ref 1)*

The multitude of possibilities that could be explored to save weight in a blade include varying the overall geometric shape, cross section thickness, and basic architectural layout. Sizing of individual members include the thickness of the spar web, its panel types as being either a foam sandwich or solid laminate, details of the spar cap, and of course, the actual lay-up of the individual composite fabric plies. The highly coupled response of all of these variables and their factorial combinations reach millions and require an automated process or software tool for rapidly performing trade studies to find the lightest weight and best performance composite wind blade. In addition to considering all of these combinations of variables, many different failure analyses need to be performed including instability failures such as overall buckling, local buckling of the spar web or surface skin, crippling of the cross section, and of course, the composite material strength analysis. In addition to structural strength and buckling integrity, the overall blade stiffness needs to be optimized to maintain its intended aerodynamic shape. Wing tip detection and twist limits can be set along with all strength and stability criteria, while performing parametric trade studies of blade cross section geometries simultaneously with composite laminate layups to reduce both weight and tip deflections.

The Lightest Composite Blade

Photo Credit Kristine Salm; Photo Credit NASA

How Do You Know When You Have the Lightest Composite Blade?

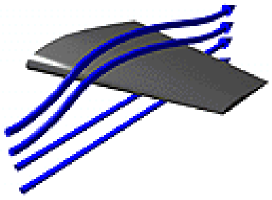
….When it's 20% Lighter

HyperSizer® has significantly reduced weight on major aerospace programs with rapid analysis and composite optimization. HyperSizer has helped aerospace customers ***achieve weight savings of at least 20%***. HyperSizer is not CAD nor is it FEA. HyperSizer is a Composite Analysis and Optimization Tool. HyperSizer works seamlessly with FEA to rapidly design the lightest-weight structure, provide insight into design innovation, and produce the most readily manufacturable design, all in less time.

HyperSizer is ***the chosen composite design and analysis tool for all of NASA's top projects***, such as the Ares V rocket, achieving major weight savings through detailed architectural designs, material trade studies, and concept trade studies on every major component. One of the most difficult challenges is the Payload Composite Shroud, shown here at the moment of separation.

HyperSizer is also the chosen composite design and analysis tool for many of the world's current **composite wing designs, from large commercial transports to smaller business jets.**

Wind turbine blades are the source of all energy and loads, representing typically 10-15% of the full system cost. Even a small system improvement offsets a large increase in blade manufacturing cost.



How?

- Starting with the FEA computed internal unit loads, HyperSizer determines the optimal combination of panel/beam concepts, cross sectional dimensions, materials, and layups.

- In doing so, hundreds of different failure modes are analyzed, achieving positive margins-of-safety (Safety Factor = 1) for all analyses, for all blade areas, and for all loadcases

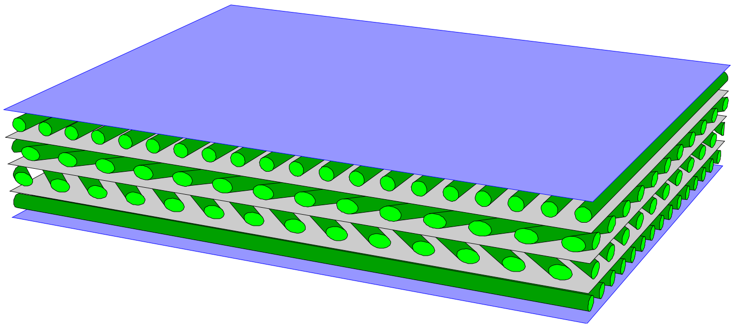
How Fast?

This entire process, excluding FEM setup, but including all HyperSizer user data entry, project setup, software run time, and results interpretation is typically accomplished for an early preliminary design in **4 hours**.

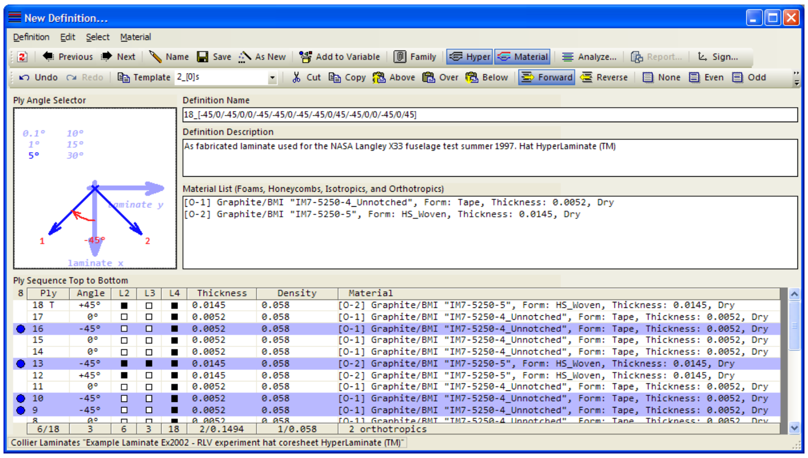
Companies Using HyperSizer for Lightest Composite Structure Designs

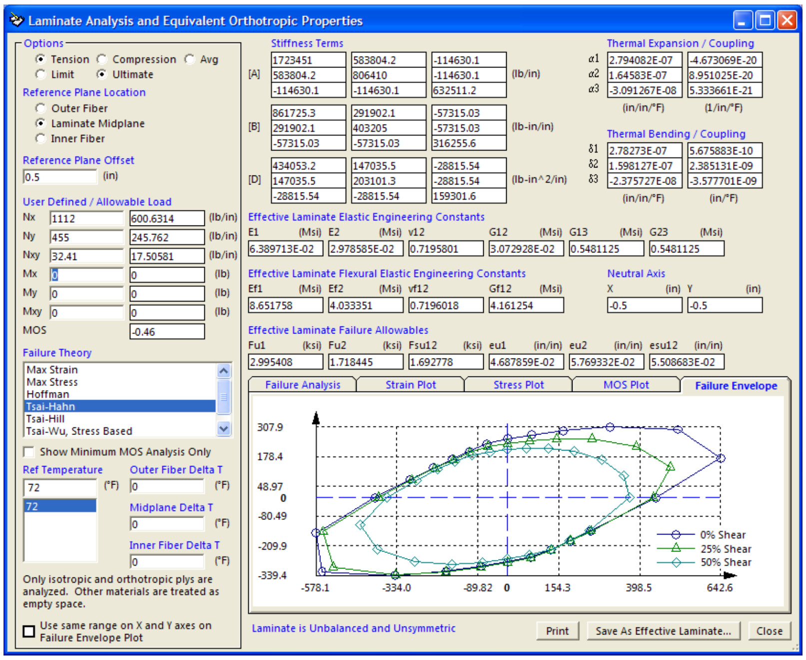
NASA
BOMBARDIER LEARJET
Gulfstream
Air Force Research Laboratory
SCALED COMPOSITES
LOCKHEED MARTIN
BOEING
NORTHROP GRUMMAN
BOMBARDIER

Composite Laminate Software



As a graphical composite laminate analysis tool, HyperSizer can build composite laminates with any arbitrary stacking of material forms or types.





Layup Creation and Editing

HyperSizer's interactive graphics are used for managing composites, metals, foams, honeycomb cores, ply tapes and fabrics.

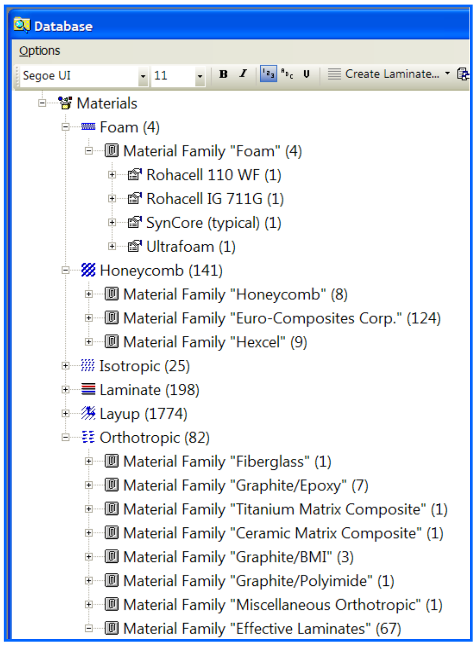
- Build composite laminates with any arbitrary stacking of materials
- Use native Windows cut, paste, and copy functions for quick ply insertions and layup arrangements
- Perform dynamic "what-if" design changes and see the effects real time
- Generate laminate equivalent properties for export to FEA packages

Composite Interactive Analysis

- Calculate [A,B,D] stiffness and thermal terms and equivalent orthotropic properties
- Graph temperature dependencies, failure envelopes, and stress/strain profiles interactively
- Compute strain and stress in each ply of the laminate
- Choose from many popular composite failure theories such as Tsai-Wu

Composite Failure Criteria Provided

- First, the more traditional **ply approaches** such as max strain, max stress, and quadratic interaction (for example, Tsai-Wu). These failure theories use the same primary material moduli and strain/stress allowables.
- Second, **physically based approaches** that attempt to distinguish between **fiber and matrix** failures.
- Third category of composite strength prediction are the **laminate approaches**. A laminate approach does not attempt to define stress/strain allowables at the ply level, but instead at the laminate level and has the advantage of being capable of more accurately capturing the effects of percent plies in the different layup orientations.

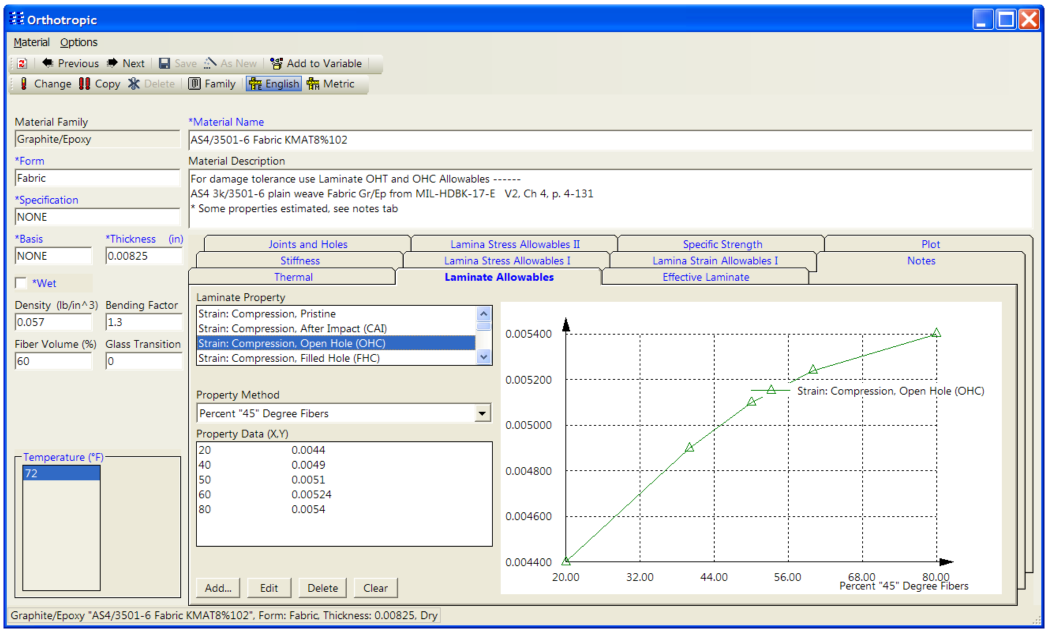


Achieve thinner and more efficient blade profiles that will yield a higher energy output. Selecting the right materials for the right structural components starts with a highly integrated system for storing and managing temperature dependent properties for all material types, as provided with HyperSizer.

Create your own materials through the user interface and have properties managed with HyperSizer's integrated database. Composite material properties can be imported from multiple sources such as material spreadsheets.

Fully Integrated Material Database

1. *Metallics (isotropics)*
2. *Graphite and glass fiber systems*
3. *Sandwich cores (honeycomb, foam, syntactic)*
4. *Hybrid laminates with plies of tape, fabric, metallic sheet, and sandwich cores of all material types*

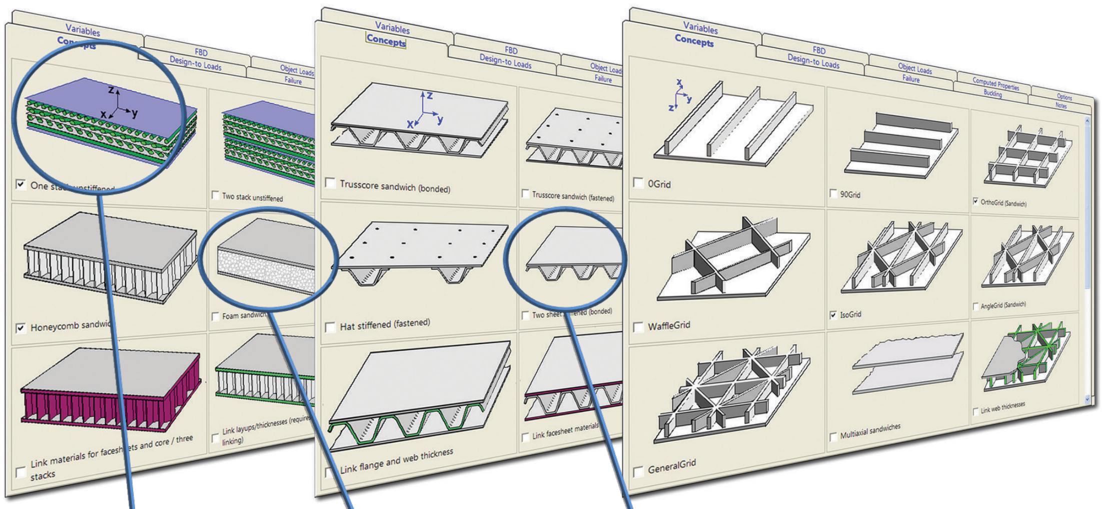


Composite material strength prediction requires correction factors to the material allowables. These allowables and correction factors can both be public and company proprietary. They are essential for establishing structural integrity and are used throughout the design process. Correction factors are used with the two primary analysis approaches. The first approach is a ply-based methodology in which the stress and strain of each individual ply is computed and then compared to the ply allowable. The second approach establishes the allowable on a laminate basis and is defined in terms of ply angle percents.

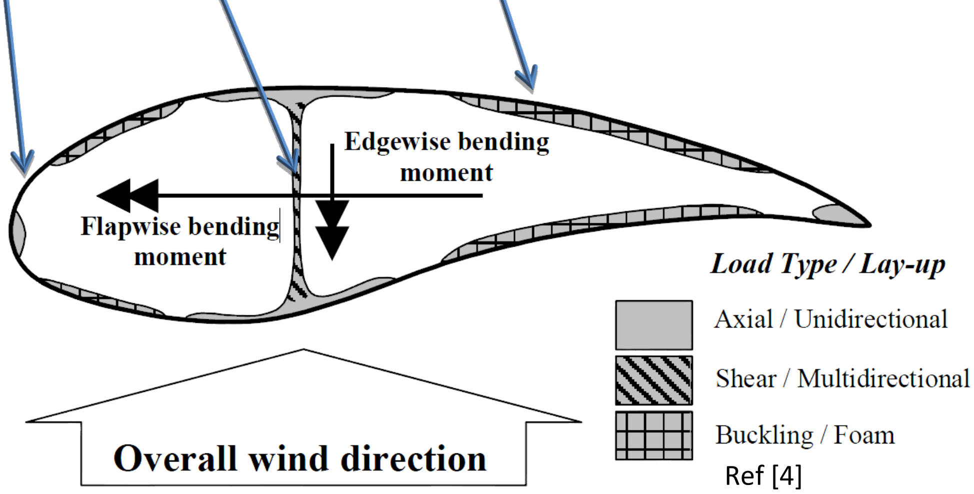
The relevant allowables are for design-to properties that apply to both pristine and damaged tolerant predictions. Commonly used allowables are for open hole compression (OHC), filled hole tension (FHT), compression after impact (CAI), and are knocked down with environmental factors. These methodologies also apply to hybrid laminates that consist of different material forms such as tape and fabric as well as material type such as glass versus carbon fiber. All of this data can be fully defined and maintained in the HyperSizer Material Database.

A new report from Sandia National Laboratories, called "MSU/DOE Fatigue Database for Composite Materials," shares data from 17 years of accumulated 10,000 results on about 150 different composite materials. The fatigue database is one of the world's largest open-access libraries on wind turbine materials made available to the public (Ref 3). With HyperSizer's capability to import external materials, an engineer could apply the MSU/DOE database to the optimization of a design.

Optimum Architectural Design



Along with the integrated material database is a library of panel and beam concepts. Each design has unique failure analysis to check.



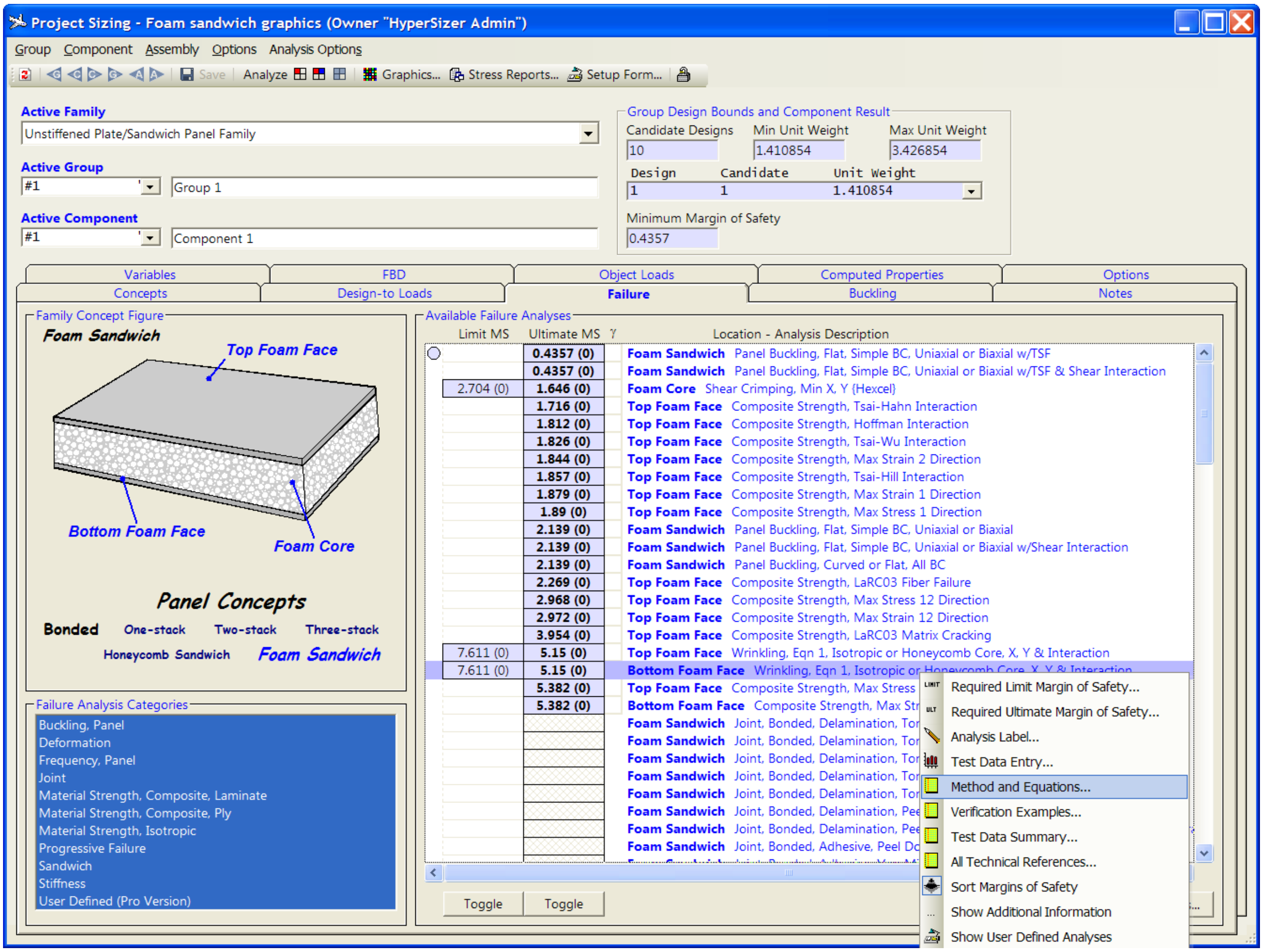
Ref [4]

Blade applied external loadings and resulting developed bending moments and blade twist inherent in the design are quantified and used for performing hundreds of failure analyses within seconds during sizing optimization to achieve the lightest and safest design.

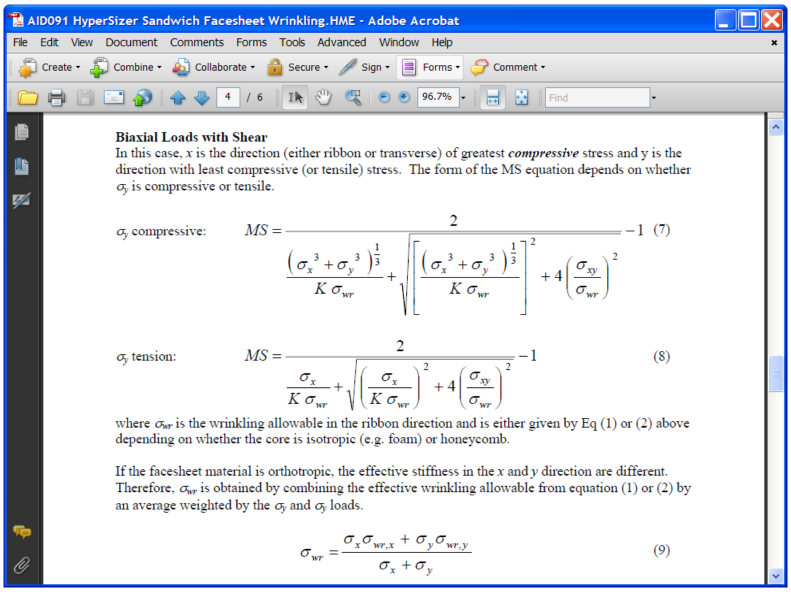
HyperSizer allows engineers to rapidly analyze over 100 different, non-FEA based failure modes for all load cases.

- Perform flat and cylindrical buckling, local buckling, post-buckling, and crippling for panel and beams
- Carry out analyses at both the ply and laminate levels for composite materials. At the ply level perform standard quadratic failure predictions such as Tsai-Wu
- At the laminate level perform Angle-Minus-Load (AML) or the Boeing 787 polynomial coefficient methods
- For both approaches, include CAI and BVID damage tolerance and OHC/OHT open-hole allowables that include customer specific correction factors for process dependent fabrication
- In addition to classical lamination theory (CLT) in-plane stresses and strains, compute out-of-plane Z axis interlaminar shear and peel stresses for multi-axially loaded adhesively bonded joints and bolt/fastener bearing
- On a more advanced R&D level, perform micromechanic analysis on the individual fiber and matrix constituents and compute crack propagation for safe-life or fail-safe designs with fracture mechanics or with a continuum damage approach

Results of the detailed analyses control the optimization process, are shown graphically on the FEM, and are reported along with sample calculations in the margin of-safety stress report.



HyperSizer provides all the failure analyses required to design the composite blade. Shown here are the unique failure analyses performed for foam sandwich such as wrinkling and dimpling of the facesheet, core shear strength and core crushing, core crimping, as well as more general analyses such as panel buckling and material strength. The engineer can right click on a failure method and pull up the '**Method and Equations**' document. In this example the equation for foam sandwich facesheet wrinkling is displayed as a PDF document.



AID091 HyperSizer Sandwich Facesheet Wrinkling.HME - Adobe Acrobat

Biaxial Loads with Shear

In this case, x is the direction (either ribbon or transverse) of greatest *compressive* stress and y is the direction with least compressive (or tensile) stress. The form of the MS equation depends on whether σ_y is compressive or tensile.

σ_y compressive:

$$MS = \frac{2}{\dfrac{(\sigma_x{}^3+\sigma_y{}^3)^{\frac{1}{3}}}{K\,\sigma_{wr}} + \sqrt{\left[\dfrac{(\sigma_x{}^3+\sigma_y{}^3)^{\frac{1}{3}}}{K\,\sigma_{wr}}\right]^2 + 4\left(\dfrac{\sigma_{xy}}{\sigma_{wr}}\right)^2}} - 1 \quad (7)$$

σ_y tension:

$$MS = \frac{2}{\dfrac{\sigma_x}{K\,\sigma_{wr}} + \sqrt{\left(\dfrac{\sigma_x}{K\,\sigma_{wr}}\right)^2 + 4\left(\dfrac{\sigma_{xy}}{\sigma_{wr}}\right)^2}} - 1 \quad (8)$$

where σ_{wr} is the wrinkling allowable in the ribbon direction and is either given by Eq (1) or (2) above depending on whether the core is isotropic (e.g. foam) or honeycomb.

If the facesheet material is orthotropic, the effective stiffness in the x and y direction are different. Therefore, σ_{wr} is obtained by combining the effective wrinkling allowable from equation (1) or (2) by an average weighted by the σ_x and σ_y loads.

$$\sigma_{wr} = \frac{\sigma_x\sigma_{wr,x} + \sigma_y\sigma_{wr,y}}{\sigma_x + \sigma_y} \quad (9)$$

HyperSizer

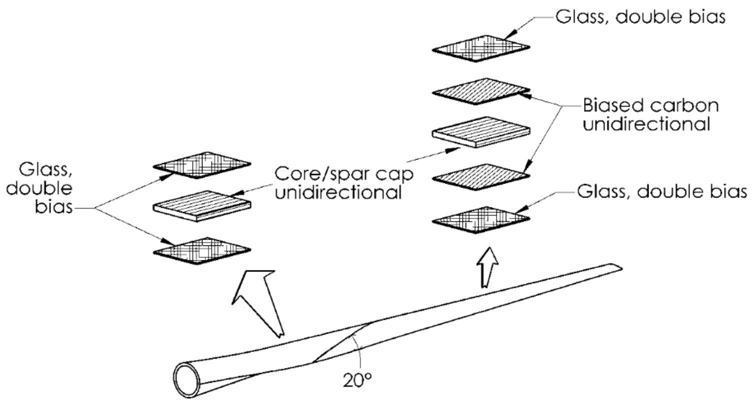
Anisotropic Laminates

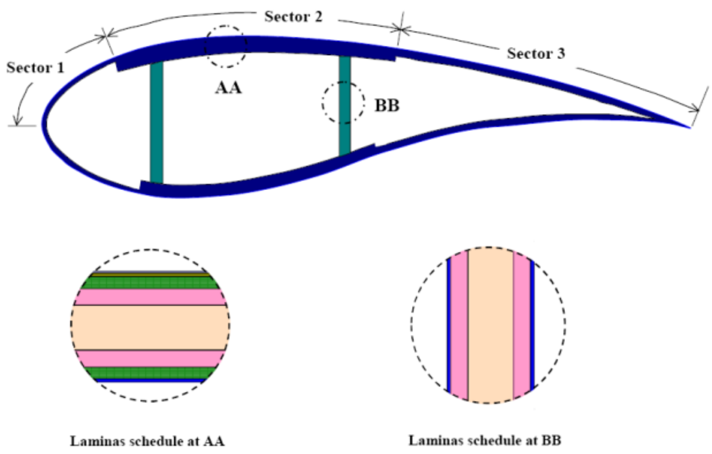
Problem

Now that the blade is strong enough to carry the wind load without failure due to material strength or buckling stability, we now turn our attention to the blade deflection and how to minimize its potential adverse affect on aerodynamic performance.

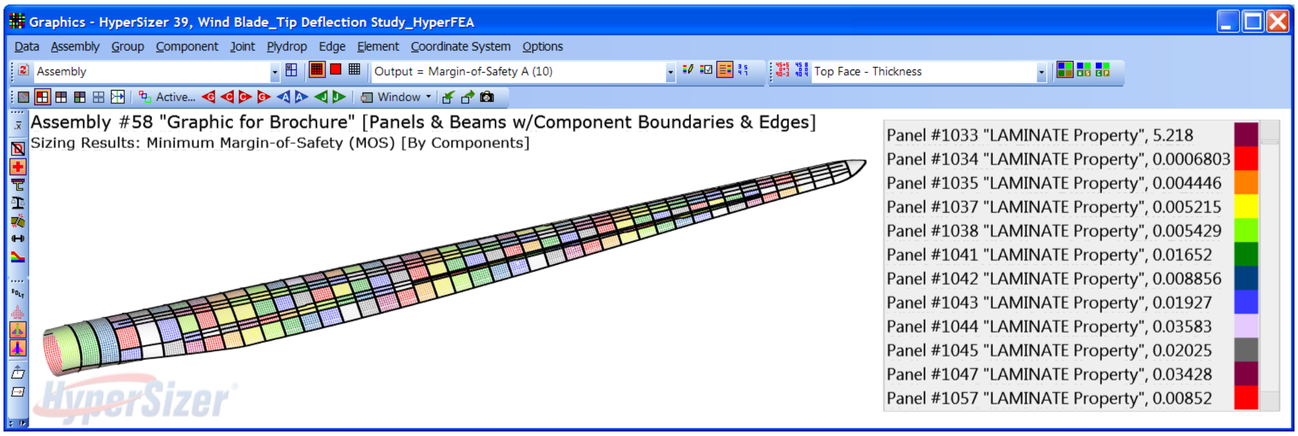
Solution

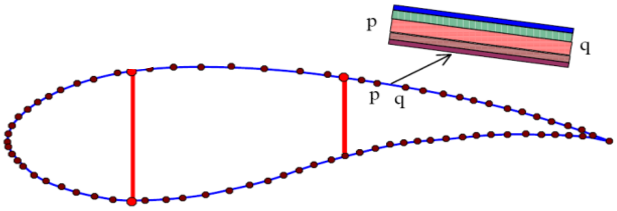
The amount of blade tip deflection can be addressed by stiffening up the overall EI of the cross section by adding uni-directional composite material in both the spar caps and upper and lower blade skins. The blade twist is more complicated to reduce. Blade makers are exploring the use of anisotropic laminates to control this deformation by using unbalanced or biased layups (Ref 5) in addition to placing carbon fiber in appropriate sectors on the skins (see figure). Tradeoffs with hybrid laminates with satin weave fabrics, prepreg tapes, preform infused woven and braided materials with differing percentages of glass and carbon fibers (Ref 6) really opens up the design space of millions of combinations to achieve desired stiffness and strength. HyperSizer is capable of rapidly quantifying these effects for any arbitrary hybrid laminate





For each candidate combination of materials and hybrid laminates, the overall blade internal loads and displacement are then quantified by coupling HyperSizer with commercial FEA software packages such as Abaqus™, NX/Nastran™, NEI/Nastran™ , and MSC/Nastran™. The HyperFEA® commercial software controls the execution of both the HyperSizer® and the FEA solver and provides the capability to specify translational and rotational constraints on user identified control FEM grids. This approach provided by HyperFEA has proven valuable by commercial aerospace companies for wing design.





2D FEM OML surface definition

Problem

Achieving a realistic, fully-optimized, and manufacturable design requires virtually endless hours of manual calculations, offline spreadsheets, model re-meshing, and long running batch jobs. And FEA is not enough.

Solution

Whether an engineer is using CAD (such as CATIA or Pro-E), a finite element modeler (such as PATRAN or FEMAP), or FEA (such as NASTRAN or Abaqus), HyperSizer begins where FEA ends. HyperSizer verifies structural integrity with the required calculations to predict all potential failure modes for all load cases, and identifies negative margins-of-safety. To resolve these negative margins, or to simply find a lighter-weight design, HyperSizer optimizes, or 'sizes,' a design by surveying literally millions of candidate dimensions and laminates, and finding optimum variables down to the ply level — in a matter of minutes.

Unlike the software PreComp (Ref 2), HyperSizer works seamlessly with FEA solvers to compute structural internal loads. As shown in the FEM graphic the colors represent areas of constant laminate thickness. Interactive graphics allow the user to instantaneously redefine areas of constant laminate thickness and the boundaries of ply drops. The FEA loads can be either statistically processed to find the appropriate design-to load, or the user can select to use each individual element load. The HyperFEA® product is then used to automatically submit the FEA solver and to monitor the convergence of internal loads between HyperSizer sizing updates and the FEA solver. HyperFEA is also used to control the blade tip displacement and tip twist. In this manner, HyperFEA rapidly iterates to the lightest-weight design while providing insight into design innovation.

HyperSizer has native graphics for displaying the Fine Element Model and hundreds of data types not supported in commercial standard pre processor software. These data types include plotting worst-ply strains and stresses and OML and IML strains and stresses, margins-of-safety, and controlling failure mode. The graphics provide a stress engineering tool utility for performing section cuts and for computing real-time cross section EI and GJs. The load transfer through the section cut is also graphically depicted.

Optimize for Manufacturability

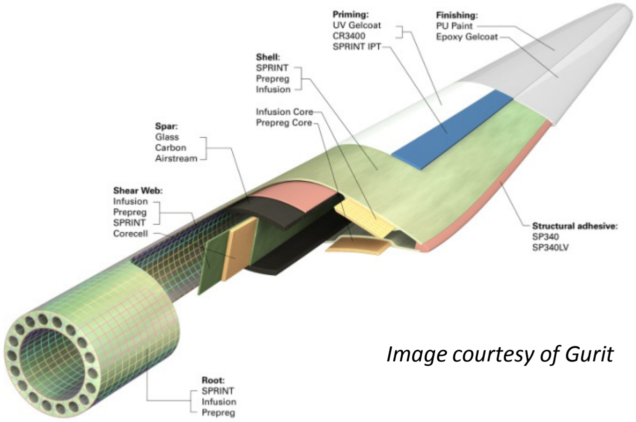
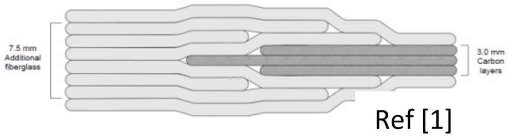


Image courtesy of Gurit



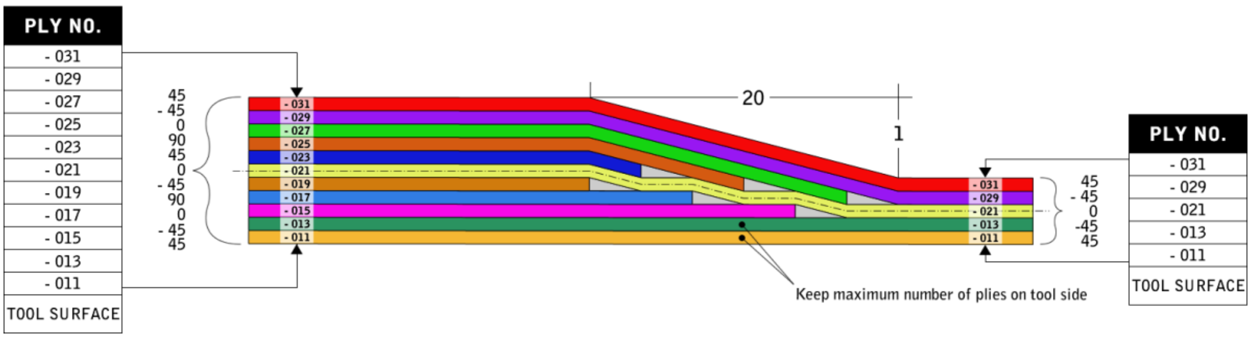
Ref [1]

Problem

After the analyst has created the Finite Element Model and applied external loadings to compute the composite ply strains and stresses in the blade, the analyst then suggests changes to the ply schedule based on the FEA results. At this point the design typically goes back and forth many times between the stress analyst and the designer and even perhaps someone from manufacturing. The engineer might start by defining areas of the part with similar thicknesses as zones. The zone information is usually maintained manually in a spreadsheet. Then the engineer will define a ply stack that delivers the mechanical properties required in each zone, as indicated by previous experience. Most companies involved in composite design have design rules that are used to guide this process. For example, the full body continuous plies are defined on the tool side with ply drops occurring at the laminate mid-plane to maintain balanced and symmetric layups. This process is very tedious, time-consuming, and error prone, as it is manually tracked in spreadsheets.

Solution

HyperSizer is able to efficiently track this data and evaluate literally millions of combinations of ply drop off patterns to simultaneously achieve the most efficient least weight laminate and the fewest amount of ply drop offs or ply adds. This automated process of exploring all the different manufacturing layup schedules for every zone includes hybrid laminates with automatic strength and stability stress analysis checks satisfied. HyperSizer minimizes ply drops for both cost savings from ease of fabrication but also for increased fatigue life (ref 4). The figure shows the manner in which HyperSizer achieves ply drops going from a thick laminate to a thin laminate or from a foam core ramp down to solid laminate while also identifying the global ply IDs (drawing ply dash number).



Bolted Construction Joints

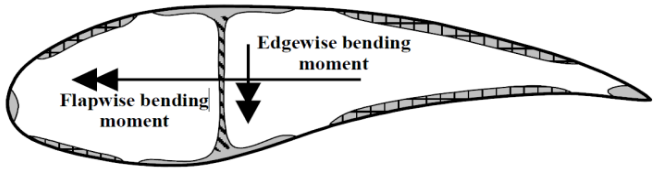
Problem

Blade makers construct wind blades in sections and then bolt them together. Because transportation costs increase significantly with blade length, shipping blades in sections and joining them on site may offer significant savings. However, the bolted joint in composite materials requires special analysis and optimization of the laminate padup thickness to minimize the joint's weight (ref 6).

Solution

HyperSizer has two different approaches available for analyzing the composite bolted-joint strength. The first is a straight-forward approach in which the engineer defines the bearing allowable as a relationship with bypass load and percentage of 45-degree plies. The second approach uses a numerical program used in the aerospace industry called BJSFM which computes the stress/strain field around the loaded hole. In this manner failure criteria are then applied to find the worst combination of multi-axial loading to cause failure. Both approaches account for fastener type such as counter sunk versus protruding head and fastener diameter correction factors. These analyses are highly integrated with the optimization such that the laminate thickness padup can be minimized and blended most efficiently with the acreage laminate layup.

Adhesively Bonded Joints



Problem

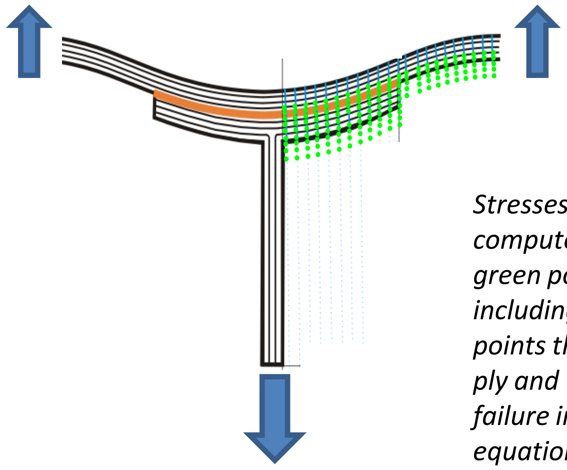
A problematic area for composite wind blade design is the joint between the spar web and the surface skin. The pull-off and shear load transfer between these two structural components is a weak link in the structural integrity of the blade (Ref 7).

Solution

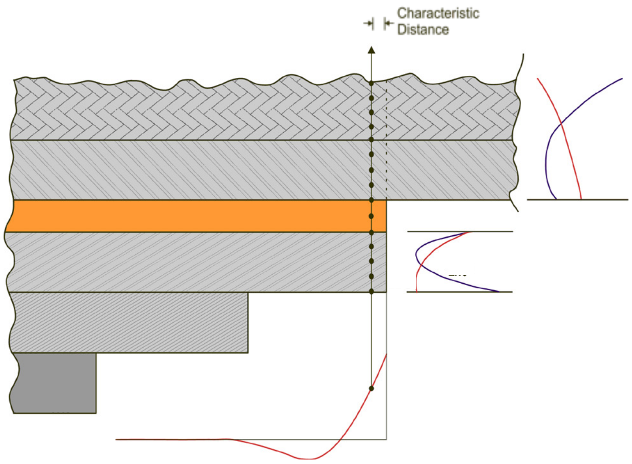
HyperSizer provides the advanced analysis required to predict potential failures in these areas. Specializing in composite analyses and optimization, HyperSizer's progressive Global-Local-Detail process of computing stresses and strains allows hundreds of different failure analyses to be included such as 19 different delamination and out-of-plane fracture theories.

Interlaminar shear and peel stress variation is computed in the adhesive for linear and five different non-linear material methods. The Z axis stress variation is also computed throughout the laminate depth, and also for each individual ply as required for the last ply of a stepped joint. The number of integration points and characteristic distance for failure prediction can be selected by user.

In addition to material strength based on damage initiation, damage tolerance residual strength of strain energy release rates (SERR) and can be computed with a rapid, non-FEA, virtual crack closure technique (VCCT). These values are compared to critical energy release rates GIc and GIIc to predict delamination propagation for a crack between laminate plies and/or a crack between the skin and bonded flange.



Stresses are computed for every green point including integration points through each ply and used in the failure interaction equation



Computing all six components of stress

$\sigma_{11}, \sigma_{22}, \sigma_{33}\ , \tau_{12}, \tau_{13}, \tau_{23}$

for every ply and every distance increment , for a total of approximately 4000 points per joint, to be used in failure criteria such as:

$$\left(\frac{\sigma_{11}^2-\sigma_{11}\sigma_{33}}{X_tX_c}\right)+\left(\frac{\sigma_{22}^2-\sigma_{22}\sigma_{33}}{Y_tY_c}\right)+\left(\frac{\sigma_{33}}{Z}\right)^2+\frac{\tau_{13}^2}{\tau_{13,allow}^2}+\frac{\tau_{23}^2}{\tau_{23,allow}^2}+\frac{\tau_{12}^2}{\tau_{12,allow}^2}=1$$

Ref (1). Veers, Paul. *Research Directions in Wind Turbine Blades: Materials and Fatigue*. Wind Energy Technology Department, Sandia National Laboratories. Web. 10 August 2009.

Ref (2). Bir, G.S. (January 2006). *User's Guide to PreComp (Pre-Processor for Computing Composite Blade Properties).* National Renewable Energy Laboratory. NREL/TP-500-38929. Web. 10 August 2009.

Ref (3). "Open-Access Database Covers Wind Blade Composites." RenewableEnergyAccess.com. 22 August 2006. Web. 10 August 2009.

Ref (4). Nijssen, R.P.L. (October 2007). *Fatigue Life Prediction and Strength Degradation of Wind Turbine Rotor Blade Composites*. Sandia National Laboratories. SAND2006-7810P. Web. 10 August 2009

Ref (5). Mason, Karen. "Anisotropic Wind Blade Design Expected to Reduce Wind-Energy Costs." *High Performance Composites.* 1 November 2004. Web. 10 August 2009.

Ref (6). Gardiner, Ginger. "Wind Blade Manufacturing, Part I: M&P Innovations Optimize Production." *High Performance Composites.* Vol. 16, Number 6. November 2008.

Ref (7). Hogg, Paul. "Manufacturing Challenges for Wind Turbines." Northwest Composites Centre, University of Manchester. Web. 10 August 2009.

HyperSizer® Information

Collier Research Corporation has provided methods research and software development to NASA and the aerospace industry since 1995. **A commercial strategy**... to combine finite element analysis (FEA) with an automated design procedure was conceived at NASA Langley Research Center in the early 1980s and has evolved, through a series of precursor codes into this version of HyperSizer® for analyzing the strength and stability of stiffened panels constructed of any material, including fiber-reinforced composites. Of particular note is the NASA code referred to as ST-SIZE (ST-SIZE© 1996 NASA. All rights reserved.). **Collier Research Corporation** obtained an exclusive, all fields of use license to ST-SIZE in May 1996. (Collier Research employees were principal developers of ST-SIZE and have been continually developing the soft ware and analytical methods for the last twelve years).

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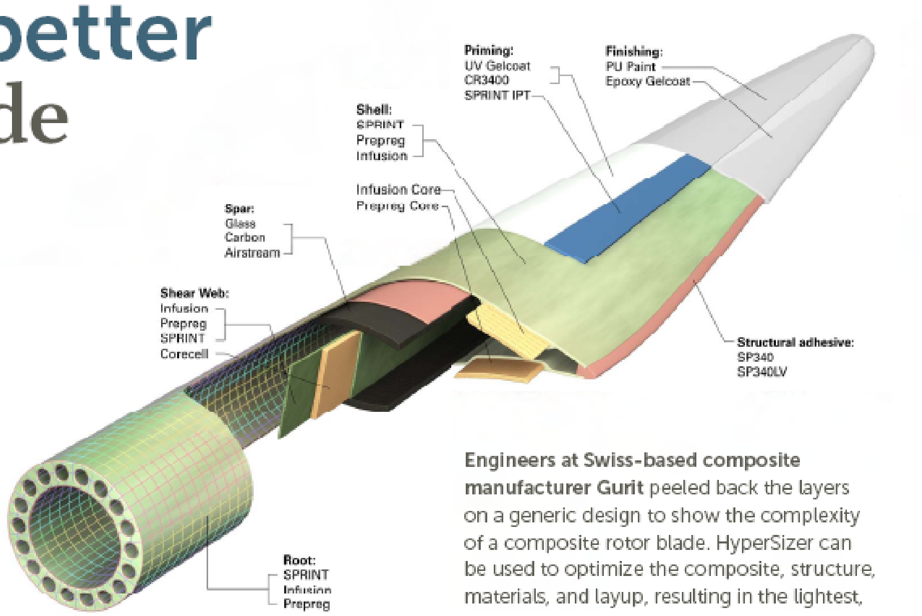
SIMULATION SOFTWARE

Craig Collier/President, Collier Research Corp./Hampton Roads, Va./HyperSizer.com

Building a better turbine blade



Engineers at Swiss-based composite manufacturer Gurit peeled back the layers on a generic design to show the complexity of a composite rotor blade. HyperSizer can be used to optimize the composite, structure, materials, and layup, resulting in the lightest, most durable design. Image courtesy of Gurit.

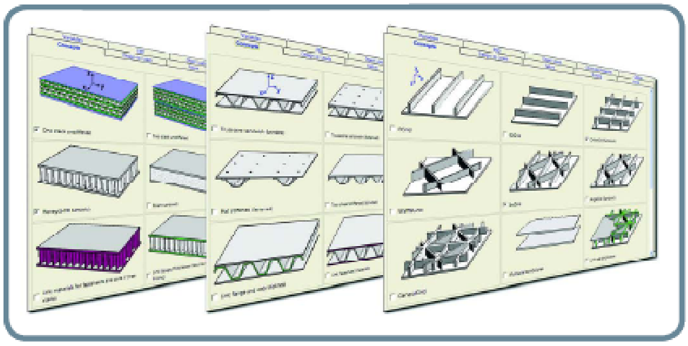
A first objective on most any large design project is to get to the lightest weight possible. At NASA Langley Research Center, where I helped develop the code that later became HyperSizer, designs for spacecraft that include composites also have a zero failure-tolerance. Those projects must strike a critical balance between low weight and high strength. The same is true in the wind-power industry. Weight is of tremendous importance when designing wind-turbine blades because a lighter blade uses less material, it is easier to manufacture and transport, and has lower fatigue loads.

With failure rates still high for turbine blades (a Sandia survey of wind energy plants documented rates as high as 20%) and down-time costly and bad for business, blade designers and manufacturers must turn to the best practices for designing composites.

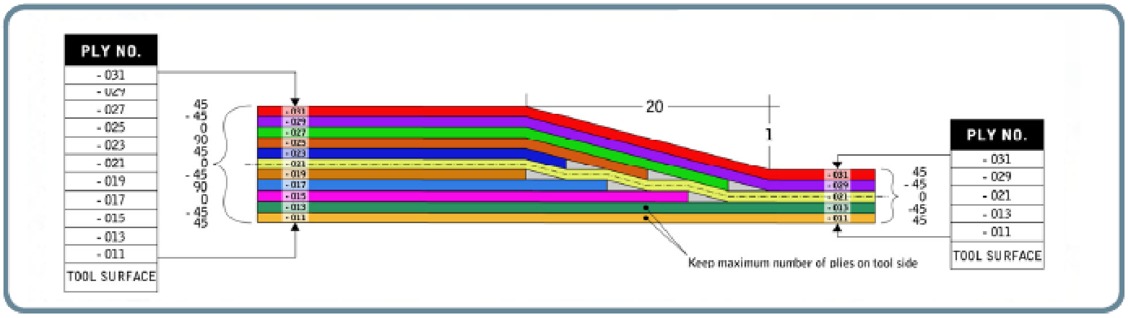
HyperSizer software, for example, is a composite optimization and structural sizing tool that works out-of- the-box with a wide variety of finite-element analysis (FEA) solvers. The tool couples with FEA in a feedback loop, searching for solutions that minimize weight while at the same time maximizing structural integrity and manufacturability. The software analyzes complex composite structures (it works with metals and other materials as well) by quickly evaluating designs in a ply-by-ply, and even finite element-by-element, manner. Optimizing all possible permutations for a composite laminate design gives engineers control of most every design detail.

Design improvements to wind-turbine blades should increase their efficiency and performance, trim the cost of harvesting the wind, and keep it competitive with fossil fuels. To increase the power generating capacity of a turbine, blades must grow in length (power captured by a turbine is proportional to the square of blade length). As they grow, blades must be kept as light as possible. Lighter weight means better performance, longer life, lower manufacturing costs, and shortened manufacturing cycles, all factors that enhance competitiveness in energy markets. With a legacy in aerospace, the software has helped users such as NASA, Lockheed Martin, Boeing, and Bombardier, trim at least 20% of the weight from structures. The same can be true for wind-turbine blades.

Current utility-scale turbines are equipped with blades that range from 40 m (130 ft) to 90-m (300 ft) diameters.



HyperSizer software performs panel swaps to find one that best meets the design criteria for a particular region of the blade.



Minimizing ply drops cuts costs by improving a blade's manufacturability and fatigue life.

But there are prototype and concept blades on drawing boards that approach a staggering 145-m (475 ft) diameters. Design engineering issues such as structural strength, fatigue performance, buckling stability, blade stiffness, wing-tip de ection, and twist limits become increasingly important as turbine blades get longer. In simple terms, a blade must be as light as possible but stiff enough to maintain its aerodynamic shape and durable enough to carry wind loads without material failure. Furthermore, large blades must have a proper distribution of weight and stiffness to avoid instabilities produced by aeroelastic loads.

To optimize a blade's design, the software begins where traditional FEA ends. Starting with a finite-element model and coupling seamlessly with FEA solvers, the software verifies structural integrity, predicts failure modes for all aeroelastic load cases, and identifies failure locations and loads, thereby achieving required safety factors. To resolve unacceptable safety factors, or simply to find a lighter weight design, it sizes (optimizes) a design by surveying millions of design-candidate dimensions and laminates. Setup, run time, and interpretation of results and initial redesign are typically accomplished in as little as four hours.

To evaluate what-if scenarios, trade studies, and sensitivities of a blade design, the software takes internal unit loads computed by FEA and determines an optimal combination of panel-and-beam concepts, cross-sectional dimensions, materials, and layups. To do so, it analyzes hundreds of different failure modes, achieving positive margins of safety (safety factor =1) for all analyses, all blade areas, and all load cases. The software also does panel trades. For example, a honeycomb or foam sandwich might be good for the shear web while a solid laminate might work best on a blade's leading edge. The software can examine different layup stacks, as well as panel cross-section shapes.

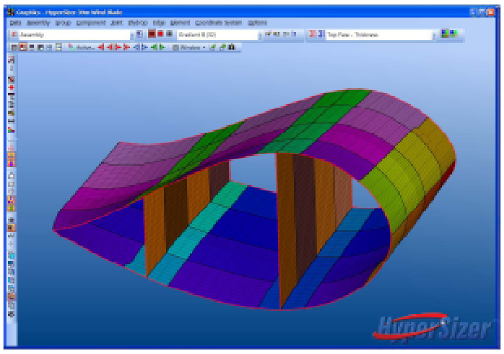
The software eliminates manual calculations, of ine spreadsheets, model re-meshing, and long running batch jobs. It also evaluates ply drop-off and ply-add patterns to help find the lightest laminate that meets strength requirements and with the fewest transitional regions.

HyperSizer includes features to evaluate blade areas with bolts (between blade sections) and adhesive joints (between the shear web and skin, for example). Analyses of bolt areas can prevent the common problem of overbuilding with heavier construction by optimizing padup thickness. Advanced analysis of adhesive joints looks at interlaminar shear and peel stress, delamination, and crack initiation.

A built-in library of materials can manage temperature and moisture-dependent properties, and can be customized with proprietary company and project data. The database includes metallics (isotropics), graphite and glass-fiber systems, sandwich cores (honeycomb, foam, syntactic), and hybrid laminates (plies of tape, fabric, and metallic foil). This extensive material list lets users analyze over 100 non-FEA based failure modes for all load cases. In addition, Sandia National Laboratories' MSU/DOE Fatigue Database with 10,000 results on about 150 materials, can be imported to provide further capability.

In one application of the software, by NASA, it was the preliminary and final design tool (for ight certification) for projects such as the Ares V rocket and the astronaut's composite crew module.

The economic and political climate is primed for growth in wind energy, but turbine performance, blade design, advanced materials, and quality in the field must reach the highest standards to help propel the industry forward. HyperSizer, with its composite analysis capabilities, has delivered great value to the aerospace industry and is ready to provide the same design assistance to the wind industry. It's time for the wind industry to share in the benefits of the aerospace community's accumulated expertise, without having to reinvent a composite wheel. **WPE**



HyperSizer can start with a finite element model and redefine the colored zones of laminate thickness. It then works with a wide range of FEA software to calculate loads which are used in its optimizing routines.

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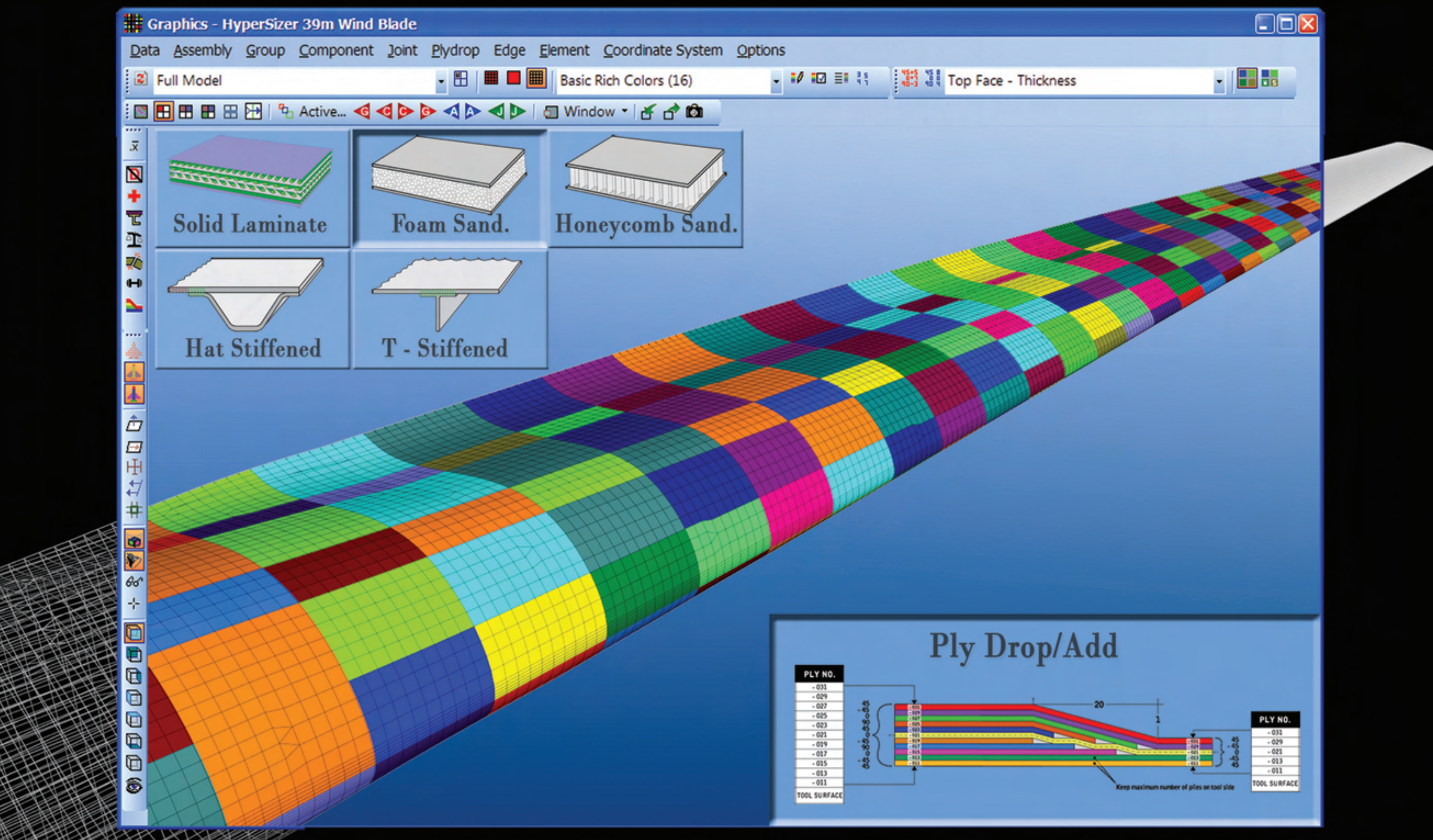

Building the better blade

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