Composite Wind Turbine Manufacturers Have Designs on Success

Aerospace blazed the trail in composite design and manufacturing, and now the energy industry is reaping the benefits.

While aerospace has led the adoption of high-performance composites and advanced composite design for three decades, other industries—such as wind energy—are now eagerly following suit. Composites are particularly well suited for developing wind turbine blades because these materials can increase the blade's stiffness while lowering its weight, the most important criteria for achieving higher efficiency and lower cost of produced energy.

In addition, wind turbine blades are rapidly increasing in size and are typically meant to last for 20–30 years, so if a blade is not precisely engineered, there is liable to be a premature failure, which can lead to a loss of credibility, reduced sales, higher lifetime costs and expensive litigation. That's where CAD integrated composite design software comes in.

Composite design software came on the scene about 20 years ago in response to the need to engineer parts made out of composite fabrics and resins. This

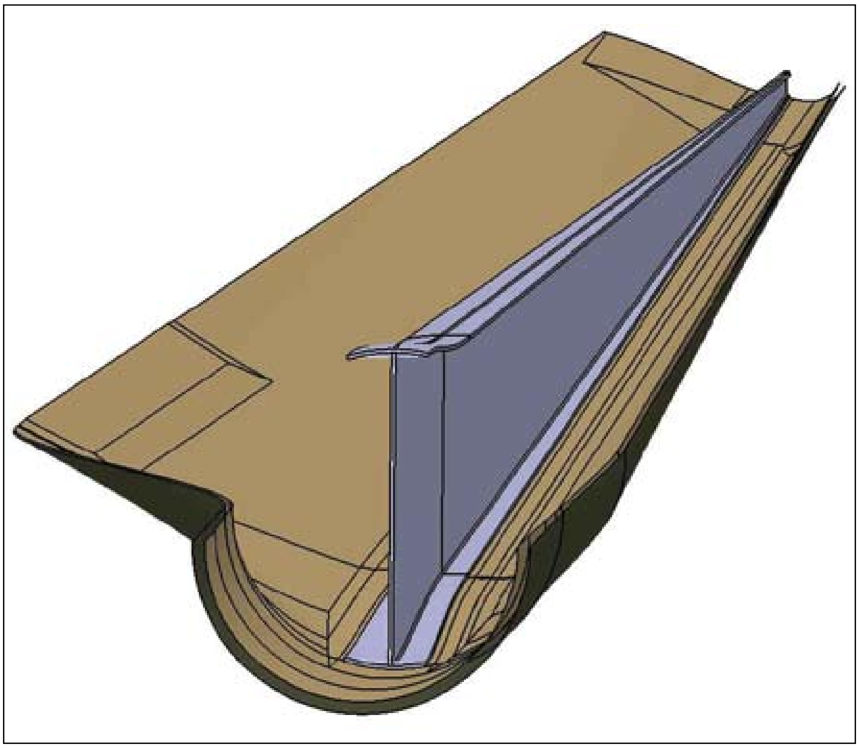


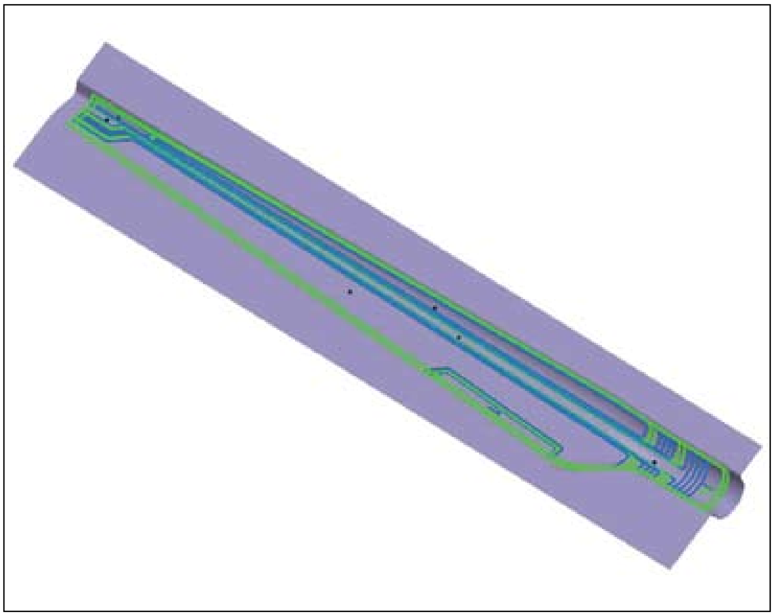
Image of lower foil spar shows laminates represented as solids. Software can automate the creation of solids representing the laminates based on the ply and core definition. This feature is essential for rapidly generating mockup surfaces, strip surfaces for spar mating, and tooling surfaces.

Olivier Guillermin
Director of Product and Market Strategy
Vistagy Inc.
Waltham, MA

kind of software has enabled the efficient and reliable use of these new materials. Today, composite design software is commonly used to design very large and complex parts and assemblies, be it a complete wing, a fuselage section or a large wind blade.

The digital model of a composite part has become the single source master for part definition and the backbone of the composite part development process. From preliminary design to manufacturing, composite design software is at the center of the development process. It interfaces with a variety of point solutions, including optimization and stress analysis tools; CAM software; cutting and offline systems for automated manufacturing, quality planning and execution; cost estimation; and project management applications.

Drawing from the lessons learned in aerospace and the early stages of wind blade development, the wind energy industry is eagerly adopting the use of composite design software and implementing next-generation methods and processes for composite part design and manufacturing.



A large blade can contain hundreds of plies with many different shapes, materials, and orientations. Using software to create and modify the layup ensures that no errors are made in the selection of materials, orientations, and sequences, and that the blade will be manufactured properly.

Circumstances Dictate Growing Demand

Hundreds of thousands of homes and businesses in a variety of locations around the world depend on wind turbines for their daily electricity needs. Wind turbine size has grown tenfold over the last 25 years, topping 61.5 m in blade length alone, and can deliver 7 MW of power per day.

Wind turbines are designed, analyzed, and built by a supply chain that spans the globe, including Europe and the Middle East, the Americas, Asia, and India. All the major companies in wind turbine manufacturing are global players with operations on multiple continents.

Due to recent political and economic circumstances, the markets for renewable energy, such as wind, have become very attractive and demand is growing at a rapid pace. Europe is actively looking at offshore wind farm installation. The Americas and Asia are busy catching up with onshore wind farms.

The wind blade is the most significant component of the wind turbine. Blade profiles affect the efficiency level of the turbine. The rotor is a gigantic moving part that puts tremendous force on the nacelle and tower. This force is a complex factor that affects the blade's performance and durability. The complexity stems from the force and variations of the wind and the various deformations in the blades, coupled with the twisting and bending of the tower.

With a few exceptions, the blades are made of composite materials, mostly fiberglass and polyester or epoxy resins.

The Evolving Blade Engineering Process

The wind turbine blade design starts with the selection of appropriate airfoil section profiles that will yield the best aerodynamic performance. This is similar to other structures that are designed to extract performance from airflow, such as aircraft wings, helicopter blades, and racing car winglets. Wind blade engineers are relying on libraries of qualified airfoil profiles, and increasingly turning to computational fluid dynamics (CFD) software, to analyze the behavior of the blade or the complete turbine under various wind flow conditions.

The structural design of the blades is the second leg of the engineering process. Blades are meant to stay in the field with minimum maintenance efforts and costs for at least 20–30 years under all kinds of weather conditions. And with increased turbine size, minimizing the weight of the blade has become a tremendous challenge. That's because as the length of the blade grows,

The digital model of a composite part has become **the single source master** for part definition.

Demand for more and larger wind turbines means manufacturers are looking for solutions that can improve the design, weight, manufacturability, and production rate of turbine blades.

the energy produced grows even more, but, unfortunately, the weight of the blade grows still more. The key is to increase the size and minimize the weight as much as possible. Blade engineers are using various structural sizing software tools to ensure optimal blade structures. They are turning to the most sophisticated FEA software to account for all kinds of nonlinear effects.

In fact, optimizing the blade's aero-elastic behavior—or determining the coupling effects between the wind forces and the structural deformations—is at the very center of blade performance engineering. The most advanced environments for blade design allow for complete analysis of the aero-elastic conditions.

Valuing Composite Design

The third leg of blade engineering is composite design. While this aspect of engineering may not have received as much attention in the wind industry as in others, such as aerospace, its importance in the overall process should not be underestimated.

The use of composite materials, as opposed to metals, brings another, higher level of complexity to the blade development process. Instead of a few aluminum panels, a blade laminate skin is made of hundreds of relatively thin plies of fibers and resin, each with a different shape and orientation. It can even consist of different kinds of material.

Accurately defining the multitude of layers that make up the blade skins, shear webs, and spars becomes a complex and tedious task, prone to errors, multiple iterations, and wasted time. In addition, appropriately accounting for the behavior of the composite materials in the structural and aero-elastic optimization of the blade is also a significant challenge.

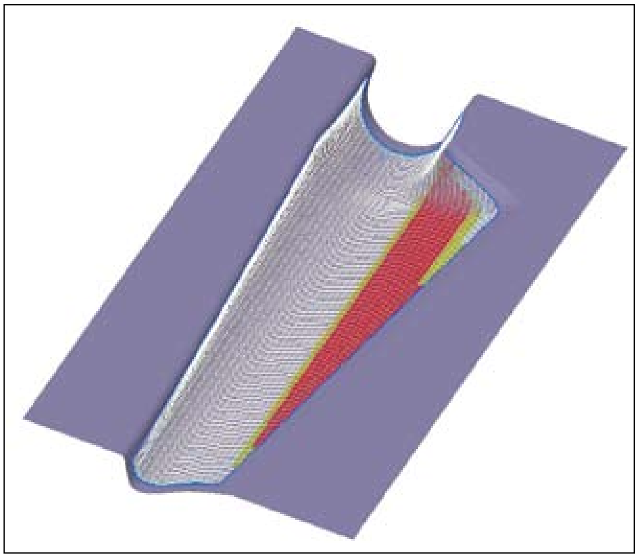
The last part of the equation, and a difficult one at that, is to ensure that manufacturing, which most likely is performed on a different continent, actually produces a composite blade that precisely corresponds to voluminous composite design specifications.

Taking the Risks out of Composites

The idea of creating specialized design software for composite materials was born about 20 years ago due to the requirements of manufacturers of fixed wing aircraft, helicopters, and weaponry and space systems. These firms relied heavily on lightweight composites and needed software to help reduce design uncertainties. At the center of their interest was the modeling of composite fabrics during the draping operation, as well as the necessity to accurately and reliably communicate the design intent to manufacturing using ply books and datasets to feed ply cutting machines, and laser projection positioning systems.

Later, the advent of automated material deposition systems, such as for fiber placement or tape laying, drove composite design software to be extended to support these new manufacturing processes.

In recent years, the leading wind turbine blade manufacturers have begun turning to the same specialized composite design software to address the challenges of composite blade engineering.



Simulation highlights fiber orientations that deviate from specification when draped over complex curvature. Excessive deviation is highlighted in red (yellow for moderate deviation), alerting engineers to potential performance problems.

skins, spars, shear webs—which makes them suitable to a component approach that allows more automation of the design process.

Materials used for blades are different from the materials employed by the aerospace and automotive industries. Their behavior warrants special scrutiny. Finally, the shear size of the blades requires an enormous amount of materials to be laid down. That is unheard of in other industries and opens up opportunities for large-scale manufacturing automation.

The wind turbine **supply chain spans the globe.**

Many of the engineers working on wind blades share the same requirements as their counterparts in aerospace, including:

- Accurate and complete laminate part definition, including plies and cores
- Optimization of the ply layup using analytical and finite-element-based tools
- Manufacturing producibility assessment
- Communication of design intent to manufacturing
- Export of the manufacturing data to automated material placement systems

Taking Composite Design to the Next Level

However, some aspects of the engineering process are specific to wind-blade development and can be addressed with additional functionality. For instance, all wind blades are based on a somewhat common set of components—

Vistagy has led the evolution of composite design in the wind industry for more than five years with its FiberSIM composites engineering software. Even the first trials showed that tremendous time savings can be obtained over the development cycle of design and manufacturing of wind blades. In addition, composite design software demonstrated the ability to support a quality enhanced process, with the built-in repeatability and accuracy necessary to ensure high-quality manufacturing.

Today, the major players in the wind-blade manufacturing industry are showing that upgrading the blade engineering process in order to take the lead and compete successfully entails taking composite design to the next level. Ultimately, that means making a complete and detailed model of the composite blade the backbone of the complete process, spanning design, analysis, and manufacturing.