DesignNews

Developing Composite Wind Blades That Will Stand the Test of Time

To support new advanced composite engineering and manufacturing processes, wind blade manufacturers must create an end-to-end engineering environment with the best-in-class assets.

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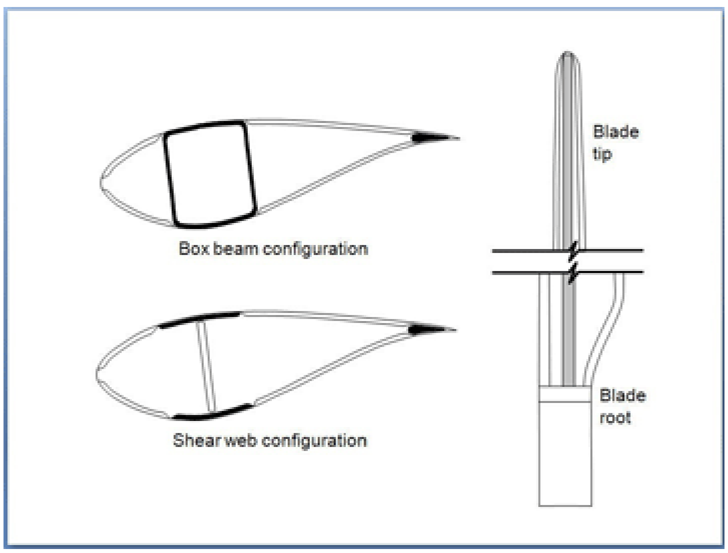
Designing composite wind turbine blades is about balancing aerodynamic performance and structural integrity. Blades must extract as much energy from the airflow as possible while resisting huge forces and deformations over a lifespan of 20 years with minimum lifecycle costs.

While blades need to be as narrow and thin as possible to achieve maximum energy extraction, sufficient strength and stiffness can only be provided by larger cross sections and/or the use of higher performance materials, leading to a design that is a compromise between efficiency, endurance and cost.

In all, hundreds of composite plies and numerous pieces of core materials are required to make a wind turbine blade. Blades must be able to stand up under the duress of tens of millions of rotations and fatigue cycles for at least 20 years. This is no easy engineering task, especially when you consider that the blade can weigh as much as 20 tons and the speed at the tip of the blade can reach up to 200 mph. Blades must also withstand harsh sun, heavy rain, snow, ice, hail, gusty winds and lightning strikes.



The most typical types of structural design for large wind blades are "box beam," where the spar is a closed section beam manufactured separately and then bonded to the pressure and suction sides. In the type called "shear web," monolithic spar caps are embedded in the pressure and suction sides, and only the shear web is manufactured separately and then bonded to the rest of the structure.

Finding the Right Approach

Blade manufacturers are currently struggling with four major issues. First, they are not able to fully optimize the design of the blade because the analysis model and simulation lack some key elements of the composite definition. Second, a number of manual steps are required to produce the manufacturing engineering documentation for blade production, which leads to errors and a lack of repeatability. Third, a lot of touch labor is involved in the manufacturing process, which raises costs and slows the process. Finally, there is no formal design change management process so there can be a major disconnect between tooling and part design.

There are other complications. As blades increase in length, weight reduction becomes a critical concern because weight increases faster with blade length than energy throughput. Today, large blades are almost all made of glass-fiber-reinforced polymer (GFRP) because it currently represents the best way to strike the balance between performance and structural integrity. The good thing about GFRP is it is relatively inexpensive and provides sufficient strength and stiffness. However, as blade size increases, carbon-fiber-reinforced polymer (CFRP) is becoming more popular for developing some parts of the blades, such as spar caps and some of the root areas.

The root laminate of a blade is typically very thick - including several inches of GFRP plies - in order to withstand the enormous bending and torsion forces acting at the base of the blade. It is usually pre-cured separately to avoid overheating issues during curing and then joined to the blade main laminate.

The spar cap or the box beam provides stiffness against flap-wise bending due to the wind pressure. The upper and lower shells - pressure side and suction side - joined at the leading and trailing edges, provide the appropriate aerodynamic outer shape. Together, they also act as a torsion box to counter blade twisting and provide stiffness against edge wise bending that is due to drag forces and gravity.

The blade shells are typically built using balsa or foam material over some areas in order to increase bending stiffness and reduce the risks of buckling. The leading and trailing edges are typically reinforced with unidirectional material for both local reinforcement and also to increase the edge-wise bending stiffness.

So what is the most appropriate process for designing and manufacturing such a complex composite assembly that needs to satisfy stringent structural and environmental requirements? We can look to the aerospace industry for some of the answers. The aerospace and defense industries were early adopters of high-performance composites so it is no surprise that the bulk of the expertise is owned by people who have worked in those industries. Some of that expertise is transferable to other applications such as wind turbines.

For instance, some of the design methodologies and manufacturing engineering processes used to develop aircraft wings and fairings are similar to the process for developing blades. However, the wind industry presents some major differences in terms of part size, material types, layup processes and design tolerances. For example, a large variety of biax/triax/quadrax and multilayered matte/woven/uni materials are used on wind blades. Some ply draping and covering techniques are more pertinent to composite blade design, such as the extensive use of 2D-to-3D mapping of rolls of material, as opposed to aerospace where most plies, which are much smaller, are defined using 3D-to-2D flattening and trimming.

Employing End-to-End Solutions

In order to support their new advanced composite engineering and manufacturing processes, wind blade manufacturers must look beyond acquiring point solutions. What companies are really looking for is to create an end-to-end engineering environment with the best-in-class assets that can maximize efficiency and effectiveness.

Implementing an integrated composite design, analysis and manufacturing environment is a must if you want to develop a better and faster engineering process. This environment must be open and flexible so engineers can easily and rapidly adapt the tools to the needs of the wind turbine industry as well as specific customer requirements. It must also allow the company to select the best software components, be it the CAD platform for 3-D design, the CAE solution for structural analysis, CAM software for manufacturing simulation, or a PDM system for data management.

As the linchpin of the new engineering environment, the composite design software must support and be integrated with a diversified CAD and CAE base. It must also account for easy and reliable data transfer across the supply chain and different engineering sites that may use different CAD, CAE, CAM and PDM platforms.

Relying on a Master Model

It is vital that the digital composite model of a blade contains all the information required for properly manufacturing the part, including definition of all laminates and plies, associated flat patterns, manufacturing sequences and steps, accurate definition of the cored panels and interface definition for all mating parts. This enables seamless collaboration between engineering and manufacturing.

Such a master model must also enable so-called producibility simulations, or simulations of the manufacturing process. Producibility simulations enable the design or manufacturing engineer to predict manufacturing issues such as composite fabric wrinkling or bridging, that may appear due to material deformation when laid up in the blade molds. By accurately predicting such issues, simulation software enables early resolution of the manufacturing issues without the need for making many costly prototypes that lengthen the development process.

As the market increasingly demands larger, lighter and better performing wind turbine blades, the need to automate the development process will only become greater. Companies that are able to master automation will thrive because they will enjoy dramatic reductions over manual methods in labor and manufacturing costs as well as cycle times. Those cost reductions will be essential to making wind energy a sustainable and profitable energy source.

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