Wind Turbines Take a Technical Spin at Generating Electricity

Simulation verifies **design durability** of a new rooftop **wind energy** system.

by **Richard Peek**

Wind turbines convert kinetic energy into mechanical power. In use for centuries, they have harnessed the power of the wind to pump water, grind grain and generate electricity.

While their popularity has peaked and ebbed over the years, interest in wind turbines to generate electricity is again gaining momentum. As an alternative to fossil fuels, wind energy is seen as a viable way to produce energy while reducing global warming and pollution.

Although there are various types of wind turbines on the market, one type that is capturing worldwide attention is known as the small wind turbine – a system with a rated capacity of 100 kilowatts (kW) or less. Some small wind turbines are designed to be installed on top of a roof and are geared to residential or industrial use.

Cascade Engineering, a leader in plastic injection-molded systems for the automotive, industrial and solid waste industries, is familiar with small wind turbines. Through close business collaboration with an established United Kingdom-based wind turbine manufacturer and a global design consultancy, Cascade used simulation to justify a move to an injection-molded rotor design over the existing, expensive, labor-intensive carbon fiber construction. In addition to mass production scalability, the molded construction presented the opportunity

The building-mountable SWIFT wind turbines feature injection-molded blades developed by Cascade Engineering.

to significantly reduce time-to-market and production costs – making wind power generation a more viable, "green" energy solution.

The Swift Solution

Renewable Devices Swift Turbines Ltd., based in Edinburgh, Scotland, unveiled its SWIFT Rooftop Wind Energy System in 2004. This building-mountable wind turbine serves as an energy source for domestic, community and industrial use.

When correctly sited, it cuts up to 1.2 tons of carbon dioxide emissions annually and reduces electricity bills. Designed to be environmentally sustainable, it produces more energy in its lifetime than is incorporated in the materials and processes used to manufacture it. Therefore, it is designated as "harm neutral."

The SWIFT has a rated power output of 1.5 kW and can supply up to 2,000 kW per year in a good wind condition – about 20 percent of an average home's use. It is a grid-connected form of embedded power generation. That is, in a normal residential application, a home is served simultaneously by the wind turbine and a local utility.

For example, if the wind speed is not high enough to spin the wind turbine's blades, there will be no output from the turbine, and all of the needed power is purchased from the utility. As wind speeds increase, turbine output increases, and the amount of power purchased from the utility is proportionately decreased. When the turbine produces more power than is needed, utilities typically institute a policy called "net metering," where the meter turns backwards and the customer gets a credit. All of this is done automatically.

The SWIFT wind turbine includes three major components – the rotor, the generator and the structural support. The rotor features specially designed blades and a patented diffuser ring that quietly capture the wind energy; the generator, with control electronics, converts the mechanical energy into electrical energy; and the support structure, or mast, has a special mounting system that minimizes vibration to the building. Cascade Engineering focused its expertise in plastics on developing an injection-molded alternative to the current carbon fiber rotor blades.

Building the Blades

Traditionally, wind turbines generate noise as the wind travels the length of the blades, which have curved surfaces. The SWIFT wind turbine, with its five blades, is quiet. That's because the wind turbine features an outer ring that acts as a diffuser as the wind travels down the blades and is dispersed along the ring. Noise from operation is less than 35 decibels for all wind speeds.

Initially, Renewable Devices constructed the blades from carbon fiber. However, it is a costly material that poses some challenges. For example, because the carbon fiber rotor manufacturing process is manually labor intensive, it can take a long time to make the blades. Second, there is an opportunity for error: if the carbon fiber material is inadvertently laid in the wrong direction, it can affect the blades' strength. Third, it is difficult to maintain consistency from product to product.

What Renewable Devices needed was a more cost-effective rotor. The company found just such a solution in an injection-molded rotor with thermal plastic blades that Cascade Engineering developed.

The Cascade Engineering team made slight changes to the original outer envelope of the rotor. Most of the design effort focused on adding internal ribbing and other geometric features that would provide strength to the rotor while also reducing stress. A key objective was to create as stiff a structure as possible.

Cascade worked to meet engineering standards set forth by the International Electrotechnical Commission. The IEC 61400-2 Small Wind Turbine Safety standard applies to wind turbine generator systems with swept areas of less than 40 m^2.

Simulation Savvy

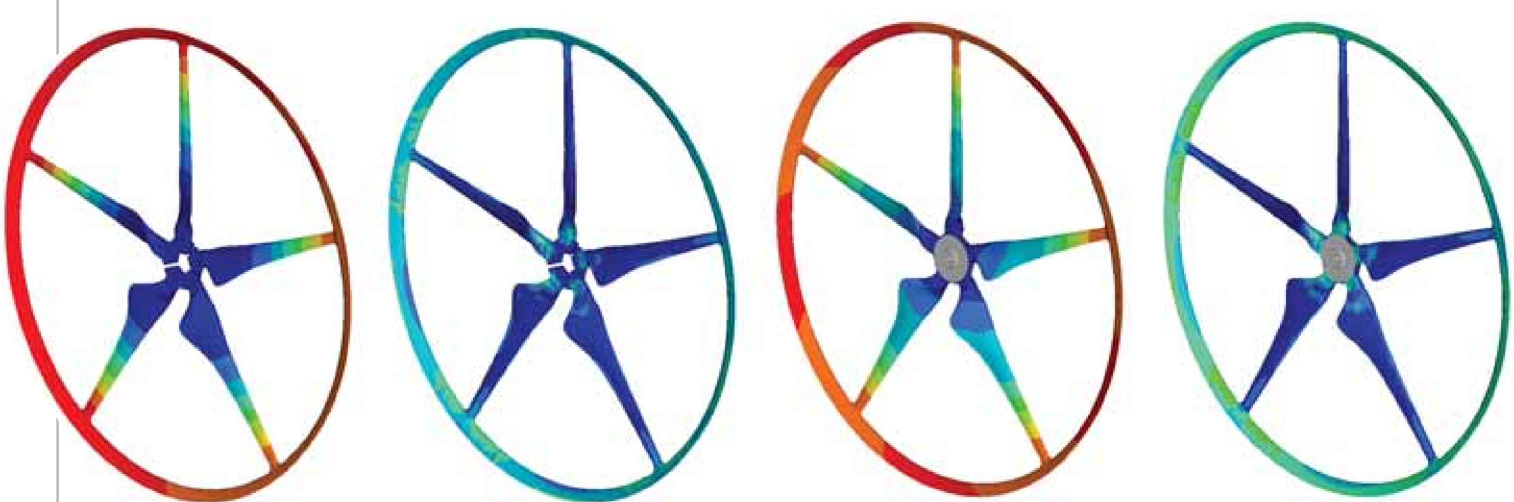
As part of the development process, Cascade Engineering collaborated with Altair ProductDesign, a global design consultancy and division of Altair Engineering, Inc., to provide design direction, through simulation, to successfully develop a thermal plastic rotor replacement. It was important to understand how the injection-molded rotor compared with the original carbon fiber design.

High-Tech Wind Turbine

Several characteristics make the SWIFT Wind Turbine unique:

- **Silent operation.** Patented, acoustic suppression aerodynamics, notably the ring diffuser, removes noisy, turbulent air currents at the blade tips. Also, the direct-driven generator contains no gear box, which means there is no mechanical noise.
- **Anti-vibration mounting brackets.** For placement on buildings, the SWIFT mounting systems are scientifically designed to dampen all resonances that may be encountered during normal operation of the turbine. The mounting brackets feature integrated anti-vibration technology that ensures that no discernable vibration is transmitted to the structure.
- **Mechanical/electronic furling.** As the wind increases past a certain speed, the turbine starts to furl, or turn itself out of the wind. Even when it is not pointing directly at the airflow, the SWIFT's rotor enables it to operate efficiently, regulating the energy taken from the wind and, consequently, the electricity generated. An electronic furling system copes with the extra strong gusts of wind by regulating the rotational speed of the rotor, thus keeping power generation at its optimal level.
- **Electronic braking.** An automatic electronic brake activates in the event of extreme wind speed, and no power is generated.

On behalf of Cascade Engineering, Altair ProductDesign, a global design consultancy and division of Altair Engineering, Inc., employed Altair HyperWorks to evaluate the fluid and structural performance of the wind turbine's thermal plastic rotor blades.



Count on Cascade Engineering

Based in Grand Rapids, MI, Cascade Engineering is a leader in the development, engineering and manufacturing of plastics solutions for multiple industries, including the automotive, industrial and solid waste markets. The company is a strong advocate for "sustainable" business practices that emphasize the key role business can play in building financial, social and ecological capital.

Fred P. Keller is chairman and CEO of Cascade Engineering. Under his leadership, the company has grown from a small injection-molding operation with six employees into a complex manufacturing organization with 1,200 employees, 13 facilities worldwide and annual sales of $300 million.

Cascade serves a diverse customer base ranging from auto manufacturers such as Ford Motor Company, Chrysler, GM and Honda, to office furniture manufacturer Herman Miller, Inc., to municipal governments including the City of Rochester, NY, and others. Cascade steps up to the challenge, devises innovative solutions and produces results.

For the City of Rochester, for example, Cascade developed a tamper-proof bar code tracking system for 70,000 waste containers. Each container included a permanent, in-molded bar code, allowing the Department of Environmental Services to assign waste containers to specific addresses.The city expects to save up to $200,000 per year in container replacement and dumping costs as well as improve operational efficiency.

For more information about Cascade Engineering, visit *www.altair.com/c2r* or check 05 on the reply card.

Altair aerospace engineers, with deep domain expertise in air flow, employed Altair HyperWorks enterprise CAE solution to comparatively evaluate the fluid and structural performance of the thermal plastic design against the baseline and IEC 61400-2 requirements. This information was used to provide critical design direction to successfully develop the molded replacement.

The injection-molded results returned similar stress areas as found on the carbon fiber design. Deflections were reasonable. The challenge, however, was to get the thermal plastic design stresses low enough to meet fatigue and yaw specifications in the standard.

The tensile strength of carbon fiber is higher than a thermoplastic material. Engineers needed to reduce the stress level in the thermoplastic rotor to acceptable levels for the material. The advantage with the thermoplastic rotor is that engineers had more design freedom to introduce geometry inside the blades and to the outer diffuser. This allowed the opportunity to reduce the stress to levels under the limits of the material.

To ensure the thermal plastic design would meet the in-service requirements customers have come to expect, a detailed design study was performed prior to committing to hard tooling. Cascade and Altair engineers leveraged HyperWorks to understand the influence of radii changes and modified design features including rib number and placement, sizing and box sections.

Blowing into Production

By implementing simulation technology, Cascade confidently went straight into production tooling, avoiding the time and cost associated with pre-production tooling. In addition, by moving from a carbon fiber to injection-molded design, overall cost savings were substantial.

In an agreement with Renewable Devices, Cascade Engineering now will supply injection-molded rotors for the SWIFT Wind Turbine on a worldwide basis. What's more, Cascade has North American distribution rights to the wind turbine, which will be introduced in September 2008. C2R

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For more information about the SWIFT Wind Turbine and HyperWorks, visit *www.altair.com/c2r* or check 03 or 04 on the reply card.