PREPREG – LENGTHENING THE DESIGN ENVELOPE

New resin technology provides rapid curing and exothermic control to turbine blade spars and roots.

By Kevin Cadd

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SUPPLYING MATERIALS TO THE WIND ENERGY market since 1995, Gurit specializes in the development of composite blade materials, meeting the demand for larger and more complex designs.

The tendency among large turbine manufacturers in the industry in recent years is to supply longer blades on existing turbine designs to suit light wind sites, or to install offshore turbines that are multi-megawatt machines, requiring larger blades, that can withstand higher loading.

The main load-bearing structure of a wind turbine blade is the spar component, which is either integrated into a structural shell as a spar cap, or constructed in parallel production to the shell as a separate spar structure complete with shear webs.

What is common to both approaches is that the utilization of unidirectional fiber (UD), glass or carbon, to provide bending strength and stiffness. The fiber also has to withstand compression loads; particularly in longer carbon blades and consequently the fibers need to remain straight and receive consistent support by the surrounding resin to prevent buckling. In order to enable longer blades to be designed it is important that the properties of the fiber are maximized when converted into a sparcap laminate.

Collimated fiber formats like prepreg provide a good starting point to achieve these requirements, but there are additional challenges to maintain the fiber straightness and prevent voiding during the application and cure of thick section spar components. Other factors outside of material performance also play an important role in material and manufacture process selection, such as storage and lay-up temperature and tooling specification.

Gurit has set out a clear strategy to address these barriers to allow the use of prepreg in order to maximize the performance of unidirectional fiber and enable the next generation of blades. Two key technology steps in this strategy are:

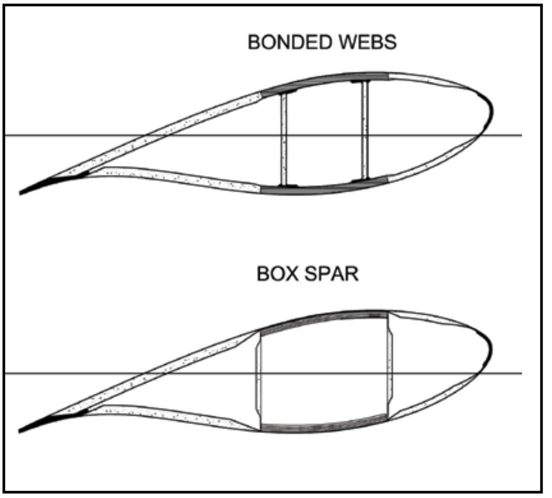

Figure 1: Structural Shell and Structural Box Spar Blade Designs

- Velinox™ Resin Technology – to enable low cost tooling, eliminate cold storage and minimize cure time
- Airstream™ Coating Technology – to enable very low void content laminates without debulking or the requirement for air-conditioned factories.

VELINOX™ RESIN TECHNOLOGY

Velinox™ is a new resin technology, developed by Gurit as a next generation resin platform to enhance Gurit's current wind energy Prepreg and SparPreg™ products. The resin has been designed specifically for the cure of thick sections, such as wind turbine blade spars and roots. This chemistry does not exotherm in the same way as a standard epoxy, enabling the cure profile to be modified to eliminate time-consuming dwell periods that control exotherms in conventional resin systems. The result is a greatly reduced production cycle improving the mould utilization with the additional benefit of lower wear on moulds due to the lower peak temperature. The system can be cured at temperatures as low as 100°C, but can also be used for rapid manufacturing of components through its 10 min cure at 130°C and 20 min at 120°C even at thicknesses up to 100mm. Therefore, both thick and thin laminates can be cured quickly and provides the option to specify low or high temperature performance tooling. Figure 2 shows the temperature profile of the centre of two 92mm glass laminates. In the laminate with the conventional epoxy system (red line) a 70°C dwell was used to minimise the peak exotherm. The Velinox™ system (blue line) does not require a dwell and therefore can be heated directly to the preferred cure temperature (blue dotted line), which in this example is 125°C. A small exotherm is observed with a delta of only 15°C and full cure is achieved in approximately 10 minutes from the peak temperature time.

While the primary advantage of the new resin system is rapid curing and exotherm control, Velinox™ also addresses another disadvantage of conventional prepreg materials – cold storage. Most epoxy prepreg systems have latent curing technology, which enables pre-mixing of the resin and hardener before fiber impregnation. The prepreg then remains in an uncured state until reaching higher temperatures (>70°C) to activate the catalysts. However, in practice, the prepreg will slowly cure at room temperature (from days to weeks depending on the system) and therefore for purposes of shipping and stock control the prepreg needs to be chilled or frozen. The new resin technology has different catalyst technology from conventional epoxy prepregs and therefore has significantly improved shelf life characteristics. With a shelf life of over 4 months at 35°C the need for a frozen or chilled supply chain is eliminated reducing both freight and storage costs.

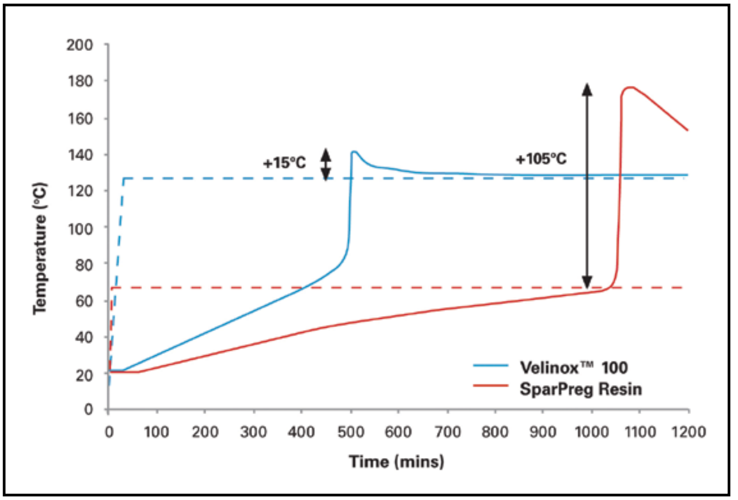

Figure 2: Despite curing Velinox 125°C, only a 15° C exotherm above the air temperature (dashed lines) is observed compared to 105°C using a standard resin.

AIRSTREAM COATING TECHNOLOGY

Velinox™ resin technology addresses two of the common problems of using prepreg materials, of exotherm and material storage. However, this

alone does not enable the manufacturing of high quality wrinkle free parts with low void content, which is critical to prevent premature failure of the laminate and maximize fiber structural contribution. The optimal utilization of the fiber properties is particularly relevant when considering the high cost of carbon fiber.

Conventional prepregs are processed using vacuum bag technology to remove the air between the plies prior to consolidation and cure. However, as laminate thickness increases it is difficult to maintain high quality, low void content laminates without the use of multiple debulking steps and/or the use of high-pressure autoclaves to consolidate the plies. However, due to the size of spar caps and the manufacturing cost targets it is not feasible to use multiple process steps or expensive capital equipment. It is for this reason that specialised prepreg products have been developed to enable the manufacture of high quality large structures for the wind energy market.

Figure 3: A Wrinkle in a carbon laminate after consolidation

While it is important to maintain voiding within the laminates to a low level (<3%) and to ensure individual voids are small in size (< 1-2mm diameter) what is more critical is to avoid the introduction of wrinkles in the laminate. A wrinkle of even small amplitude can

produce an area of laminate that would be more susceptible to buckling under compression loading. The avoidance of wrinkles is a significant challenge in spar cap manufacture due to the geometry and thickness of the component. The tooling often has a double curvature profile, which requires the prepreg material to have significant drape capability and wrinkling resistance. This can prove a challenge for a number of reasons: the prepreg is typically only 500-600 microns thick and therefore is generally susceptible to buckling if not handled carefully; the drape increases with temperature, but the removal of inter-ply air decreases rapidly with temperature reducing the process window for good drape characteristics; and the draping of a prepreg is a time dependent viscoelastic process, which complicates rapid deposition using automated application techniques.

One approach to increase the process window of spar manufacture is the use of a lightweight scrim laid in between each ply of prepreg. This increases the airflow between the plies under vacuum pressure enabling the removal of air between the plies and therefore reducing residual void content. However, this approach has some drawbacks as the scrim can decrease the compression strength of the laminate and the beneficial air removal effect is still limited to temperatures around 25°C at which point the tack of the prepreg becomes problematic. As a typical blade manufacturing plant can run at temperatures as high as 35-40°C in the summer months this solution has its limitations due to the high operating costs of air conditioning.

To overcome the conflicting material characteristics of low tack at the same time as high drape, and avoid any detriment to mechanical performance, the new product using a specialized coating technology to give the combination of:

- An air venting structure on the prepreg surface(s) that operates under vacuum even at temperatures as high as 40°C;
- A controlled level of tack and handling properties over a wide temperature range (15-40°C);
- And mechanical performance consistent with uncoated prepregs

The increased air permeability between the plies provided by the coating is an extremely effective way of removing inter-ply porosity when the vacuum is applied. The resulting laminate has very low void contents (<2%) even when factory temperatures are in excess of 35°C.

The second feature of the product is the low tack and high

drape it exhibits over a wide temperature range. The coated surface of the prepreg promotes sliding of the prepreg plies during layup and subsequent vacuum consolidation, preventing “stick-slip” and the formation of wrinkles.

Conventional prepreg processed at temperatures around 25°C would produce laminates with void contents in the order of 10-20% even without considering the formation of large wrinkles.

As the design of large multi-megawatt wind turbines progress, more designers are investigating the benefits that prepregs bring in terms of mechanical performance and quality assurance. As many of the designers are more familiar with infusion technology they have some reticence about the manufacturing complexities and overall cost of using prepreg. With Velinox™ Resin Technology and Airstream™ Coating Technology, Gurit hopes that its new prepreg developments will address many of the concerns surrounding the adoption of these materials and significantly reduce the cost of use by taking a holistic approach to material development.

Figure 4: A laminate manufactured using Airstream™ Coating Technology at +38°C. Void content <1.5%.