WINDTECH INTERNATIONAL

January/February 2019 Volume 15 No. 1

Using Polyester Resins in Rotor Blades

A Cost Reduction Opportunity?

Using Polyester Resins in Rotor Blades

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A case study performed within We4Ce shows a blade cost reduction opportunity for polyester resins in rotor blades. However, will this cost reduction for the blade also lead to a lower cost of energy?

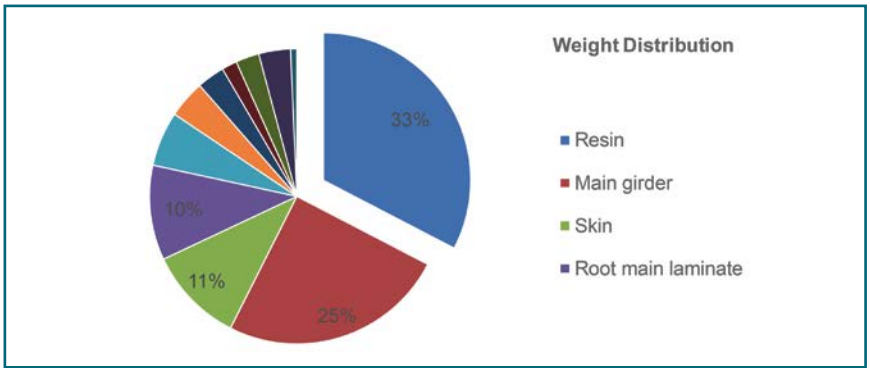

Figure 1. Weight distribution for the default blade design

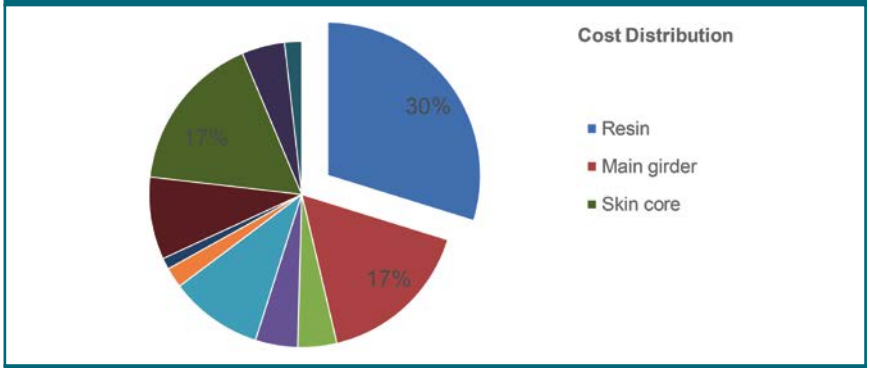

Figure 2. Cost distribution for the default glass blade design with epoxy resin

Epoxy

Many of the present blade designs use glass fibres or carbon fibres embedded in an epoxy resin system. Epoxy is a high-performance resin with a low viscosity suitable for the resin infusion moulding system. This is a vacuum closed moulding technique implemented and used in most rotor blade manufacturing facilities in the past 20 years.

Epoxy has high fatigue properties and is a resin system capable of surviving the 20–25 year load spectrum. Epoxy has a low shrinkage percentage, which is beneficial for those applications where geometrical tolerances are essential. Further, it is a material that is widely accepted when it comes to health, safety and environmental topics. From a technical performance point of view, epoxy can therefore be classified as a 'tier 1' resin system with a good track record for the last decade of the wind industry.

One big disadvantage chases the epoxy system – the cost level. Epoxy requires process tooling including a heating system and the resin system is not the cheapest available. The cost for epoxy resins is about € 4/kg. Noting that one third of a rotor blade weight consists of resin (see Figure 1), this means that the resin system has a big footprint in the final bill of materials (BOM) price and the blade price. In Figure 2, the resin system accounts for 30% of the costs, the glass fibre of the main girders (spar caps) 17% and the core materials (excluding resin absorption) another 17%.

Polyester

To lower the costs of a set of rotor blades, one of the many parameters to look at is alternative resin systems. In this, polyester or unsaturated polyester, polyurethane and vinyl ester are first glance alternatives. Looking at costs, polyester is by far the preferred matrix system to use, having a price level of around € 2/kg. This is thus half the price of the epoxy competitor.

The mechanical properties or engineering properties of polyester resins are lower compared with those of epoxy, the styrene emission is worrying and shrinkage is high(er). However, some of the drawbacks seem to have been overcome or will be mitigated in the future with ongoing developments.

Trend Towards Longer Blades

With the trend towards longer rotor blades together with a demand for a fast time to market when launching a new product, the use of polyester might become more attractive again (at least for certain parts) or is even already considered the way to go. This is supported by dropping power densities of the on-shore turbines due to lower wind class regimes, and also by the expected need for a higher capacity factor (more full load hours) offshore. The relative long rotor blade designs are generally strain or stiffness driven instead of strength limited. This is due to tip to tower distance constraints, constraints for pre-bend, as well as constraints for pitch moment loading. The outboard part of the rotor blade will often be less critically loaded, which opens doors to a lower grade and more cost-effective resin system for that blade part, at least for the shell structure.

Split Joint

The interest in applying a different resin system, for example for the outboard part of the rotor blade, is amplified with upcoming split-joint or modular rotor blade solutions coming from, for example, Nabrawind and We4Ce.

The use of polyester as an alternative resin system or parallel resin system will lead to lower capex costs since mould heating is strictly speaking not required

Modular Root

Features that are important for the blade root of a wind turbine blade are stiffness, form geometric tolerance and cost. The use of a polyester resin in a modular root (see Figure 3 and 4) for cutting costs seems feasible when considering the high shrinkage percentage in the tooling of the root manufacturing and adopting the proper design and testing methodology for the interface with the rest of the blade.

Case Study

A case study performed with the engineering properties given by One Shot Blade manufacturer Cartflow showed that transforming an epoxy blade into a polyester one gives a potential 20% material cost price (BOM) reduction (see Figure 5).

As an example, for the Chinese market, assuming the 2.5MW We4Ce 59.5m rotor blade, this would mean a cost saving for the blade manufacturer of around € 25,000 per set.

For the 3.xMW rotor blade of We4Ce, a gain of towards € 40,000 can be accounted for, while an 8MW rotor blade will achieve a benefit of nearly € 60,000 per set of three blades.

By adopting the lower engineering properties of polyester, if a complete blade is to be produced out of polyester it is important to consider that the blade mass and the blade mass moment will increase by about 10%.

Due to the mass moment increase of the blade, an increase in cost of energy (COE) is expected if the turbine is still in the development stage, as main turbine components like the drive train and tower could require additional reinforcement.

This raises therefore the question of whether it would be beneficial to use polyester for a complete blade design and rather suggests the use of polyester for sub-parts.

For existing wind turbine platforms having enough design reserve margin (a so-called oversized turbine), the change towards a heavier but cheaper blade would lead to a lower COE, simply made possible by consuming the turbine margins left.

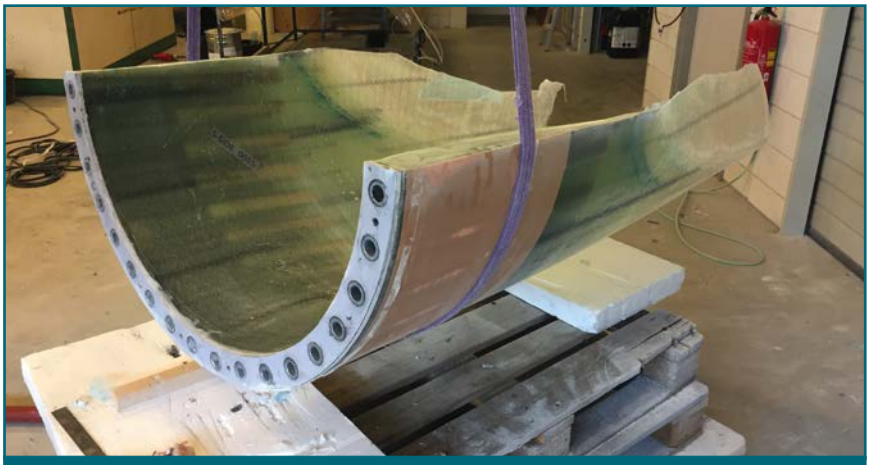

Figure 3. Root connection technology, We4Ce

Figure 4. Example of a prefab modular blade root solution shown here in M20 size

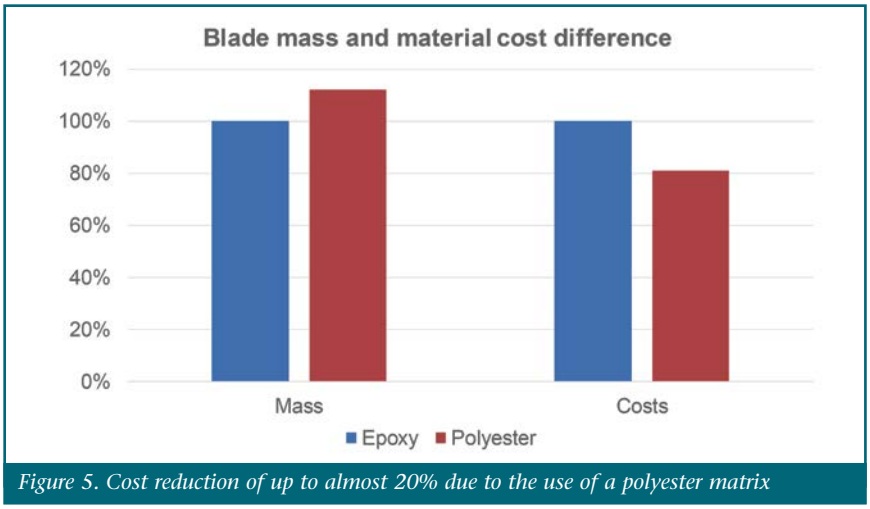

Figure 5. Cost reduction of up to almost 20% due to the use of a polyester matrix

Opportunities

For new wind turbine platforms the use of polyester in rotor blades is of interest for a fast(er) time to market, a reduction of the capex, or for adaptive blade lengths using, for example, modular blade tips to reach several rotor diameters (blade families) for limiting turbine oversizing. Also, a modular blade root seems feasible. In the case of the latter, part of the blade design can be equipped with polyester for lowering costs without mass moment disadvantages.

A full polyester rotor blade being used in the design process of a new wind turbine platform can lead to an unacceptable increase in the mass moment, leading to a lower cost price for the blade manufacturer, although not by definition leading to a lower COE for the end customer.

For wind turbines that have already been on the market for a while and for which it has been shown that design margins are still in place, or for wind turbines that lower their COE by concentrating on the serial purchase of

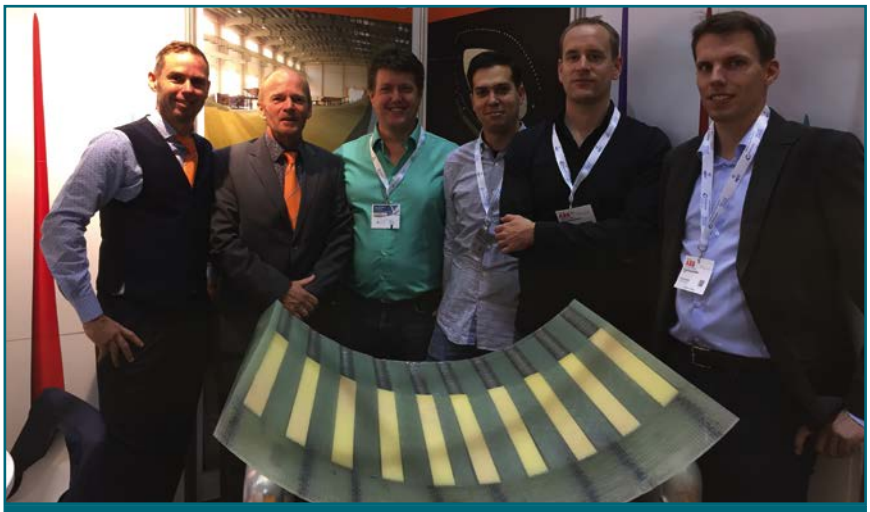

Figure 6. Part of the We4Ce team from left to right: Edo Kuipers, Arnold Timmer, Erik Vos, Gerardo González, Arjan Bronsvoort and Kees Huckriede presenting the new modular root sample at WindEnergy Hamburg 2018

components, a full polyester blade can certainly lead to a further lowering of the COE.

Carbon Girders

Then, as everyone could also imagine, the same story and discussion can be held for the use of higher qualified materials, like carbon, in rotor blades. The use of carbon will lead, among other things, to a lower mass moment, but it will also lead to a much higher blade price. The final COE will, however, be potentially lower. ■

With more than 20 years of experience in blade design, Edo Kuipers is one of the founders and co-owners of We4Ce. His main responsibility is running the engineering department from the aerodynamic rotor blade design, structural design, up to accomplishing the certification documentation. His special interest is the application of the in-house developed bushing connection in many wind turbine blades as connection technology between the rotor blade and the turbine. Edo studied Aeronautical Engineering in the Netherlands and holds a BEng degree.

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