# Polyester Resins in Rotor Blades, a Cost Reduction Opportunity?

By Edo Kuipers, Engineering Manager, We4Ce, The Netherlands

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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 (CoE)?**

## 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 (RIM) 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 capable resin system to survive the 20-25 years load spectrum. Epoxy has a low shrinkage percentage, 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 “tear 1” resin system with a good track record for the last decade of 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 costs for epoxy resins is about 4 Euro’s per 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 blade price.

See Figure 2, where the resin system gives 30% of the costs, the glass-fibres of the main girders (spar caps) 17% and the core materials (excluding resin absorption) another 17%.

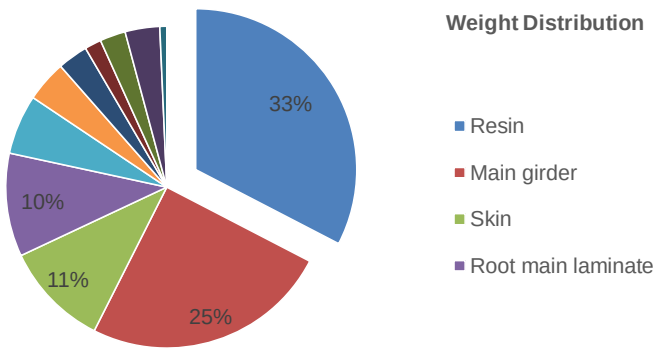


Figure 1: Weight distribution for the default blade design.

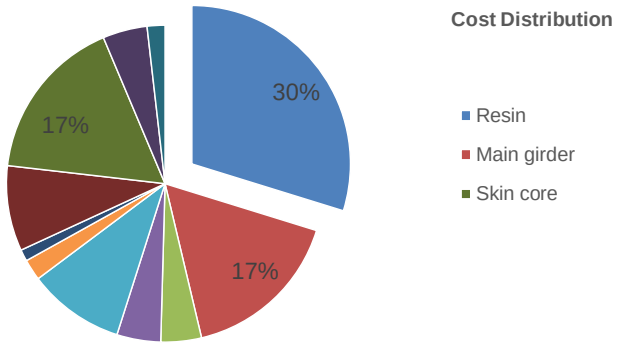


Figure 2: Cost distribution for the default glass blade design with epoxy resin.

## Polyester

To lower the costs of a set of rotor blades, one of the many parameters to look at are alternative resin systems.

In this, polyester or unsaturated polyester, polyurethane and vinyl ester are first glance alternatives.

Looking at costs, polyester is far out the preferred matrix system to use, having a price level around 2 Euro per kg. This is thus half the price of the epoxy competitor!

The mechanical properties or engineering properties of polyester resins are lower compared to epoxy. The styrene emission is worrying, shrinkage is high(er).

However, some of the drawbacks seems to have been overcome or will be mitigated in future with on-going developments.

## Trend to Longer Blades

With the trend to longer rotor blades, next to 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 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 due to tip to tower distance constraints, constraints for pre-bend, as well constraints for pitch moment loading.

The outboard part of the rotor blade will often be less critical 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 to apply a different resin system for example the outboard part of the rotor blade is amplified with upcoming split-joint or modular rotor blade solutions coming from e.g. Nabrawind and We4Ce.

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

## Modular Root

Important features for the blade root of a wind turbine blade are stiffness, form geometry tolerances and costs. The use of a polyester resin in a modular root (See Figure 3 and 5) 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.

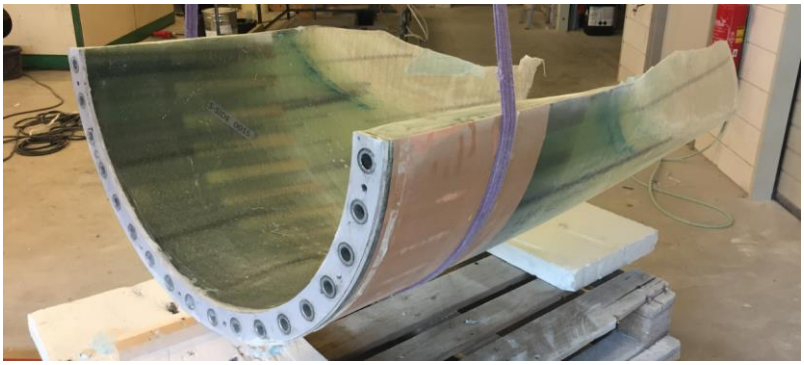

Figure 3: Root connection technology We4Ce.

## Case Study

A case study performed with the engineering properties given by one-shot-blade manufacturer Cartflow showed that transforming an epoxy blade into polyester gives a potential 20% material cost price (BoM) reduction (see Figure 4).

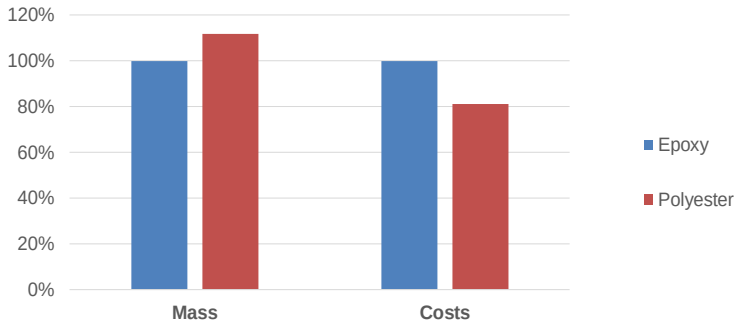


Figure 4: Cost reduction up to almost 20% due to the use of polyester matrix.

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 Euro per set.

For the 3.x MW rotor blade of We4Ce a gain towards 40.000 Euro can be accounted for.

While an 8MW will be in the race for a benefit of nearly 60.000 Euro per set of 3 blades.

With adopting the lower engineering properties of polyester, there is also a counterpart to be considered if a complete blade would be produced out of polyester: 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 CoE is expected if the turbine is still in the developing stage, as main turbine components like drive train and tower could require additional reinforcement.

This raises therefore the question if it would be beneficial to apply polyester for a complete blade design and would point the finger more in the direction of 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 more heavy but cheaper blade would lead to a lower CoE, simply made possible by consuming the turbine margins left.

Figure 5: Part of the We4Ce team from left to right Edo Kuipers, Arnold Timmer, Erik Vos, Gerardo González, Arjan Bronsvoort, Kees Huckriede presenting the new modular root sample at Windenergy Hamburg.

## 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 latter case, 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 however not per definition leading to a lower CoE for the end- customer.

For wind turbines that are already 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 serial purchase of components, a full polyester blade can certainly lead to a further lowering of the CoE.

## Carbon Girders

Then, as everyone could also imagine, a 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 a.o. to a lower mass moment but will also lead to a much higher blade price but potential lower final CoE, when considering the holistic process.