The circle of life

Ray Lewis, Market Segment Manager, Wind Energy at Diab, looks at the evolving product life cycles of core materials used in the manufacture of composite wind blades. How do market conditions and supply chain issues affect production decisions and what might the future look like as demand grows for zero carbon energy types?

Following articles published in PES in 2013 and 2015, there have been many changes taking place in an ever-dynamic global wind market. After the 2020 bubble, the market is currently flat, ahead of anticipated growth in offshore and repowering.

Consequently, all stakeholders face a challenging period, and many are now focusing on getting ready for the next scalability challenge. As such, now seems an opportune time to reflect on how this has and is developing in one specific area, structural core to meet market needs. Both the author and Diab have been involved throughout the period of modern day wind turbines, so share their experience here on the journey they have seen and expect to see.

Energy

Fundamentally, with energy being an essential resource, it invariably is heavily influenced by respective countries' individual and collective political and economic drivers.

In general terms, demand for energy increases year-on-year to meet increased domestic consumption, as the population grows and electrifies, not to mention industrial demand.

This growth and, most significantly, the mix of energy types is shown in the graphic from Wood Mackenzie.

With the climate debate arguably at its highest right now, this graphic seeks to remind us of the world's heavy dependence on hydrocarbons.

Hopefully the recent COP26 in Glasgow, UK, will lead to actions taking place to increase the market share even further towards zero carbon energy types. Such a shift would be highly significant and place a challenge on the respective energy form to have scalability and cost bases in place to meet this demand. This represents an enormous opportunity for all renewables, including wind.

Wind

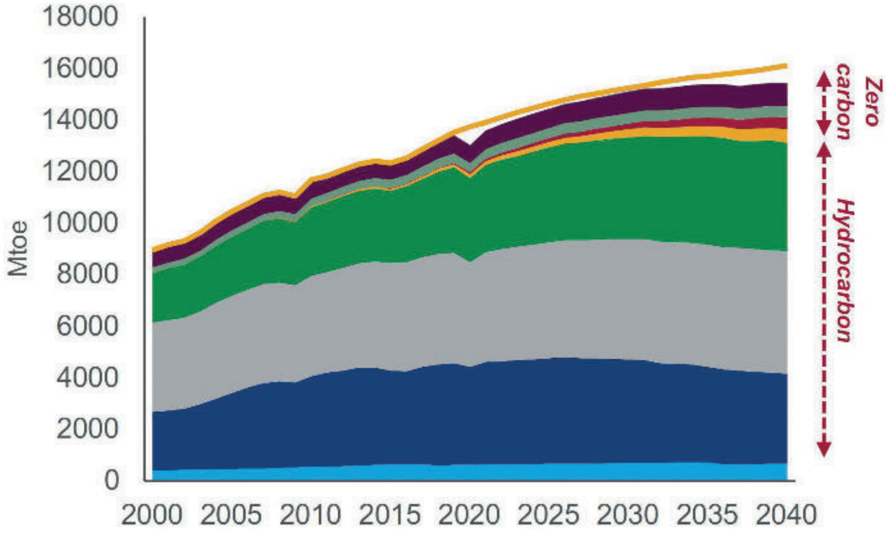
Since the beginning of time, this natural resource has been used in many ways, not least to provide energy to power sailboats, windmills and in recent decades, modern wind turbines.

In the last 50 years, these wind turbines have progressively increased in size from 25KW to 14MW to more effectively and efficiently capture and reduce the Levelized Cost of Energy (LCoE).

Initially, onshore has been the major segment to date and whilst this will continue to grow, the largest % growth will come in offshore, to harness more power effectively from new sites, and repowering, as the ageing fleets come to end-of-life.

The chart below, based on Wood Mackenzie data, shows the significant growth of wind, but again this needs to be taken in context with the previous graphic on all energy sources.

In addition to the size, one can also see the significant peaks and troughs which have occurred through the evolution thus far, primarily driven by tariffs in China and the USA. As the market size has grown year-on-year, the resultant impact of these becomes

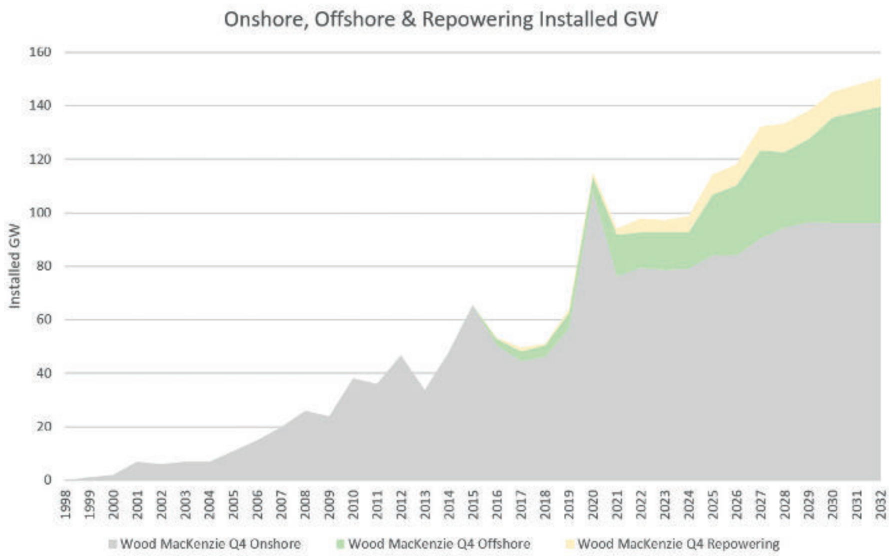


larger, most recently in 2020, when a largely unforeseen demand was achieved, as stakeholders rushed to beat the ending of onshore tariffs in China.

Wind blades

The wind blade is one of the key components of a modern-day wind turbine and is, more often than not, a key differentiator between OEMs. As a result, whilst blades look similar, there are considerable differences of detail beneath the surface, which lead to variations in blade bills of material (BOMs).

The use of a sandwich composite design has become the default approach in the production of the blades of modern day, horizontal axis wind turbines. Simplistically, sandwich composite blades consist of a resin, for example epoxy or vinyl ester, and reinforcement, for example glass and/or carbon, on either side of a structural foam core material.



The core has a density typically of 60-250 kg/m^3, with a typical example being balsa wood, or polymer based foam from PVC and PET, which is used primarily to reduce the laminate, and as a result, the blade weight, while sustaining the out-of-plane strength and rigidity.

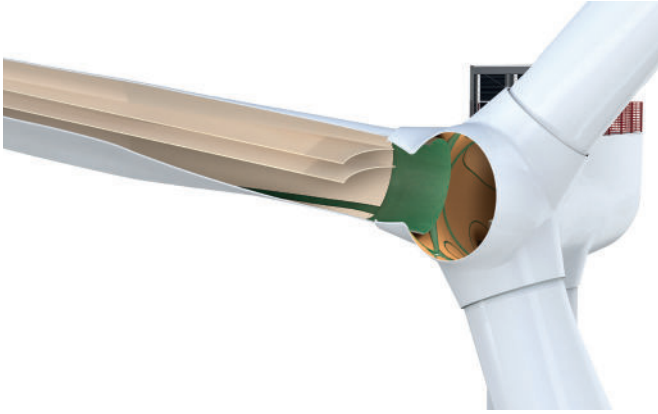
The load carrying members of a typical blade consist of structural webs connected to monolithic girders to form an approximation of a boxed beam, which in turn is joined to the root end. The surrounding two-part shell transfers wind loads to the load carrying members while providing the optimum aerodynamic shape.

Core material is used in the following sub-components, optimised to deliver the required design performance.

- Webs: using PVC core in the 60-80 and/or PET, 100-115 kg/m^3 density ranges
- Shell in the Root-Shoulder: This and its immediate adjoining spar/girder area is often referred to as the primary structural element of the blade, as here, the considerable forces and loading come to bear in service life. It is most common to find balsa 130-150 or PET 150-250 kg/m^3 range used
- Shell in the Shoulder-Tip: These typically use a much lighter PVC core in the 60-80 kg/m^3 density range, and/or PET, 100-115 kg/m^3

As mentioned earlier, with turbines increasing in KW/MW size, so have blades, from 4.5 to over 100 metres in length. Whilst the effect of fewer turbines to produce the same GW generally reduces the materials required, with core this is not the case, as the thickness and from that volume in m^3 consequently increases.

Furthermore, since there are many ways to achieve the end goal, it is not surprising to find blade bills of materials differ. Thus, the success, or otherwise of a given player, in



given market geographies and sub-segments can have a significant impact on the volumes used of different core materials.

Core materials

In the early years, balsa and PVC were the default choices to meet these needs. Northern European based blade manufacturers typically had designs using either 100% PVC foam core of around 80 kg/m³ or hybrid designs of balsa with a density of 150 kg/m³ and PVC in 60-80 kg/m³. This then became the default as designs globalised, then localised as new domestic players entered, most noticeably in China.

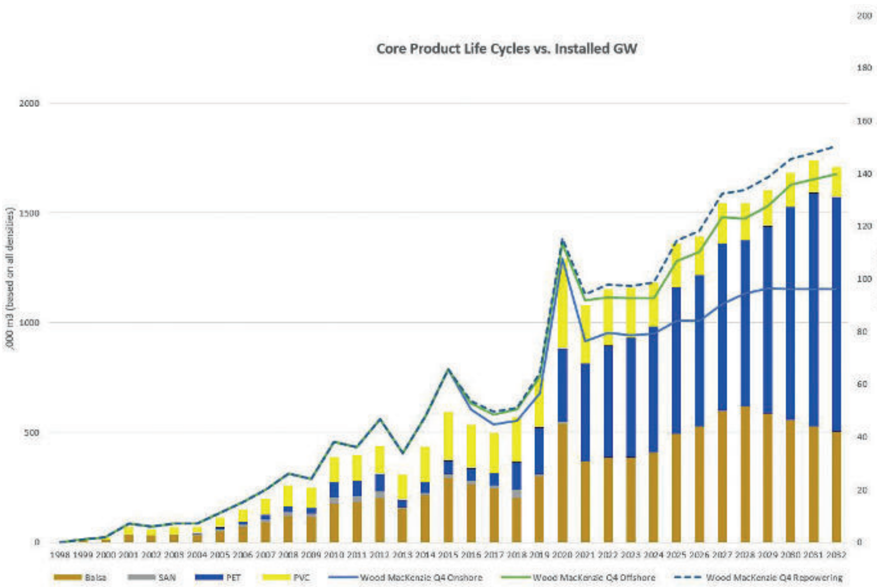
The growth years, in the early 2000s, saw the introduction of SAN, as an alternative to PVC 60 kg/m³ and most significantly PET 115 kg/m³ as an alternative to PVC 80 kg/m³ in prepreg blades, as the market struggled to meet the demand. At the time, the volumes to meet technical and commercial demands from wind OEMs were a significant new addition to the composite market.

The globalisation years, with PET starting to replace western PVC, saw demand grow significantly yet again. Up until this point, blade manufacturing had been done largely in-house, or by sub-contractors. Increasing commercial pressures saw OEMs use new build-to-print manufacturers, which also led to the market moving to infusion manufacturing as a default method of manufacture.

This development and the continuing focus on cost saw PET being developed and introduced increasingly into infusion blades, replacing PVC 80 kg/m³ and in some cases 60 kg/m³. Such a product shift occurred mainly with Western players, with Eastern players still using balsa/PVC BOMs.

More recently, the market has seen unprecedented growth and demand, resulting in supply chain focus, with PET starting to replace balsa and some Chinese PVC. A combination of price, sustainability and supply chain pressures on balsa leading up to and including the huge growth in 2020 has led to further significant paradigm shifts, in part.

Most significantly, many designers began creating alternative designs and BOMs which used heavy density PET 250 kg/m³ and for the first-time balsa is being replaced, much in the same way that PVC had been previously. Time will tell how fast this will develop.



Again, existing designs are very rarely changed due to the cost of change linked to certifications, production etc, so products often live and die through the blade life cycles, typically 5-7 years, they are used in. Geographic and OEM preferences also have a huge bearing on the shift in volume terms.

The immediate years ahead place several challenges on stakeholders as the market focuses heavily on total cost, sustainability and scalability. Already some trends are beginning to emerge, as follows:

- Consolidation of the supply chain sees core and kitting once again combine, with several acquisitions and partnerships emerging, taking the supply base back to the original combined one which Diab supplied and developed to offer a total solution in terms of core, finishing, kitting, process optimisation with feed into future blade designs.
- Increasing use of high density PET instead of balsa in new blade designs with some OEMs.
- A continued use of balsa and PVC for those OEMs who prefer to design with lightweight core solutions which offer beneficial properties and-or weight benefits.
- Recycled PET, subject to availability in years to come.

Diab has over 70 years' experience of core materials and sandwich technology and was one of the original PVC core producers. It has since adapted by developing other core materials such as PET, balsa and PES for the wind, aerospace, marine, industrial and transportation markets.

Diab's DNA has been around application knowledge and combined with enhanced materials, today makes it more relevant than ever through close partnerships with customers, helping them to optimise processes and take learnings into next generation designs.

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