Wind in the Blades

The Development of a New, Yield-Optimised and Cost-Effective Rotor Blade

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Project information: Development of an Innovative, Yield-Optimised and Cost-Effective Rotor Blade for Offshore Wind Turbines

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Project partners:
- Hottinger Baldwin Messtechnik GmbH
- Leibniz Universität Hannover, Institute of Structural Analysis
- RWTH Aachen, Institute of Plastics Processing

9.1 What Is Required of Rotor Blades

As far as the rotor blades of offshore wind turbines are concerned, noise, sound emission or shadowing are not a priority. More important for rotor blades used offshore are their aerodynamic characteristics, their durability under high stress caused by strong winds, gale-force gusts and salty sea air – and especially and despite all this: cost reduction in the production of the rotor blades, despite them being subject to significantly higher loads. Achieving more at less cost – offshore rotor blades should do no more and no less.

One of the two wind turbine manufacturers in Alpha Ventus is Senvion. The company took the lead for the research project, working together with scientists from the Institute of Structural Analysis at the Leibniz Universität in Hannover, Hottinger Baldwin Messtechnik GmbH and the Institute of Plastics Processing at RWTH Aachen. The main aims of the Alpha Ventus rotor blade project were to improve the aerodynamics and reduce production costs. The aim was to achieve this with a newly developed "profile family" of rotor blades, by developing a production concept for the process engineering to increase the efficiency of the manufacturing and possibly by the use of so-called "double blades", extra trailing edges integrated into the rotor blades like a kind of spoiler. The new blade was to be made entirely of glass-fibre-reinforced plastic (GRP) instead of partly carbon-fibre-reinforced plastic. The plan was to also develop an innovative condition monitoring system.

Like many wind turbine manufacturers, for the 5M Senvion also used blades made by the Danish blade manufacturer LM, the world's biggest independent rotor blade manufacturer. The six Senvion turbines in Alpha Ventus are fitted with LM blades. The rotor consists of three rotor blades, each 61.5 m in length, that are connected to the cast iron hub with double-row four-point bearings so that they can be individually pitched about their longitudinal axis by means of the co-rotating pitch drives – the so-called pitch control. The rotor is operated in a speed range between 6.9 and 12.1 rpm. In partial-load operation, below the rated capacity, the turbine works with a constant blade angle and variable rotary speed. To ensure continued operation of the pitch system in the event of a grid power cut or plant malfunction, each rotor blade (Fig. 9.1) has its own, independent, co-rotating electrical energy storage device.

The rotor blades manufactured by LM at the time that Alpha Ventus was being planned included components made from carbon-fibre-reinforced material. The blades used back then did not have any wing fences, so that turbulences (radial currents) occurred, which reduced the aerodynamic efficiency on the suction side of the blades. The use of "wing fences" on the blades was to be tested as part of the project and thus required fundamental research. And the so-called "double blades" had up to then only been installed on smaller wind turbines where their aerodynamic characteristics were investigated. The corresponding investigations had not yet considered their possible application on blades over 60 m long.

9.2 The Work Packages for the New Blade

9.2.1 In Abundance

The new blade structure was to be robust, reliable and economical. To this end the developers used GRP and PET foams, which enabled them to keep

Fig. 9.1 Rotor blades being loaded for installation in an offshore wind farm. © Senvion GmbH 2015

the blade weight down to the desired maximum of around 21 tons despite doing without carbon-fibre parts. The use of PET foam in blade production is far more environmentally friendly because it can be thermally recycled without leaving any residue. PET foam is also cheaper than the PVC foam used previously. A modified groove construction for the resin infusion process also reduced the amount of waste. The statistical analysis of rotor blades has also been improved across the industry at the same time. This applies to the FE modelling of the blade and more refined load calculation, and also to the strength analysis. While for years previously just the pure fibre strength was investigated, an inter-fibre failure analysis is now standard. This is an essential prerequisite for the use of fibre composite rotor blades. Before this research project at Alpha Ventus all rotor blades of this size, with a length of 60 metres and more, used carbon fibres.

In the model for the new blade design, the developers repositioned shear webs inside the blade in order to distribute the loads more evenly. In their opinion the wing fences on the surface of the rotor blades that were to be investigated did nothing to improve the aerodynamics, the more so as the production and maintenance costs and effort were greater. The same opinion was formed of the so-called "double blade" during the course of the investigations. The aerodynamic advantages that had been hoped for could be achieved just as well with a cut-off trailing edge on the blade profile. Due to its use of GRP and PET foam, the new rotor blade is thicker around the root – which thus increases the overall aerodynamic performance and safety. The new blade geometry, with a flattened trailing edge, is now a hallmark of all of Senvion's longer rotor blades (Fig. 9.2).

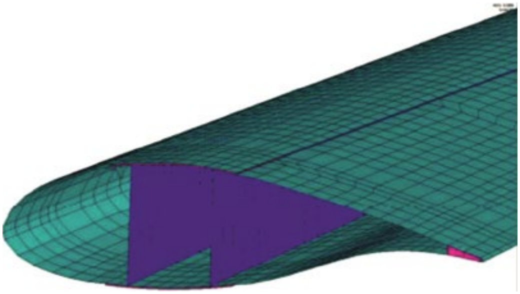

Fig. 9.2 Computer model: section through the newly developed rotor blade. © Senvion GmbH 2015

9.2.2 Process Development and Mould-Making

The choice of material also played a major role in the implementation in the production process. In drawing up the concept for series production, special attention was paid to the adhesion work, particularly in the sensitive blade root area. The new, thicker rotor blade, with a cut-off on the trailing

Fig. 9.3 The prototype of the rotor blade is prepared for installation. © Senvion GmbH 2015

edge, obviously required a new production mould. In the end, as always, two large blade halves were manufactured and glued together. But with the new blade, structurally important components on the inside of the blade did not have to be made within the main form. They were made separately earlier and then inserted. The complete set of moulds thus consists of individual forms to manufacture the girders, shear webs and shells of the two blade halves. This enables greater quality control in the preliminary stages while at the same time reducing the amount of work needed on the main mould. Since this had always been the bottleneck during the production of every blade, the new method achieved a significant increase in efficiency.

9.2.3 Stackable Transport Racks and a Set of Prototype Blades

The 61.5-metre blades are produced manually at Senvion. New transport racks were also developed parallel to this. These new racks make it possible to stack several blades, which provides logistical benefits as less storage area is required. This is especially true for transporting the blades out at sea. The glass and sandwich kits for the blades are now preassembled in a separate station so that there is less waste and the time needed for insertion in the main mould is also reduced. During the later production process, cooperation with the gluers improved the fitting precision of the cut pieces and increased the insertion speed. The web-setting mechanism for the individual components was extensively measured, tested and compared with the CAD model. As well as manufacturing the prototype set, refinements were also made to the production process.

9.2.4 Blade Test and Measurement "in the Field"

The new rotor blade was tested on the test stand to gain precise knowledge of the blade behaviour. The tests included blade behaviour under static and oscillating loads, the analysis of natural frequencies, blade bearing, durability and quality. These tests were successfully concluded, and in spring 2011 measurements began on a real wind turbine onshore (Fig. 9.3). And incidentally, for the first time the complete rotor star was not dismantled; the blades were replaced one by one. This only requires cranes with a smaller load-bearing capacity, so not only are such cranes more easily available, but they are also cheaper. Senvion used this erection technique – individual attachment of the blades to the hub – for the first time offshore in the 295-megawatt Nordsee Ost wind farm around 30 kilometres north of Helgoland.

Once the rotor blades had been swapped on the onshore prototype in Schleswig-Holstein for the Alpha Ventus research project, they were fitted with strain gauges and the hardware and software necessary for the measurements. The integrated condition monitoring system (CMS) was developed externally and also tested and validated in this field trial.

As far as loads are concerned, measurements were made of the blade root bending moment, the tower torsion and the rotor shaft bending under heavy load. Together with the rigidities of the individual components (generator, brake, etc.) this provides a comprehensive picture of the load situation of the whole wind turbine.

Peripheral Anecdote: Too much wind = not enough grid = no research!

The best strain gauges and measurement software in the world are no use at all if the wind farm management switch the wind turbine off beforehand! It is well known that there is often grid congestion at the strong wind location for the measurement prototypes in Schleswig-Holstein – especially when there are high wind speeds that result in "too much" energy being generated. So as far as the measurements of the new rotor blades was concerned there were several what appeared at first glance to be paradoxical situations where the wind turbine had to be switched off – not because the turbine and the new blade were subjected to too much load as a result of the high wind speed, but because the grid was simply unable to carry off the six megawatts of electrical power output. So at exactly the right moment, when the wind is blowing strongly into the rotor and the great forces and loads that are of interest to the scientists and developers are working on the wind turbine, the grid control centre can order temporary shutdowns. When it is not possible to make continuous measurements at such times the whole research project gets behind schedule.

Björn Johnsen

9.3 Advances Made by the Others

Even if it is not part of the Alpha Ventus project, we should not fail to mention the advances made by others during the project duration 2007–2012. Siemens manufactured a 52-metre blade in one casting and without adhesives. Adwen announced a 66-metre blade, LM Glasfiber, a 73.5-metre blade for the Alstom prototype Haliade 150, and Siemens a 75-metre blade for a six-megawatt turbine. The prototypes mentioned here have in the meantime – after the end of the project – been erected. And Senvion has also extended the rotor diameter of its 6.15-MW machine to 152 metres with the addition of a new 74.4-metre blade.

9.4 Outlook: What Have We Got from It, and What Can We Still Get from It?

The project achieved successful blade certification and push-started the construction of a rotor blade production plant in Bremerhaven. The blade production by PowerBlades, a one hundred per cent subsidiary of Senvion, creates jobs and strengthens Germany's position as a business base. The blade's improved aerodynamic properties have resulted in increased yield compared to the conventional blades used to date. Senvion will also use the new rotor blade developed in the Alpha Ventus project for its 6M series. The knowledge and experience gained from the project make it possible to develop new, larger rotor diameters with greater energy yield.

9.5 Sources

- Schlussbericht Forschungsvorhaben 0327646: Entwicklung eines innovativen, ertragsoptimierten und kostengünstigen Rotorblattes; Förderkennzeichen 0327646, Bericht vom 06.09.2012
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