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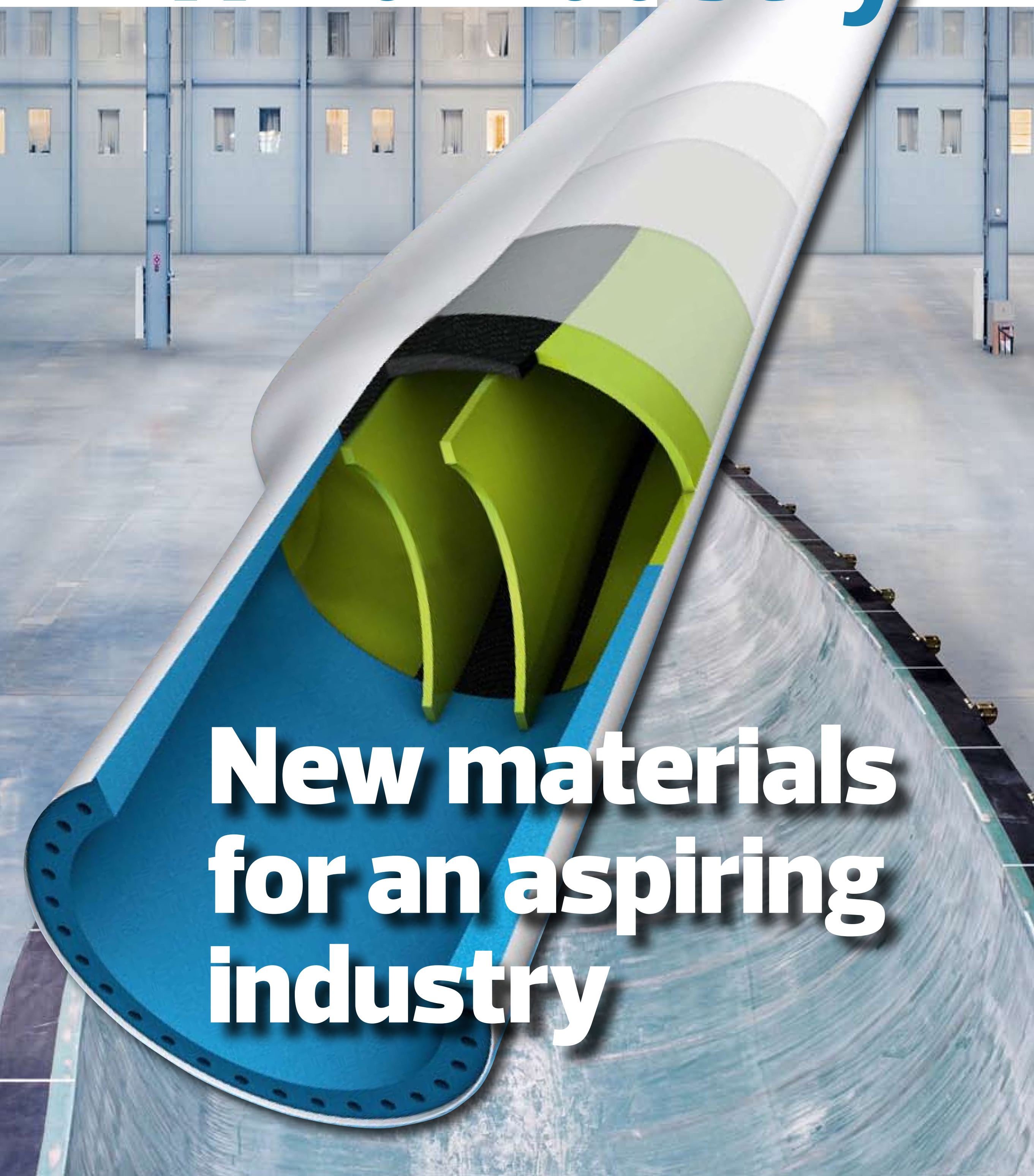
Chemicals in Wind Industry



New materials for an aspiring industry

Starting in September

Chemicals in Wind Industry

New materials and technologies for construction and maintenance of wind turbines

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The chemical industry has technical solutions lined up for the wind industry that will help to reduce costs significantly. Chemicals in Wind Industry provides detailed reports on technical innovations, new products and interesting market participants. The magazine creates a strong bond between chemical companies and the wind industry.

In our categories

- Markets & Actors
- Products & Applications
- Research & Development and
- Company Profiles,

we report on new materials and techniques in the fields of coating, corrosion protection, lightweight construction, as well as rotor blade manufacture and repair.

The first issue of Chemicals in Wind Industry will be published in September 2014. Starting in 2015, the magazine will be published twice a year. Chemicals in Wind Industry is only available by subscription and at selected trade fairs.

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Material with potential

Fibre-reinforced plastics, also called composites, are generally considered a new type of material with considerable potential for development in terms of possible applications in the future, whether in the automotive industry or aviation – or in the wind industry. Indeed, the wind sector plays a big role when it comes to selling composites both nationally and internationally.

Consulting firm Roland Berger was commissioned in 2012 by the German Machinery and Plant Manufacturing Association (VDMA) to conduct a study (titled "Serienproduktion") investigating serial production and evaluating it for the machinery and plant engineering industry. The experts found that the market for high-strength composite components will enjoy solid growth through 2020, with demand for high-strength carbon fibre reinforced plastics (CFRP) growing at a rate of 17 % per year, much higher than for fibreglass reinforced plastics (FGRP). Essential growth drivers are applications in the automotive and aviation industries, but increasing demand is also anticipated in wind energy and mechanical engineering.

Costs must be cut further for the market to really grow. In a ten-year period, component costs for CFRP can be realistically expected to drop by about 30 %. This will be due in part to process improvements amounting to 40 %. Industrialisation of the manufacturing process for medium production runs is already underway.

According to the Roland Berger study, almost 100 % of rotor blades now consist of high-strength fibre composite structures. Composite manufacturers are therefore increasingly setting their sights on the wind industry as customers. However, the wind industry still seems to be a long way off from production standardisation and the associated cost reductions.

According to the 2013 Composites Market Report prepared by AVK and Carbon Composites, the aerospace and defence sectors are the most important market segments for composite manufacturers, based on revenue. In terms of volume, however, the wind energy industry is already far ahead. The largest share of carbon fibres – 23 % of the overall demand of about 43,500 tonnes – is used for wind turbine rotor blades. By 2020, that volume will most likely increase fourfold, whereas revenue in this segment will "only" triple due to cost pressure and the assumed cost reduction potential, according to Carbon Composites.

Today's business climate is clearly positive

Since 2013, Composites Germany has been conducting a semi-annual member study to gather data on current and future market trends in composites. The business climate in Germany and around the world was rated very positively in the first poll, and that trend is continuing unabated. Worldwide, some 88 % of the people surveyed rate the current business climate as more positive or very positive.

Regionally, the study expects Germany, Europe as a whole and Asia to be major players. In terms of material, CFRP is still expected to drive growth on the composites market the most.

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Seizing the opportunity

As the market for wind energy grows, new business segments are opening up to the chemical industry, which can provide products for unsolved problems. There are new opportunities for sales in polymer materials, paints and adhesives.

Bayer MaterialScience introduced polyurethane wind turbine rotor blades at K 2013. Photo: Thomas Isenburg

Wind power, wind energy – these terms leave no doubt about what is vital for this technology: power and energy, the powerful models of physics. When converting air flows into electricity, considerable forces have an impact, in particular, on the rotors. Nacelles and towers are also exposed to harsh weather conditions – from the sun in North Africa to the rough sea climate in the North Sea.

The wind energy market is growing because of plans to substitute fossil and nuclear primary energy with energy from renewable sources in Europe. North Africa also aims to supplement, substitute and build its energy supply using renewable sources. Against this backdrop, the wind power industry's demand for polymeric materials, paints and adhesives is growing, creating profitable business fields for the chemical industry.

Resistant materials

A physical perspective of the basic conditions for the application of materials for wind power reveals that the bigger the rotor's radius, the larger the area that the wind can affect and therefore the more energy that can be harnessed from the wind. For this reason, the rotor blades must be as long as possible, which in turn makes high turbine towers necessary. Another reason is that wind speeds accelerate with increasing heights. Total heights of up to 200 m are needed offshore in order to fully exploit the turbines' capacity. Rotor blades can be up to 75 m long in such cases. Multi-megawatt capacities can already be achieved with blade lengths of 50 m. Then centrifugal forces occur that may be equivalent to 18 times gravitational acceleration. Wind turbines need to achieve the load resistance required, under varying climatic influences, in constant operation for up to 25 years.

The rotors of larger turbines are mostly made of fibreglass and, in some cases, carbon fibre-reinforced plastics. They are characterized by consistent lightweight construction and a targeted use of material combinations, says Holger Ruckdäschel, head of system research for wind energy at BASF SE in Ludwigshafen, Germany. The matrix systems mostly consist of epoxy resins, which companies such as

Experts assess the cross-section of a freshly cast rotor for a new wind turbine. Photo: Bayer MaterialScience

Momentive, Dow Chemicals and BASF can supply. Alternatively, Bayer MaterialScience offers polyurethane, while other manufacturers supply polyester.

In some cases, fibreglass is replaced with carbon fibre for high loads and long blade lengths. The large structures in the shell area and the shear webs use the sandwich construction method, where two fibre-reinforced coating layers envelop a stable, light-weight core material. This results in a high bending stiffness and dent resistance at a low overall weight. Balsa wood, PVC and, increasingly, PET structural foams are used as core materials.

Epoxy and polyurethane-based adhesives join a blade's individual segments together, such as the shear webs to the spar caps. Finally, polyurethane coatings and form fillers ensure good aerodynamics and resistance against the weather and erosion, BASF's Ruckdäschel explains.

Cost pressure encourages innovations

Bayer MaterialScience provides solutions based on polyurethane and polycarbonate as well as raw materials for varnishes, adhesives and other specialities. "Polyurethanes are an alternative to the matrix materials that have been used so far," explains Marc Schütze, head of Bayer's department for the production of rotor blades using polyurethane infusion resins. Bayer has already presented their in-house developments to a specialist audience at K 2013, a trade fair for plastic technologies.

Wind energy is a young industry that has had to overcome some challenges over the last few years. Because of the cost pressure to achieve grid parity with fossil and nuclear electricity, the innovation cycle is moving along at a quick pace. "We're seeing similar developments here in line with those in other industries that have a need for our composite products, such as the automotive industry. Companies in the chemical industry, especially plastics, are essential to the wind energy industry, since setting up wind turbines would not be possible without today's plastics and composites," Schütze says when asked about his expectations for the market. "This market, strongly driven by technology and innovation, is therefore important for Bayer MaterialScience." However, he is not ready to say more, much less provide concrete figures, about his expectations at this moment.

BASF also plans to supply increasingly more powerful materials for turbines to the wind industry. The company provides products and solutions for all main turbine components (rotor blade, nacelle, tower and foundation). The chemical group believes the market will continue to grow in the future. Wind power is considered to be one of the growth areas within their current strategy, Ruckdäschel states.

Thomas Isenburg

Composites on the rise

In order to serve the growing demand for composites in the wind industry, the companies involved are joining forces. The main focuses in the collaboration are technology and innovation support

The VDMA (German Machinery and Plant Manufacturing Association) represents more than 3,100 primarily mid-sized companies from the capital goods industry with about 990,000 employees. They currently include more than 160 suppliers of technology for making fibre-reinforced composites from about ten trade associations. They have come together in the multi-sector VDMA Composite Technology Forum.

The companies cover the entire production chain, from machinery for manufacturing fibres and textile reinforcement structures to automation technology, tool and plastics machinery and joining and testing technology, as well as machining tools and tools for surface treatment. Automating the manufacture and processing of fibre composite components and upstream products is considered to be a central challenge. Improved production methods aim to reduce the production cycles and guarantee consistent quality of serially produced composites.

A joint study conducted by the VDMA and Roland Berger Strategy Consultants analysed serial production of high tensile strength fibre composite components in more detail. The main driving forces are the automotive, aviation, wind energy and machinery and plant engineering industrial sectors.

Offshore applications and other factors have generally led wind turbines to trend towards higher capacities and therefore longer rotor blades. The higher loads associated with such long blades increase the requirements for their strength and stiffness. Therefore, the considerably more expensive carbon fibres are increasingly used instead of fibreglass, resulting in a drastic change in tonnage, as well. Through 2020, an annual growth of 20 % is expected for continuous fibre-reinforced carbon composites, compared to just 5 % for fibreglass composites.

The global market for newly installed wind turbines is expected to reach a record level of more than 45,000 MW this year. Offshore wind energy, with an expected 3,000 MW, makes up a still relatively small but growing part of that figure. In 2013 the German market for onshore wind turbines amounted to about 9 % of the global market with just under 3,000 MW, while the total of 240 MW for offshore wind in the country was equivalent to about 12 %. In 2014 the onshore market is anticipated to reach 2,500 to 3,000 MW and the offshore market some 1,500 M.

In 2012, wind turbines with a production volume of approximately 6.5 billion euros were manufactured in Germany, with the export rate amounting to about two thirds. Due to the strong domestic market and the weak global market in 2013 along with an increasing share in global production, the VDMA estimates the production volume in Germany to have been comparable to the previous year, but with a significantly lower export ratio. In 2014, this will reverse again, as the domestic market will, at best, stagnate while the global market grows enormously. Export ratios of 60 to 80 % are also realistic in the coming years with a relatively stable domestic market and a slowly growing domestic market.

Together with partner organisations AVK, Carbon Composites and CFK-Valley Stade, in mid-2013 the VDMA Composite Technology Forum formed the trade association Composites Germany aiming to strengthen collaboration between mechanical engineering and application industries. While members remain independent, its purpose is to strengthen the composite industry and research, develop common positions and represent common concerns.

In particular, expertise is pooled for forward-looking topics related to high-performance composites and automated production technologies, which are especially relevant in Germany. The joint work focuses in particular on technology and innovation support, basic and advanced training and standardising. Regular market information and trend data help the companies, as does joint participation in trade fairs and events.

Joining forces

A seemingly futuristic sculpture made of CFK/GFK composite material is officially unveiled in Stade, Germany.
Photo: CFK-Valley/Strüning

CFK-Valley Stade pools research activities in order to conduct them more effectively. The next step for the industry network is setting up a national centre for rotor blade development.

CFK-Valley Stade is a globally leading network for composite technology located in northern Germany, in the heart of the northern European wind energy industry. The business network also has the best possible logistical conditions for further developing offshore wind technology. So far, the network's focus has been on carbon technology designed to meet the highest demands in the aerospace industry. The entire value chain from training to recycling is represented in Stade.

Such high levels of quality are not required in the cost-driven wind energy industry, which tends to use fibreglass-reinforced plastics. Nevertheless, optimization processes are necessary here, as well, and the whole value chain needs to be considered – for example, a truly satisfactory recycling concept is not yet in place.

CFK-Valley Stade can provide excellent support based on its partners' expertise. Moreover, a private university of applied sciences, PFH Göttingen, is located nearby. The institution offers academic programmes and advanced training courses on composite technology. The research environment also includes the Fraunhofer Society and the DLR (German Aerospace Center), which are both very actively involved in wind energy. Moreover, there is a wind energy working group within CFK-Valley Stade which has already brought innovative developments in rotor blade optimization to the market. The group brings together an ideal mixture of research companies, innovative small and medium-sized businesses and wind turbine manufacturers.

The CFK-Valley Stade network has learnt from the wind energy industry that not all rotor blade manufacturers are able to conduct research and development work detached from production. In consequence, many innovative ideas have initially been shelved and will possibly never be put into practice. Major manufacturers – and not just in the wind industry – have also come to see that it makes more sense and is far more effective to do research work jointly in a network than on their own.

CFK-Valley Stade provides ideal conditions for this and has been encouraged by many letters of intent (LOIs) to start planning a national centre for rotor blade development in Stade. The association will not be able to finance this project alone and will therefore apply for a grant. The City of Stade will also provide financing backed by lease agreements. This ambitious goal should be achieved soon, and it fits perfectly into the association's new strategy, which intends to put all of its technology-specific expertise at the disposal of all the industries that may benefit and draw added value from it.

Gunnar Merz

Awareness is growing in the industry about the impact of leading edge erosion on wind turbines.

Innovative materials advancing the industry

Sample tested in rainfall of one inch per hour at 500 mpg at the University of Dayton Research Institute Rain Erosion Test Facility Graphics (2): 3M

According to a study conducted by 3M in collaboration with the University of Illinois/USA erosion can result in annual energy production (AEP) losses of up to 20 %. Damages caused by erosion not only compromise the turbine's efficiency, but can also cause blades to fail prematurely.

GCube, a provider of renewable energy insurance services, has published a report of the most common wind energy insurance claims made in the US. The data based on 2012 US reported claims show that blade damages account for 41.4 % of the total claims reported. Even though many of these can be attributed to lightning strikes, delamination is also frequent and needs to be addressed according to GCube.

For many years, 3M's Wind Blade Protection Tape has been the proven solution to protect leading edges of wind blades against erosion. The tape, constructed from tough, abrasion-resistant polyurethane elastomers, is designed to resist erosion, puncture and tearing even with the tough weathering that turbines endure.

Nevertheless, many customers expressed interest in a coating solution. Various coatings were already on the market, but could not match the level of protection offered by 3M's Wind Blade Protection Tapes.

Following customers' demands

Given what 3M learned from customers about their needs, the company set out to make a coating that was equal to or even better than its tape.

In order to prove that a new coating could perform as well as the tape in real world conditions and to quantify the life of a leading edge protection accurately, tests had to include the wind blade exposed to intermittent rain, sand, and other particles in the air, while rotating at very high speeds.

3M researchers identified a resource to help, the Rain Erosion Test Facility at the University of Dayton Research Institute (UDRI). The facility is run cooperatively by UDRI and the U.S. Air Force and is equipped with a rain rig that serves as the national and international standard for testing rain erosion resistance of aerospace materials.

Sand erosion tests were also conducted. Here coated airfoils are put in a highly controlled sandblaster for various intervals. The mass of the airfoil is measured both before and after sandblasting, giving an exact figure of how much erosion occurs during testing.

It is obvious that exposure to sun, heat, and humidity can have an impact on a product's properties, making weathering data essential to understanding the true performance of a product. 3M's Corporate Weathering Resource Center's expertise played a key role in evaluating the effects of weathering on the new coating.

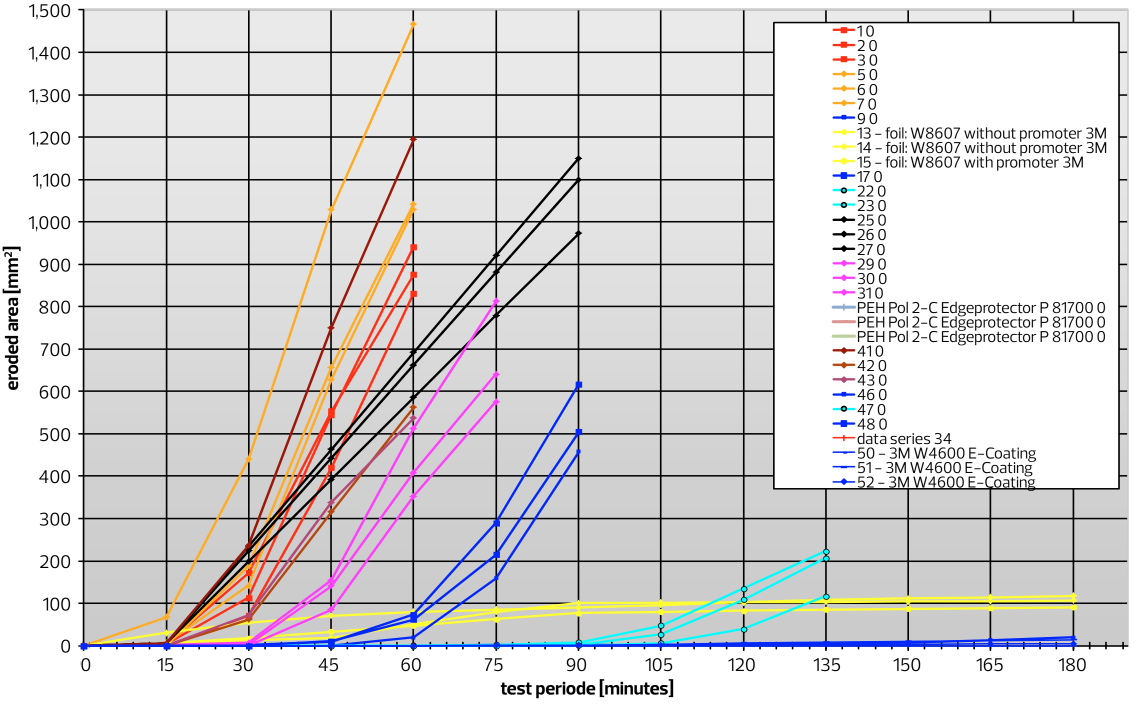
Practical application

Another variable 3M engineers set out to understand was how customers apply coatings to wind blades and the effects these application methods have on a coating's performance. Research was conducted on applying the coating with a roller, spray, and brush. The test showed that application with a brush results in the smoothest finish and least amount of air entrapment.

Using the insights gained from research and development, 3M engineers created a coating formula that offers the same high performance as wind protection tape.

3M Wind Blade Protection Coating W4600 is a two-component polyurethane, providing erosion protection in a single layer. In order to ensure proper mixing, the product is packaged in a two-part cartridge with a static mixing nozzle. This allows operators to dispense the accurately mixed coating directly onto the blade and then smooth it out with a brush. The coating cures quickly after application, allowing maximum application efficiency. Additionally, manufacturers can produce blades that are protected against erosion from the very beginning of service, reducing potentially costly and cumbersome repairs in the field.

Rain erosion test at PolyTech



Next generation materials

The chemical industry supports high tech composite products. New material developments pave the way for the next generation of wind turbine blades.

Wind turbine blades are exposed to extreme environmental and mechanical loads. At the same time the industry is in a strong competition and experiences a high cost pressure. The branch faces this challenge using high-tech materials such a fibre reinforced polymer materials and efficient processes.

In 2013, 35 GW of wind energy capacity were installed worldwide. Almost all blades are manufactured from fibre reinforced materials, mainly glass fibre reinforced epoxy laminates. This makes the wind turbine blade to a billion Euro market for the chemical industry. The main materials used are reactive resins, reactive adhesive, polymer core materials and coating materials.

Currently the wind turbine blade industry is joining forces to reduce the cost in the German funded research project BladeMaker. The goal of the project is to reduce the blade costs and increase the blade quality by using new materials, new processes and automation technologies. The development of new materials is one of the major challenges in the project to achieve the project goals. Three materials are in focus: innovative epoxy resins, new polyurethane core materials and polyurethane adhesives will jointly help to reduce the material costs, significantly speed up the production process and increase the blade quality.

How can new epoxy resins help to speed up the blade production?

Epoxy based resin systems are mainly used as infusion systems, adhesives as well as for high performance toolings. With the focus on automated processes for rotor blade and subcomponent manufacturing, the targeted performance criteria are

Eroded rotor blade Photo: IWES

· reduced process cycle times, higher efficiency in mould utilization, increased productivity

· reduction of material usage (costs and structural weight)

· process safety (robustness against process variations, Environment, Health and Safety aspects)

These challenges need to be tackled and novel reactive systems, especially designed to suit the automated processes evaluated in the BladeMaker project need to be developed. The performance of resin systems will enable direct reductions in process cycle time. Optimized viscosity profiles will lead to improved vacuum infusion characteristics and faster impregnation of the fibre preforms. The reaction kinetics of the resin systems are another important aspect in this context. Improvements in the rate of mechanical property development during the curing process, as well as a reduction of the generated process exothermicity are main development goals. These core properties bear a high potential for cycle time reductions, especially in the context of automated processes.

In order to reduce material usage it needs to be focused on improved end (cured) properties of the newly developed systems. For example, a reduction in chemical shrinkage will result in lower internal stress build-up in the composite laminate, which can lead to improved mechanical fatigue performance.

With the combination of improved processing properties and optimized mechanical characteristics of the reactive polymer matrix systems employed it will be possible to contribute significantly on the route towards automated and optimized manufacturing processes for wind energy rotor blade production.

Where are the opportunities for Polyurethane core materials?

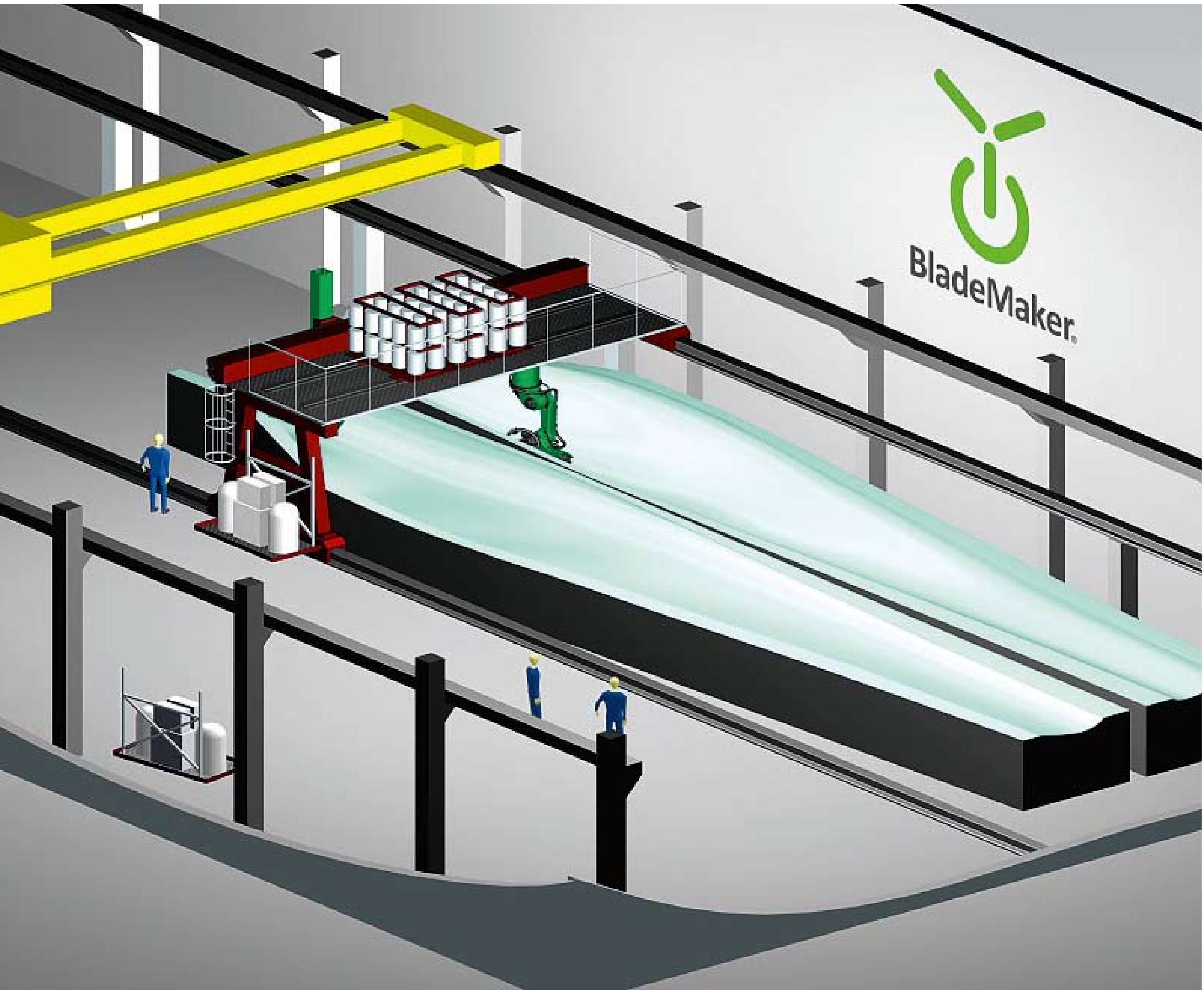
Rotor blades for wind turbines usually have a sandwich design with the core materials accounting for only about 5 % of total rotor blade weight but roughly 30 % of component volume. Depending of the internal component stressing they have the characteristics of a filling foam with lower mechanical strength and density or of a structural material with higher mechanical strength. For the sandwich skin mainly epoxy and polyester resins are used. Owing to the high temperatures (>120 °C) during curing reaction of the resin layer the core materials have to withstand both temperature stressing and the vacuum infusion process, which calls for a high degree of closed-cellularity and a high softening point of the core.

In addition to mechanically very strong balsa wood, which has relatively open cells in its untreated state and quickly absorbs humidity PVC foam is mainly used as core material. This partially cross linked Polyvinylchloride-Polyurea rigid foam is produced in an elaborate multistage production process from PVC and Polyisocyanates and shows ductile behavior and good mechanical properties. Its drawbacks are the high chlorine content (disposal of waste) and its relatively limited possibility to produce large scale parts, because cutting them of from discontinued produced blocks. The other core foams used in rotor blades are thermoplastic materials (PET, SAN, PS) which are usually produced continuously as extruded slabstock. Since the cross linking of the polymer chains in thermoplastics must stay within certain bounds the softening temperature is much lower than those of thermosets like highly cross linked PUR rigid foam. Another advantage of PUR rigid foams over linear thermoplastics is their improved chemical resistance and the possibility to produce large-scale and geometrically challenging parts in one step respectively an on-site foaming of parts.

By resorting to the broad range of raw materials available, including those from renewable resources, researchers are able to define the foam's polarity precisely and thus achieve both chemical resistance and good adhesion of the resins for PU surface.

What can new adhesives do to reduce manufacturing costs?

Henkel operates worldwide with leading brands and technologies in three business areas: Laundry & Home Care, Beauty Care and Adhesive Technologies. Founded in 1876, Henkel globally holds leading market positions both in the consumer and industrial businesses with well-known



First aim of the German funded research project BladeMaker: reducing cost. Graphic: IWES

brands such as Persil, Schwarzkopf and Loctite. Henkel employs about 47,000 people and reported sales of € 16,510 million and adjusted operating profit of € 2,335 million in fiscal 2012. Henkel's preferred shares are listed in the German stock index DAX.

Under the Loctite and Frekote brand Henkel supplies its solutions for mold release, and adhesive binders for the glass laying process as well as its GL certified PU adhesive to bond rotor blades. The hotmelt binders will on one side increase the efficiency and will at the same time improve the reproducibility of the glass laying process.

The new PU adhesive technology has been tested and certified by Germanischer Lloyd and will be of particular interest due to the fact that it will substantially reduce manufacturing time.

The highlighted developments show the great impact of the chemical industry on the innovations in wind turbine blade manufacturing technology. Beyond the mentioned developments the chemical industry is also working actively on other innovations. These are, for example, the fibre sizing as well as the binders for dry fibre placement processes or release agents for infusion processes.

Material selection for robust blades

For 18 years EUROS has been developing and producing rotor blades for wind turbines. Custom tailored blades for their customers wind turbines are optimised regarding Cost of Energy (CoE). During a service life of 20 to 25 years this is significantly driven by the reliability of the rotor blades. EUROS has built the second longest rotor blade in the world having a length of 81.6 m aiming for durability.

Aerodynamic design drives the robustness of energy conversion under any environmental condition. Thereby aerodynamic and structural loading are driving the mass of a rotor blade and the turbine's components. The availability of the turbine directly influences its yield were structural integrity of the rotor blades and the whole turbine is highly appreciated.

EUROS with a Berlin based engineering and production sites in South Poland and on the Baltic coast supplies optimised rotor blades to reduce total CoE over a turbine's lifetime. The reduction of rotor blade structural mass while maintaining or improving durability and robustness regarding aerodynamics and structure is the central challenge. One approach is choosing the right material in the right position. To increase quality, carbon and glass fibres, epoxy resins as matrices, PMI foam and balsa wood as core materials as well as toughened epoxy adhesives for structural bonding are sourced from European's premium suppliers.

E-, E-CR-, R-glass or carbon fibre are chosen for the spar caps to provide superior stiffness to EUROS' rotor blades utilising the Direct Roving in-house Tow-Preg Processing (DRiTP). This results in low structural mass, stability, robustness regarding waves and undulations, prolonged fatigue life and processing stability.

Important contributions to the damage properties of the final composite products are made by fibre sizing and resin matrix. Here the durability of the rotor blade can be improved by delaying the onset of matrix dominated damage in the load carrying structure due to fatigue loads. High performance epoxy resins are applied within the shells providing ultra-low viscosity, extended open time at fast TG build-up and short curing time.

The core materials for sandwich application deliver high mechanical performance at low mass and resin and high thermal stability. In EUROS blades sandwich panels with intermediate buckling loads feature a high performance PMI foam core. Panels with high buckling loads are designed incorporating balsa wood which delivers superior mechanical performance related to its density. They provide high buckling resistance at low structural mass and short production cycle time due to increased allowable curing temperatures. Shells and shear webs of the blades are joined adhesively during the production process utilising a toughened epoxy adhesive to provide reliability.

Resistance of the rotor blade coating against all kinds of environmental conditions such as particle and rain erosion or UV radiation, especially the choice of the right leading edge protection coating, contribute to extended reliability of the rotor blades.

EUROS cultivates a close cooperation with its suppliers regarding the development of the applied materials facing increasing requirements to their mechanical and processing performance, durability and cost. Thereby understanding and knowhow are gained for the materials of the next rotor blade generation.

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