Bigger, better blades for wind turbines

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Credit: Kindel Media from Pexels

As Europe's wind turbines grow in size, with individual blades longer than a professional football pitch, the biggest challenge will be delivering more power with less wear.

Europe is full of wind—and making good use of it. Wind energy is set to make the largest contribution to EU renewable energy targets.

This makes it a key component in Europe becoming climate-neutral, an objective the EU wants to reach by 2050. Home-grown technologies and tools will help Europe meet its climate goals while enhancing the competitiveness of the EU wind ecosystem on the global stage and create new green jobs.

The winds of change

In 2020, wind energy met about 16% of Europe's electricity demand, including a majority of installations on land and a fraction offshore, both floating and fixed.

Europe has plans to significantly up the ante, with projections to increase total wind-based power generation by about 50% over the next 5 years. Increasing power performance will be achieved not only by more installations but also wind turbines that can generate more power than their predecessors and that are out of commission less for maintenance and repairs.

Wind turbines are huge, fast (considering their size and weight), and subjected to very harsh working conditions. Imagine a football pitch spinning around in the air at about 15 to 20 revolutions per minute in some of the gustiest places on Earth.

From 2000 to 2018, the average length of wind turbine blades more than doubled. Newer models are expected to reach lengths exceeding 85 meters by 2025. Some offshore turbines could be sweeping the sky in the near future with blades 110 meters long—a rotational diameter of two football pitches end to end.

The larger the blades, the faster the tips move—and the greater the erosion on their leading edges. The industry has made tremendous technological progress in materials, design and manufacturing. Still, putting up bigger blades that deliver more power with less wear is a tremendous challenge.

Fortunately, the EU has a plan that includes improving resilience to degradation—which will only increase with larger blades and more and more extreme weather events—and better non-destructive monitoring to catch defects early, even during manufacture.

A coat of armor that 'gives'

To withstand the forces of nature and the huge forces the rotation itself generates, blades are manufactured with a multilayer "coat of armor." Typically, the outer layer erodes during operation and the inner layers can become detached.

According to Asta Šakalytė Director of Research and Development at Aerox Advanced Polymers, SL, although the lifespan of a turbine is theoretically 25 years, current medium-sized systems typically require extensive maintenance at about 10 years due to blade deterioration. Newer ones with larger rotational diameters show severe erosion by the second year of service.

To address the problem, Aerox developed AROLEP, a pioneering proprietary leading edge protection system that is now market-ready thanks to work done by the LEP4BLADES project.

Unlike conventional coatings you might find on pipes, Aerox's coating is viscoelastic, meaning that it gives or, more precisely, deforms under stress and bounces back. As Šakalytė explained, 'this is achieved with a combination of two polymers with different complementary properties.

The AROLEP coating can absorb high-speed and high-frequency impacts caused by raindrops and other particles hitting the leading edge of the blade. Tailor-made modification of polymer properties ensures the coating and blade materials work together so the impact effects are dissipated throughout the structure of the blade."

Independent performance tests showed AROLEP protects the integrity of the blades better than any other available solution—and it can be used for new blades as well as those already in service.

Market uptake should have significant ripple effects back to consumers: significant savings in maintenance, repair and downtime translating to lower energy costs. In the meantime, Aerox is continuing to improve the formulation while targeting novel coatings and adhesives for future blades that could help make wind turbine manufacture a zero-waste business.

And an angel to watch over them

Coatings are designed to minimize damage, but they cannot completely prevent it. Improved structural health monitoring technologies could catch defects early before the scales tip and repair or replacement creates financial and practical problems as large as the turbines themselves.

Blade failures are a significant issue for the wind turbine industry. Approximately a third of the billions of euros annually that go towards operation and maintenance (O&M) of wind turbines is for inspection and/or repair of blade coatings.

Until now, it had been impossible to identify internal defects in blade coatings. Visual inspection is the method of choice during manufacture and maintenance, but it misses defects lurking under the surface.

Even technologically advanced methods of inspection like inductive and ultrasound technologies fall short when it comes to the coatings on wind turbine blades. They require contact that can damage blades and coatings, particularly if wet, and they cannot analyze individual layers, only total thickness.

One way to see inside multilayer coatings may lie in the terahertz (THz) region of the electromagnetic spectrum—between microwave and infrared frequencies. It can "see" through things and identify what is inside—and its chemical composition and electrical properties—in a non-destructive, non-invasive and non-ionizing way.

Until a few decades ago its potential was difficult to tap in part due to our inability to efficiently generate and detect the waves. But that is changing now with proprietary THz technology developed specifically for industrial use by das-Nano and introduced to the market in the context of the NOTUS project.

According to Eduardo Azanza, Chief Executive Officer of das-Nano and NOTUS coordinator, "NOTUS is the first contactless tool for non-destructive material inspection specifically designed for wind turbine inspection. It can perform deep characterisation of individual layers of any coating structure and any blade, independent of materials, enabling quantification of interlayer adherence."

NOTUS is available in three versions for applications along the life cycle of blades supporting development, manufacturing, operation and even inspection by receiving personnel or insurance companies. It could save windfarm operators approximately 10% of O&M costs based on Azanza's estimates.

And windfarms are not the only ones who will benefit. NOTUS works with all sorts of multilayer substrates, including metal, composite and plastic. It accommodates flat and curved surfaces and dry, wet and cured paints.

The THz technology also enables electrical characterisation of advanced materials such as graphene, 2D materials, thin films and bulk materials.

Azanza said: "das-Nano has brought to market NOTUS, a harmless technology for fast and non-destructive inspection of every single product in a manufacturing line, identifying defective pieces at the earliest possible time."

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