Testing lags behind blade development

As rotor blades get longer and lighter, more complex designs introduce potential errors during manufacturing, while testing and certification are too limited in their nature. The result can be expensive failures and downtime. Sara Knight investigates

LM WIND POWER

"Satisfactory solutions to older known blade problems have been developed, but the new generation of longer and heavier blades is throwing up entirely new failure modes"

Despite the huge advances in technology and servicing and condition-monitoring methodologies over the past 30 years, blade failure among onshore wind turbines has yet to be fully eliminated.

Even turbines that have been operating for less than two years have suffered serious problems. In October 2018, for example, one of the blades mounted on a 2.35MW Enercon E92 turbine at the Neuss project in Germany snapped in half, just 16 months after commissioning. In mid-January, Enercon said the examination and analysis of the blade to explain the failure had not yet been completed.

In late November 2018, wind operator EPV Windkraft said problems had developed on the rotor blades of some of the 34 Vestas 3.45MW turbines at the Ömossa wind farm in Finland, installed in 2017-18. The preliminary corrective measures required the use of lifting cranes, implying that the blades were damaged to the extent that they had to be dismantled from the turbines.

And in December 2018, a blade broke off a 2.4MW Kenersys K110 turbine, one of 16 machines commissioned just six years ago at the Gau-Bickelheim wind farm in Germany. The cause is still under investigation.

New blades, new problems

The manufacturing process offers potential for failure. According to the Internek Group, a UK-based multinational assurance, inspection, product testing and certification company, resin addition and the bonding process are fabrication procedures that sometimes lead to defects. These include delamination between layers, wrinkles or waviness between layers, and lack of bond or debond of the composite layers.

Industry sources say satisfactory solutions to older known blade problems have been developed, but the new generation of longer and heavier blades is throwing up entirely new failure modes. In 2018, several hundred problems with blade root sections were discovered, mainly in China, but also involving blades of European design, sources say.

Human error can also play a drastic role. In March 2018, the rotor blades and nacelle of an Enercon E115 turbine were destroyed during installation at the Borchen-Etteln project, also in Germany. The damaged blade pieces were spread over a radius of some 500 metres. In May, the district government of Paderborn reported that "a fatal combination of repeated human error, strong wind, and a not-yet activated safety system process" led to the incident.

The expert report on the extent of the damage at Borchen-Etteln and the reasons behind it were provided by certification company 8.2 Consulting and engineering firm H&P. Enercon rapidly initiated new training for its installation teams, paying special attention to the relevant blade safety steps, with changed safety procedures rolled out to all construction sites worldwide.

The level of damage varies. In October 2018, GE Renewable Energy, which acquired blade manufacturer LM Wind Power the previous year, described a category 1 problem as a "cosmetic flaw". According to the company, "a large crack on the verge of catastrophic failure would be a category 5".

Repair costs rise dramatically with the severity of the flaw: a category 4 defect costs, on average, six times as much as a category 2 issue. Category 5 repairs costs 12 times as much as a category 3. Catching a problem before it deteriorates further is crucial to avoid the high costs of deploying cranes. If a replacement blade is required, it will cost around €100,000 for a 1.5MW turbine, rising to €200,000 for a 3MW turbine. Costs could easily reach €300,000 if transport and installation is included.

Lightning strikes

The biggest threat to blades in Europe is lightning strikes. Enser Versicherungskontor, an insurance broker in Germany that specialises in environmental technologies, reports an annual average of 23 blade incidents between 2010 and 2015 among the roughly 4,000 turbines for which it provides advisory services. Nearly 70% were due to lightning strikes, with less than a quarter due to structural blade problems.

The cumulative damages paid out by insurance firms for the 139 reported blade incidents in 2010-15 totalled €1.75 million, with a further half a million euros disbursed to cover loss of income during the turbines' downtime. Average payouts per incident were

Cause unknown
Enercon is still investigating why a blade on a less-than-two year old- 2.35MW E92 snapped in half last October

FEUERWEHR NEUSS

€12,533 for repairs and €3,667 for loss of earnings.

"Since 2016, we have observed a similar number of blade incidents per year within the fleet for which we provide services," says Thorsten Schulte, head of technical claims settlement at Enser Versicherungskontor. "Lightning strikes continue to be the main problem."

Lightning damage affects old and new blades alike. The stability required for ever-longer blades is generally achieved by using more carbon fibre. Modern turbines often have tip heights exceeding 200 metres, which makes them more vulnerable. They often take hits, with the damage mainly occurring at the lightning receptors and the blade area around them.

Blade repair costs after lightning strikes average around €2,000-5000, says Schulte. The repair is usually performed at the next scheduled maintenance appointment and usually takes less than a day.

Internal structural blade problems have become less frequent over the past five or six years, Schulte notes. Only a handful of incidents are reported each year across Germany's total onshore fleet of more than 29,000 turbines. Major structural damage requiring a complete blade replacement is rare.

Inadequate certification

However rare, catastrophic blade failure can cause significant economic loss and reputational damage. Every step must be taken to prevent this, says Xiao Chen, senior scientist at the Technical University of Denmark, in a forensic investigation report on blade failure on two turbines at a wind farm in 2014, published in May 2018.

But even today, a good 30 years into the history of commercial-scale onshore wind, there are still cases where rotor blades fail during normal operation for reasons no one had seen coming.

Blades are generally over-engineered, designed to include a margin of safety to ensure they can withstand extreme conditions, and that expected lifetime loads can be comfortably accommodated. These qualities are checked when prototype blades are tested and certified.

However, today's blade test and certification methods are not sufficiently sophisticated to reveal all potential causes of failure modes that change with different designs and manufacturing processes. Tests currently account for dominant load directions according to the standards used for certification. Many load combinations that could occur during operation are simply not captured because the required test methods have yet to be fully developed.

A further problem with the certification process is that it has been derived from that used for ship design, says Jim Platt of the Institute of Manufacturing at the University of Cambridge. The blade type that passes through the process is generally a one-off unit painstakingly manufactured and tested. This process, however, fails to recognise that turbine blades are mass produced, and detail errors can occur in each manufacturing step of every element of the blade.

"There needs to be a fully established and working quality assurance process, which inspects every process step and both sees and corrects every detail error and records that it has done so — with before-and-after photographs — before the next process step is allowed to begin, creating a complete quality assurance document for every single blade," says Platt.

LM WIND POWER

Striking Blades being tested to withstand lightning, the main cause of damage in Europe

This is common practice in the aerospace, automotive and pharmaceutical industries, he points out. Composites manufacture requires not only a skilled inspector, but also a camera in the plant roof, trained by the inspector to scan each cloth layup layer, to highlight spots that look like wrinkles or misplacement, and draw the inspector's attention to each potential fault.

An overhead camera can similarly watch the resin infusion and cure processes, drawing attention to any overheating or under-curing spots.

"This sort of computer vision-assisted quality assurance inspection exists in the aerospace industry, and could — should — be used in the blade industry. But it isn't," he says.

"[Overhead] computer vision-assisted quality assurance inspection exists in the aerospace industry, and could – should – be used in the blade industry. But it isn't"
Xiao Chen, senior scientist at the Technical University of Denmark

Chen agrees that his means that blades have been certified for use even though they have weak points that could lead to damage or failure in real-world conditions. Research institutes are working hard to provide more advanced testing techniques and equipment to fill these gaps, he adds.

"Although catastrophic structural failures of rotor blades are sometimes reported by the media, they are rarely published in academic literature from a technical point of view, mainly because relevant companies do not want to disclose their problems, nor always make technical data available due to commercial confidentiality," Chen points out.

This denies others "the opportunity to improve blade design and manufacturing processes so as to prevent similar blade failure happening in the future", he says.

Because reducing the levelised cost of energy is the overall driver for research and development in the wind-power sector, making blades that are lighter, stronger, and more consistent in performance is a priority. However, this has to be balanced against the requirements of manufacturing costs and durability. W

Windpower Monthly's Blade O&M Europe conferenec takes place 12-14 March in Amsterdam. For more information, please visit bladeomeurope.com