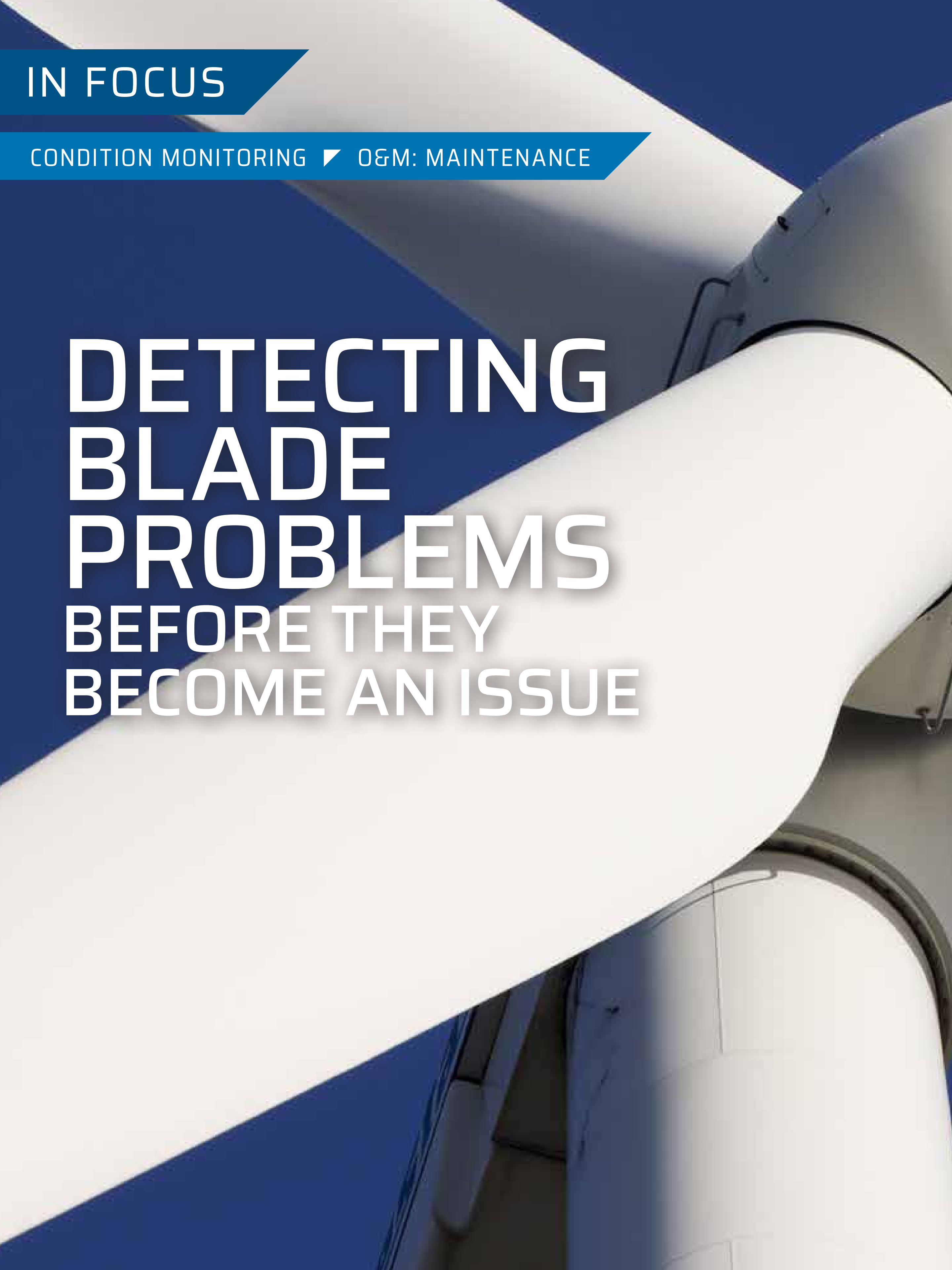
IN FOCUS

CONDITION MONITORING ◤ O&M: MAINTENANCE

DETECTING BLADE PROBLEMS BEFORE THEY BECOME AN ISSUE



With a new focus on predicting blade failures, accurately reducing costs and repairs will only add to a company's bottom line, making wind farms that much more efficient by minimizing downtime. (Courtesy: Shutterstock)

Condition monitoring sensors, used for years to detect imminent failures in a turbine's gearbox and drivetrain, are being adapted to find often hard-to-see defects in an asset's massive blades.

By KENNETH CARTER ◤ Wind Systems editor

Condition monitoring can cover a wide array of preventive measures to ensure wind turbines function optimally. In many cases, this monitoring is focused on the gearbox and its surrounding mechanisms.

However, massive spinning blades, with their almost constant exposure to harsh elements, can be a major source of headaches for owner-operators.

"When you want to do condition monitoring for the blade, you need to focus on the failure mode and focus on the area of the blade that you're interested in," said Ashley Crowther, chief commercial officer for ONYX Insight.

According to Crowther, with blade lengths 50 meters and larger, there are many different failure points that can occur on such a large structure.

"You can have a hole at the end of the blade that's clogged — that's a simple failure mode," he said. "More trouble are bond line failures and interior structural cracks, often in the mid-section of the blade (see zone 3 in Figure 1), and leading-edge erosion (zone 1), which is well monitored by drone inspection. And at the base of the blade (zone 2), you've got the bolted joint where pull-out of the insert or failure of the stud are not uncommon issues."

CATEGORIZING AREAS OF THE BLADE

The trick is to understand issues that are categorized into the three zones and how those areas on certain blades from certain manufacturers are going to be different. Often, a problem with one blade will be mirrored on more of the same model turbine. According to Crowther, blade condition monitoring is best focused on these present serial issues, as opposed to trying to solve every possible issue.

Blade condition monitoring consists of three principles:

◤ **1. Target the failure:** This is found by identifying the present defect or design flaw.

◤ **2. Direct measurement:** Even with the use of SCADA data and analytics with machine learning, the information is most often not in the SCADA signal to reveal; it isn't the right sensor data. To correct this, additional sensing is required, whether that be acceleration, strain, or sound pressure, for example.

◤ **3. Work at scale:** The solution needs to be practical and reliable and be backed by an infrastructure for thousands of turbines worldwide.

To accomplish this, off-the-shelf, mass-produced equipment that can withstand turbine lightning strikes and other

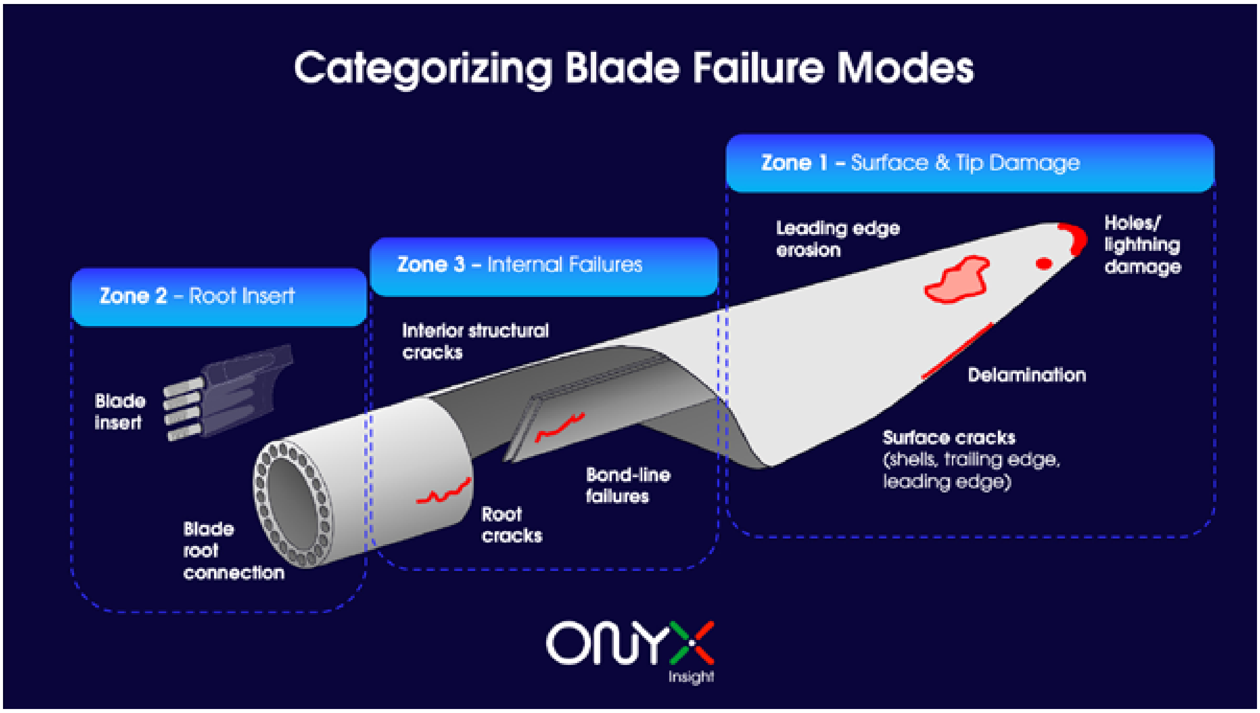


Figure 1: Categorizing Blade Failure Modes. (Courtesy: ONYX Insight, 2024)

harsh handling needs to be efficiently installed with easily repeatable work instructions. Businesses can then be trained to repeat this in all types of potentially inclement weather.

"Looking at these blade failure modes, we've been working on solving problems with these three principles in mind," Crowther said. "One of the problems that's been manifesting itself a lot in recent years is the blade root insert and its failure by pull-out. When you manufacture a blade, you need to be able to attach it to the hub and the blade bearing, obviously with a lot of bolts.

There are two main design philosophies that the industry has been using: one is a glued insert and the other a T-bolt, also affectionately known as an IKEA nut."

COMMON BLADE FAILURES

When a blade is manufactured, the bushing is glued into a hole and bonded so the bolt can be fixed into the bushing that connects the blade to the pitch bearing, which is then connected to the hub.

The failure mode that can occur happens when the bushing is pulled out and loosens, according to Crowther.

"Once you get one loose, you're getting a reduced-joint integrity," he said. "And then the next bolts in the side are under higher fatigue loads. So, the next bushing is becoming loose and so on."

Several root causes are touted, including improperly cured epoxy caused by temperature, oil contamination during manufacturing, or moisture getting into the blade through overuse, according to Crowther.

"There are different problems, too, that have caused it, but, at the end of the day, when this is failing, it is very difficult to repair; you're going to have to replace your blade," he said. "And there have been many cases where the blades have come off. The industry likes to call it 'blade liberation.'"

DISCOVERING DEFECTS

This euphemistic term for a catastrophic problem can sometimes result in entire wind farms shutting down for a period of time. In some countries, governments have gotten involved and ordered wind facilities offline until the problem is resolved, according to Crowther.

Visual inspections are a common method of searching for potential defects, but expense, worker safety, and human error can make this type of preventative method challenging at best.

ONYX Insight has adapted its ecoPITCH monitoring system for blade bearings to predict and protect against blade joint failure. The system monitors day-to-day operation and the integrity of the blade joint for the life of the turbine. It is currently monitoring about 3,000 blades across 1,000 turbines worldwide.

"That's one failure mode," he said. "But blades are fun. They have lots and lots of different failures. We can all work on them. We need to improve our designs and manufacturing process, but even if we solve all those problems today and every blade that was made from now on is perfect — it never broke — there are still tens of thousands of blades to maintain for their lifetime; some of which you can't get anymore, so you need to repair them; you need to maintain them."

Figure 2: Blade failure at a U.S. wind farm. (Courtesy: The Oregonian, 2022)

HARD-TO-FIND PROBLEMS

These types of blade sensors become even more important to detect structure problems such as cracks that might not be immediately visible to visual inspection or drones, according to Crowther.

"If these cracks are in areas that are structurally really important, then there could be a big problem," he said. "If they're detected early, then there are more options for making repairs. But if they're detected really late and they've gotten quite big, then it might be impossible to repair them. And they can develop quite quickly. Obviously, drone inspections, both internal and external, are good for managing these problems, but not all cracks you can see."

Again, maintaining visual and drone inspections becomes costly, so Crowther said his team is developing a permanent online monitoring system that, once installed, can be monitored from anywhere while awaiting an alert to a problem.

"If you don't get the alarm, don't worry about it," he said. "We also have to scale up and automate the analytics process. You can't have people punching numbers all day and night, so we can scale that up and automate this as well. We're working toward this, and we've expanded our same ecoPITCH system, which ironically enough, we developed and launched to the market to monitor pitch (blade) bearings, and now we're using it for blade joints and structural cracks."

THE EVOLUTION OF THE SENSORS

The original ecoPITCH sensors were installed in the hub to detect wear-out of the pitch bearings. Now, the sensors have been moved farther into the blade. The existing solution has all the infrastructure in place for monitoring of nearly 20,000 turbines, every day, according to Crowther.

"And now we're trying to just change 10 percent of the solution — the sensor at the end — and make that work for this different problem, which actually is a challenge: Which sensor? What's going to do the best job, and how are you going to do analytics?" he said.

Crowther said ONYX Insight sees strain sensors as a good approach for certain failure modes. These strain sensors can be placed, for example, on the pressure side shell of the blade near the shear web for crack monitoring that is known to occur in that region.

"To do the installation, you need an operator, have the blade horizontal, and a technician needs to climb up inside the blade and put the sensors in place on the cables, connected back to our ecoPITCH cabinet inside the hub," he said.

PREDICTING FAILURES

The need to monitor turbines all comes down to O&M costs and unscheduled repairs. Drivetrains make up 55 percent of unplanned repair costs, but other factors, including blades, can also add to those unplanned repairs, according to Crowther.

"You never plan for something to break, so predictive technology helps you plan the maintenance, optimize around low-wind periods, group multiple activities, and plan for part and labor availability," he said. "As we solved the drivetrain monitoring problem quite a while ago, blades are a natural expansion area."

With a new focus on predicting blade failures, Crowther said accurately reducing costs and repairs will only add to the bottom line, making wind farms that much more efficient by minimizing downtime.

"About 25 percent of the industry's cost for unplanned repairs are blade issues," he said. "So, there are a lot of issues to get to."

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