Advancing turbine blade inspection

Words: Stephen Chambers, Head of NDT & Inspection at 3WIS

New nondestructive testing techniques, artificial intelligence and robotics are helping the wind industry move towards more predictive blade maintenance strategies as turbines continue to grow in size and complexity.

As wind turbines continue to increase in scale, the demands placed on their components are becoming more challenging. Modern turbine blades are longer, lighter and designed to capture greater amounts of energy, but this increased size also creates new engineering and maintenance challenges. Larger blades experience significant cyclic loading, complex aerodynamic forces and harsh environmental conditions throughout their operational life, increasing the risk of fatigue-related damage.

For asset owners, maintaining blade integrity is becoming an increasingly important priority. The cost of unexpected failures can be significant, with repairs requiring specialist equipment, extended downtime and complex offshore logistics. As a result, the industry is placing greater focus on inspection techniques that can identify developing issues before they progress into major structural failures.

Nondestructive testing (NDT) is already a key part of this approach, allowing operators to assess blade condition without causing damage to the structure itself. However, as blade designs evolve, traditional inspection approaches are facing new limitations.

Many inspections still rely heavily on visual assessments, which can identify surface-level defects but may not reveal issues developing internally within composite materials. Some forms of damage can remain hidden until they have progressed significantly, making early detection more difficult. This challenge is amplified by the size and location of modern blades, where access can be complex and inspection campaigns can be both time-consuming and costly.

Developing more advanced inspection procedures is therefore essential to improve understanding of blade condition and support more targeted maintenance strategies.

Improving the approach to blade inspection

At present, there are no universally adopted standards or guidelines that define the most appropriate inspection procedures for identifying every type of defect found within turbine blade structures. While new standards are currently being developed, ongoing research and testing are helping the industry establish best practices for composite blade inspection.

The most common issues that inspection methods are designed to identify include delamination, wrinkles, voids and disbonding.

Delamination occurs when layers within the composite material separate, potentially reducing structural stiffness and allowing damage to spread under continued loading. Wrinkles, which can form during the manufacturing process, can affect the strength of the blade by creating areas of reduced performance under compression.

Voids within composite materials can act as stress concentration points, while disbonding occurs when materials that should remain bonded separate from one another, potentially affecting the structural performance of the blade.

Identifying these defects at an early stage requires inspection techniques that can look beyond the surface and provide a clearer picture of the internal condition of the blade.

Current testing programmes are therefore focused on developing methods that can provide deeper insight into composite structures, improve the accuracy of defect detection and make inspection campaigns more efficient.

This includes targeting known problem areas of blades, improving access to difficult-to-reach sections and using technology that can increase inspection speed while generating higher-quality data.

The challenge is no longer simply collecting more data. It is turning that data into practical maintenance decisions.

Combining technologies for more accurate results

Recent trials have demonstrated that different inspection techniques can provide valuable results depending on the type of defect being assessed. Rather than relying on a single method, combining complementary technologies can improve confidence in findings and provide a more complete understanding of blade condition.

For example, visual inspection combined with Wave Check Laser Technology has shown potential for detecting wrinkles within blade structures. Ultrasonic testing is being used to identify delamination, while more advanced ultrasonic approaches, including phased array technology, are being investigated for detecting voids and disbonding.

These approaches allow inspectors to examine areas that may not be visible during traditional assessments, helping operators build a more detailed picture of blade health. As turbine blades continue to grow in size, improving the depth, accuracy and efficiency of inspections will become increasingly important.

The role of artificial intelligence in inspection

As inspection technologies develop, the amount of data generated during testing is also increasing. Reviewing large volumes of scan data manually can be challenging, particularly when inspectors need to identify small or complex defects within composite materials.

Artificial intelligence (AI) is now being explored as a way to support this process by helping analyse inspection data more quickly and consistently. Rather than replacing experienced inspectors, AI systems can assist

Stephen Chambers

by identifying potential findings, highlighting areas requiring further review and reducing the time needed to analyse large datasets.

A proof-of-concept project carried out with Abraham George Smith at the University of Copenhagen has demonstrated the feasibility of AI-assisted analysis of phased array ultrasonic testing (PAUT) data. The model was trained to identify patterns in trailing-edge bond scans and estimate effective bond width, helping to flag positions requiring further review. The next phase will explore AI-assisted analysis of camera images from internal blade inspections, led by Kasper Sorensen and Abraham George Smith. The aim is to accelerate data interpretation while supporting more consistent defect identification and engineering decision making.[1]

The potential benefits of AI-assisted inspection are significant. Faster analysis, improved consistency and the ability to process larger quantities of information could help operators make better-informed maintenance decisions and move towards more predictive approaches.

Robotics and drone technology improving accessibility

The physical challenges of inspecting modern turbine blades remain one of the biggest obstacles facing the industry. Their size, height and location mean inspections can require specialist access solutions, significant manpower and periods of turbine downtime.

Advances in robotics and drone technology are beginning to address these challenges by improving accessibility and reducing the need for extensive manual intervention. Recent testing has demonstrated the potential for robotic systems to scan spar caps up to 850 mm wide in a single run, while tethered specialist composite climbers operating at heights of up to 100 m are producing reliable inspection data with reduced downtime and fewer personnel requirements.

These developments could transform how blade inspections are carried out, allowing operators to gather more detailed information while minimising disruption to turbine operations.

Towards a new standard for blade inspection

The ongoing development of new inspection technologies is helping shape the future of turbine blade maintenance. By combining improved NDT methods, advanced data analysis and automation, the industry is moving towards inspection strategies that are more targeted, predictive and efficient.

International standards are also being developed to support more consistent approaches. IEC 61400-32, which is currently being developed and is expected around 2027, aims to provide guidance for composite blade inspection and bring together knowledge from companies, researchers and industry bodies working in this field.

As turbines continue to increase in size and offshore projects move into increasingly demanding environments, the ability to identify potential issues before they become serious failures will become even more important. Improved inspection standards and emerging technologies will help asset owners reduce unnecessary downtime, optimise maintenance planning and extend the operational life of turbine blades.

The development and testing described in this article is being carried out by 3WIS UK Ltd, working alongside industry partners and research organisations to support the next generation of wind turbine blade inspection.

3wis.uk

Reference

[1] Abraham George Smith, 'Defect Detection in Composite Blade Images: Final report - AI Denmark', Department of Computer Science, University of Copenhagen, 22 July 2026.