FOR DTU, MOOG TAKES BLADE TESTING TO THE EXTREME

According to industry reports, each year one out of every 200 wind turbine blades fail. Those failures pose a twofold concern for turbine owners. First, when a blade fails, there's unplanned downtime and potential insurance issues. Second, how can blade manufacturers and turbine owners and operators feel confident that the blades on their turbine are tested adequately?

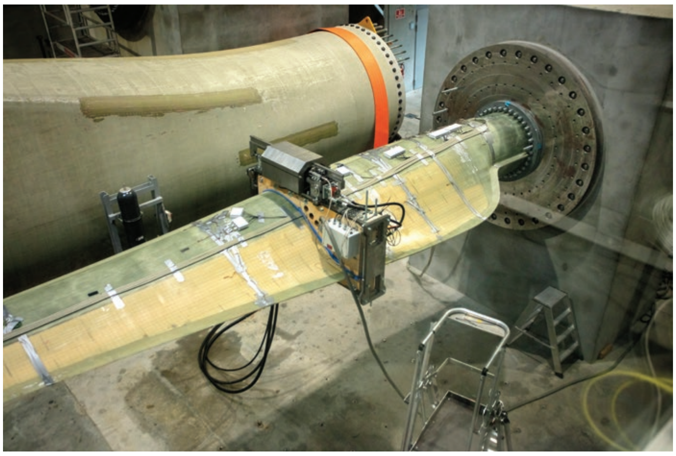
Researchers at the Technical University of Denmark (DTU) Large Scale Facility, part of Department of Wind Energy and the Villum Center for Advanced Structural and Material Testing (CASMaT), believe they have answers. The test facility, built by the Danish Building and Property Agency, opened in 2017 on the DTU Risø campus. Scientists at the facility focus on developing new, advanced test methods to gain a better understanding of failure in large structures. DTU works with the wind energy industry conducting research projects funded partly by government grants and with money from leading global turbine manufacturers.

For the wind turbine industry, testing and certifying blades to established standards is mandatory.

"But the current version of these standards is from 2014, and it's based on experience when turbines were much smaller," says Dr. Kim Branner, senior research scientist and head of the Structural Design & Testing Team for DTU Wind Energy. "The standard requires a static test in four different directions and fatigue testing that makes the blade swing in two directions, exciting the blade at its natural frequency."

According to Branner, those testing methods aren't robust enough to mirror what happens to a blade in service. Today's standards, he says, only test certain parts of a blade, while in reality the loads in the field are much more complicated. Branner and his team are undertaking projects to load blades in more realistic ways and to do it faster than conventional testing. The wind industry wants faster test methods, especially since bigger blades – measuring up to 100 meters in length – have a natural frequency that's slower, meaning current industry testing standards would require a manufacturer to wait up to a year to know if its blade passed the test.

Prior to 2017, DTU had a vision to develop a facility with the capability to test large-scale blades and other industrial components to help manufacturers reliably and efficiently replicate field conditions. DTU solicited proposals from engineers who could design a building and equipment capable of running advanced testing methods and research about the strength and fatigue behavior of large structures when exposed to complex loading. After soliciting proposals and securing funding from the Danish government, DTU picked Moog in the United Kingdom and its technical partners T A Savery and Qualter Hall for the project.



Mass resonance exciters (MRE), installed on a test blade at DTU Large Scale Facility.

Moog's expertise in aircraft structural testing and range of precision control systems, actuation products and engineering support services, which includes modelling and simulation capability, appealed to DTU's team. Furthermore, Moog had already developed actuation devices specifically engineered for wind turbine blades.

"Testing is an essential element to success in the wind-energy field," remarks Branner. "Moog understands that."

THE CHALLENGE TO BUILDING A LARGE-SCALE TEST FACILITY

DTU and Moog began thinking through what kind of equipment they would need to carry out more advanced tests, including bi-axial frequency tests that loads a blade in different directions at the same time. The tender amount for the equipment design was fixed, yet Moog knew there would have to be a bespoke design. From the outset, there was little if anything about the project that could be solved with commercial off-the-shelf solutions.

Moog initially undertook simulation and modelling work to demonstrate its designs could meet DTU's specification. For instance, one DTU requirement was to excite a wind turbine blade in two directions at the same time, with three test stands (ranging in size from 15 meters to 45 meters) running simultaneously. By comparison, the wind industry's standard blade test involves exciting a single axis, one frequency at a time. The requirement for three stands operating at once was a desire by DTU to use the facility to the fullest, which would give customers and DTU greater flexibility in testing.

"In research, we're trying to go in new directions all the time, and it's important to have equipment that offers flexibility," says Branner. "We had to have a set of equipment we could use in many ways."

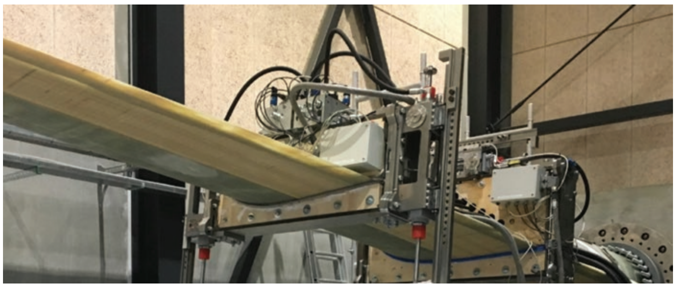
DESIGNING A SOLUTION

Moog's expertise with closed loop servo control and actuation helped it create a testing facility underpinned by a digital closed loop control system and application software. To provide DTU testing flexibility, Moog and its partners designed and installed test equipment to be used with the three test stands, which are part of the original building design and construction and designed to take 15m, 25m and 45m blade sizes. Moog engineers carried out the installation and commissioning of the suite of test equipment and provided training and ongoing support for DTU staff. The Moog scope of supply for the three blade test stands included the hydraulic power plant and distribution network, six hydraulic winches for the static test and a combination of eight Mass Resonance Exciter (MRE) and linear actuator assemblies for dynamic test work. The solution also included all pipe work, hosing and actuation devices, control system electronics and application software.

"Much analysis went into how the MRE would work, the frequency and how DTU would like it to perform," adds Graham Wood, Managing Director with T A Savery, a U.K.-based firm with a 200-year pedigree of engineering and machining for industries ranging from defence to mining and a long-standing relationship with Moog. "This was not a contract in which the customer simply said make A, B and C and that's that. Moog won the contract, and then began a great deal of technical research, modelling and hardware design."

In designing the facility's equipment, Moog gave DTU the latitude to conduct an array of tests. For example, if researchers wanted to use a test bay to conduct a dynamic test on a blade, the hydraulic system would accommodate wide pressure fluctuations. If the next test required a static one with winches, DTU could set the hydraulics to meet a very-low flow.

Designing the winch assemblies, the team partnered with UK based Qualter Hall – another long-standing Moog business partner with proven technical excellence in providing bespoke hoisting, winching and haulage systems. This project, included discussions about the type of rope, safety factors and mounting a hydraulic manifold on the winches, so DTU researchers can angle the winches depending on a configuration of 2, 4 or 6 load points. Competing blade-testing designs use enormous towers with winches that facility managers move with a fork truck for static testing sidewise. DTU's winches load the blade vertically, so researchers can perform a static test to extreme loads with six winches loading a blade at six positions, while pulling the test specimen toward the floor and mimicking an extreme wind load experienced in a 100-year storm. The tip of a blade in the DTU facility can move up to 14 meters, while the root of the blade moves a few centimetres. DTU wanted a facility wherein gravity and the test direction were the same. The advantage to testing a blade vertically versus sidewise with a tower is that with the latter configuration, researchers have a tower that will bend during a test; this makes it difficult to control load position as well as taking up a lot of facility space, even when not in use.



DTU researchers set up a blade test by attaching three hydraulically controlled MREs in DTU Large Scale Facility.

"DTU can literally select what they want, without being constrained by the equipment," adds Kevin Cherrett, business segment manager for Systems and Services with Moog's Industrial Solutions & Services group.

With regard to designing the MRE, Wood and Cherrett say the concept was well established. But what they undertook was to develop a more robust version of that concept with flexible tools grafted onto it.

"One of the challenges of fatigue testing is ensuring you're fatiguing the test specimen, not the equipment performing the test," adds Cherrett. "We carried out extensive tests and modelling and simulation to predict the life of the equipment; we analysed each component for life expectancy."

In designing the actuation for the MRE, Moog included hydraulic actuator designs it had used for the aircraft industry. Within the MRE is a standard Moog actuator building block that excites the blade. The weight of the MRE was also of concern to DTU because similar devices manufactured by test houses included manifolds and piping that added mass. Working with DTU, Moog created a control manifold made from high-strength aircraft aluminium that DTU could mount anywhere.

"For every customer, with these types of systems, we seek to engage in a service level agreement, support package, preventive maintenance and tech support," adds Cherrett. "Our definition of tech support is not just a one-off exercise; we'll be with DTU for the duration of the use of the equipment."

Another example of how Moog continues to support DTU's work is via a project in which researchers hope to see what the future holds for a working wind turbine blade. By developing sensors to embed in a blade, DTU wants to know if it can predict damage.

"Moog's technology is helping with this because we will embed sensors in test blades with built-in defects and monitor how the damage grows," says Branner. "The Moog exciters will put realistic loads on the blades."

Branner sees the project helping blade makers build better blades but also creating a digitized twin of each blade that a wind farm operator could use to model what a blade's future state might look like. If all goes according to plan, someday a wind farm control centre could predict a blade fail before it happens.

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