

# LAUNCHING LIBERTY

## CLIPPER ADDRESSES TEETHING ISSUES



What do you do when something goes wrong? When a new product or design goes into serial production it can face a new set of challenges, and sometimes things don't go as planned. This was the case last year for US-based wind turbine manufacturer Clipper, as its first batch of 2.5 MW Liberty turbines ran into problems with drivetrains and rotor blades. The company is open to talking about its challenges over the past months and here, company executives explain to **Eize de Vries** the nature of the two Liberty problems, the solutions, and how the remediation operation is being tackled.

Grinding preparation for rotor blade reinforcement CLIPPER

Teething problems – sometimes serious – that surface in new designs of wind turbine are often linked to the application of innovative technology and/or upscaling processes. Wind technology is not alone here – the same phenomenon is true of many other complex technologies. Such problems can either be a result of design or manufacturing imperfections, or a combination of both. Some design faults show up early during the prototype-testing phase, while other product shortcomings may surface only after a prolonged operational period, in the form of material fatigue-related failures.

neither supplier met Clipper specifications. As we went through our inventory of turbines at our factory and inspected those in the field at other sites, we realized this quality deficiency was apparent in almost all drivetrains manufactured to that date to different degrees.’ Clipper decided to refurbish all 67 turbines immediately. That involved removing some drivetrains in the field and replacing them with new units containing gearsets manufactured to Clipper specifications.

Shouldn’t the problems have become apparent during the prototype stage? Christenson says the prototype operated in

Two problems – in the drivetrain and rotor blades – in the Liberty turbine were originally detected by Clipper’s on-site service personnel

Depending on the nature of the specific imperfection and its relative impact on total system function, production-related shortcomings can occur in the product at various operational stages.

**WHAT WENT WRONG, SETTING IT RIGHT**

Craig Christenson, vice president of engineering at Clipper Windpower, explains that the two problems in the Liberty turbine – in the drivetrain and rotor blades – were originally detected by Clipper’s on-site service personnel and at the same site. ‘They heard an unusual noise in one turbine and decided to investigate.’ Christenson was responsible for the process of figuring out how to approach the root cause analysis, finding a solution and deciding how to implement it.

**Drivetrain**

Investigation revealed fractured teeth in the drivetrain’s secondary stage. ‘We informed the project owner, took the turbine offline and conducted a root cause analysis. This isolated a problem with gear-timing tolerances. Improper timing in the Clipper drivetrain creates uneven stress between the gears within a gear set which can lead to premature failure of the gear teeth. The cause of the timing deficiency was found to be a gear supplier quality issue attributable to the suppliers’ manufacturing and quality control processes’, says Christenson, explaining: ‘We procure gears from two different suppliers. The root cause analysis revealed that gearsets from

Wyoming for approximately two years prior to production, during which time they utilized results to make improvements to the turbine before entering into the production phase. But it is quite common for issues to show up once a turbine moves into production – any new turbine requires time in the field in a variety of site-specific conditions in order to uncover any remaining issues.

**Root cause analysis**

Christenson explains the root cause analysis procedure: ‘We utilize the DMAIC Six Sigma quality process at Clipper to guide our root cause analysis. The DMAIC process has five steps or phases – define, measure, analyze, improve, and control. During the first week of June we became aware of the drivetrain problem on one turbine. We then embarked upon a process to determine the exact cause and identify (and validate) a corrective action. As part of this effort we brought two drivetrains back to our factory for teardown and component analysis.’

The procedure also revealed another problem that had not yet come to light. ‘During the root cause analysis, we looked into every possible cause for the gearing failure. That led us to check into the high-speed pinion. Again, we found a manufacturing flaw, but this time traceable to only one of our two gear suppliers. While this was not a major issue, we corrected this with the supplier and have taken the appropriate action of replacing the defective high-speed pinions as part of the drivetrain remediation process.’



LEFT TO RIGHT: Rotor installation; Clipper 2.5 MW Liberty turbine; drivetrain installation; nacelle manufacture

## CLIPPER OFFSHORE

In April, The Crown Estate (UK) signed an agreement to purchase Clipper's 7.5 MW prototype, likely to be at that time the world's largest offshore wind turbine. This turbine – also referred to as the 'Britannia project' – is currently under development by design teams based in the UK as well as the US, and the giant will feature an up-scaled Liberty-type drive train and a 150-metre rotor diameter.

### New quality control on gearsets

To ensure the problem is not repeated, Christenson says Clipper 'developed and implemented a new gearset timing measurement fixture to confirm this "critical to quality" feature for every gearset delivered by our component suppliers. 'In addition, we developed and implemented a drivetrain qualification test in which we confirm proper timing in each unit by measuring load distribution in the gear mesh before approving shipment. While these important quality control provisions ensure that drivetrains leaving our Cedar Rapids plant meet our quality standards, we have, in addition, extended the QC tooling and process improvements further up the supply chain to the gear vendors. This way, gear set and timing quality is completely verified at our suppliers prior to shipment to our Iowa facility. The end result is the application of higher precision during gearset production and confirmation of meeting tolerance specifications at the suppliers' factories.'

### Rotor blades

One of the fleet service personnel also heard an unusual noise coming from one of the rotor blades at the same project site. Christenson explains: 'We stopped the machine to inspect the blades and found that an internal structural reinforcement panel in the root area of the blade had come loose. This panel, referred to as the aft shear web, is a longitudinal secondary spar that connects the high pressure and low-pressure skins to each other in the maximum chord area of the blade. However, the connection of the spar to the blade skins was found to lack the required strength to withstand the loading experienced during turbine operation.'

Out of 250 blades inspected, this problem was found to exist in approximately 20 blades, says Christenson. 'However, we decided to conduct a rotor blade reinforcement of the entire fleet by adding a shear clip that strengthens the connection of the spar to the blade skins. The fiberglass reinforcements provide additional structural integrity to the rotor blade and assure its 20-year design life. The root cause and corrective action was identified through the same DMAIC process and used on the drivetrain issue. Similar blade reinforcements have now been integrated into the design of factory-built blades currently in serial production. The blade reinforcement concept was initially validated using coupon tests and a blade static test, and is now being confirmed with blade fatigue testing.'

### FIXING THE PROBLEM IN THE FIELD

To remove the drivetrain on the Clipper turbine, the rotor must first be removed, says Christenson, so it makes sense to take care of

both issues simultaneously. 'Our approach is to ship a new drivetrain to the site, remove the rotor and reinforce the blades with the rotor on the ground while we replace the drivetrain up-tower. Once the rotor blades are reinforced, the rotor is re-attached and machine re-commissioned.'

His colleague Jeff Maurer, vice president of fleet services at Clipper, says the company is conducting remediation efforts at eight locations: 'This encompasses six wind farms around the country, as well as the Port of Houston where blades enter the country and the blade factory located in Brazil. Maurer explains how the company is organizing such a massive remediation effort that spans so many sites. For the turbines already installed, cranes bring the rotor down to ground. 'Once on the ground, the gearbox is replaced, if necessary, and we begin work on the blades. For example, at one of our large sites, one crane drops the rotors, one is used to replace the gearboxes, and a third reinstalls rotors,' he says.

### Blade remediation process

Maurer says Clipper has segmented the blade remediation process into a series of steps – surface preparation; lamination, post cure and clean-up. 'Surface grinding the remediation area on the blade is required as a preparation step for applying lamination. Due to winter conditions, heating elements as well as industrial electric blankets were placed around the blade to produce the required temperature for curing. We also rig up a lighting system and generators to power the lights and hot air units to warm the inside of the blade. Further, we utilize a control system to assure blades are heated or cooled to a

## ABOUT CLIPPER

California-based Clipper Windpower made its commercial entry into the US wind market in late 2006 with a batch of eight 2.5 MW Liberty turbines manufactured at its Cedar Rapids facility in Iowa. A prototype has been operating in Wyoming since May 2005. In 2007, the company's assembly production was ramped up to 137 units, and the prognosis for 2008 is expected to increase to 300 turbines (7500 MW). The Liberty turbine differs from the majority of large geared wind turbines in its drive technology, having an unusual gearbox concept with four permanent magnet type generators (see *REW* November–December 2006). Above all, Clipper sees its innovative wind technology as a key asset in the company's ambitious drive to become a major global player in the years to come.

certain constant temperature to assure the fiberglass cures properly. Between each phase, a quality inspection is conducted by one of our independent Quality Control specialists to verify the blade meets our requirements before moving on to the next step. During our work we had to deal with winter temperatures, gale force winds, snow, sleet, rain, a lot of mud, and other challenges.' In fact, Clipper decided to start at the site with the coldest climate: 'Our reasoning was that if we could figure out how to cure in cold temperatures, we could do it anywhere. Although it was extremely difficult, we pulled it off within a month and have since been exporting the process to sites across the country.'



**Rotor with thermal insulation wrap to facilitate curing of laminate during blade reinforcement**

The scale of this on-site remediation programme is extensive. About 250 contractors were hired, trained and deployed by Clipper to the various project sites. Clipper managed the contractors, as well as QC experts from Europe, OSHA safety staff, independent engineers representing Clipper's customers, crane operators, training staff and other necessary workers. Maurer explains how much of the work was completed during the peak wind season. 'We do a lot of work at night when the wind speeds are lower. When we're installing rotors, we schedule our work around the clock in order to get efficiencies with our crane operations. The crane usage is one of the more costly elements of the work.'

**MEETING DESIGN – AND COMMERCIAL – CHALLENGES**

Bob Gates, vice president of commercial operations at Clipper Windpower and current president of the board of AWEA, sees Clipper's growing pains as a part of the process of introducing the next generation of turbine. 'The Liberty is a production model operating in the 2–3 MW class at a time when most turbines in production operate below 2 MW. Older technology, used in 1.5 MW and other sub-2 MW turbines, has had many years to mature and went through the same teething issues that larger turbines now face.' Gates says that, historically, a new set of obstacles has had to be overcome each time the industry has stepped up to a higher level of capacity. 'Every new generation required a complete redesign as it moved into a whole different level of stress and strain. At each stage, gearbox and blade manufacturers, for example, are forced to provide parts that go beyond the bounds of current technology.'

'Unfortunately, you don't have a decade between each generation where you can produce a dozen machines, run them for five years and then perfect them. The industry is continually pushing the envelope and extending the capabilities of the entire supply chain as it expands. In many cases suppliers are also forced to build new facilities and new equipment to manufacture parts that are larger than those demanded by any other industry. By working closely with its supply chain partners, the industry has been able to steadily raise capacity without serious disruption.'

Then there are the commercial factors – the market demands more capacity while at the same time it insists upon a lower cost of wind energy, says Gates. 'So if you have a blade that produces 10%



**Nacelle assembly at the Cedar Rapids site**

more energy, then that larger blade has to cost less than the gain it provides. If it's proportionate, then there is no reason to build the larger machine. Every step of the way, therefore, you have to push the technology forward while keeping it cost effective.'

For that cycle to end and new machines to work as intended from the moment they are launched would probably mean the machine had been over-designed and therefore is too expensive, says Gates. 'Product design is a delicate balance of robustness and cost competitiveness.'

**A POSITIVE NOTE**

Clipper reports that its customers embraced the root cause investigations. Says Craig Christenson: 'Both the drivetrain and rotor blade RCAs were subjected to extensive external independent technical reviews by consultants retained by our customers. We received very positive feedback on both the results and the process used.'

As the company faces the greater challenge of its next phase of upscaling, chairman Jim Dehlsen is optimistic, writing in the company's 2007 annual report 'I believe our thorough, methodical and focused response in dealing with these issues, will reflect in meaningful reductions of future warranty costs and in further strengthening of customer confidence in the long-term reliability of our technology. This prompt and disciplined approach to early-stage teething issues in advance of our increasing production volume to fill current firm orders should serve the company well.'

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