

Aerones robotic repair setup at a test turbine

Robotic severe erosion repair: from field tests to wind farms

Severe leading-edge erosion has long sat in an awkward place in blade maintenance: too deep for coating-type repairs, too common to treat as an exception and traditionally addressed by rope access teams. Aerones says it has now carried out the first robotic repairs of Category 4 leading-edge erosion on operating wind farms, following engineering trials at its own test site.

Severe leading-edge erosion is one of the most common problems in operating wind fleets and one of the hardest to plan around. Once erosion breaks through the protection layer and filler and reaches the glass-fibre laminate, the job changes character. It is no longer a coating job. It becomes a structural rebuild on a suspended blade, traditionally carried out by rope access technicians, governed by weather and slow cure chemistry, with quality that varies from technician to technician.

For operators, that has meant a familiar dilemma: repair slowly, defer and accept the production loss or start thinking about replacement earlier than the blade deserves.

Manual repair has meant technicians on ropes at every blade, sanding eroded areas by hand, rebuilding the laminate patch by patch and reshaping the profile with filler and a spatula by eye. It is dangerous work, and the result depends on the person doing it. Uneven edges change the aerofoil, cost efficiency and give erosion a place to start again.

Robotic repair is already used for lighter erosion: Aerones robots prepare the surface, restore the profile and apply leading-edge protection in a planned, documented sequence operated from the ground. This year the company extended its process to severe erosion. Aerones reports that the method is now in use on operating turbines, with a current operational target of one blade per day.

Why severe erosion is a different job

The step from moderate to severe erosion is larger than it looks. In moderate cases (Category 3 on the industry scale), the protection layer has worn through in places and the filler may be damaged, but the structural laminate is usually intact. In severe cases (Category 4), erosion has moved into the laminate itself: exposed glass fibre, localised thinning, surface pitting and, in some cases, minor delamination. The geometry of the leading edge is compromised.

That changes what the repair material has to do. A soft, elastic erosion coating is the wrong tool. Severe erosion needs a hard filler that rebuilds lost laminate, bonds to exposed fibre and existing blade materials and gives the protection system something sound to sit on.

It also changes the time equation. Conventional two-component systems cure through chemical crosslinking that depends on temperature and humidity. For a technician or a robot on a blade, every hour spent waiting for a layer to cure is an hour the turbine stays stopped while the weather window keeps closing.

One robotic workflow, not a patchwork

Aerones' solution combines three elements into a single process run from the ground.

The first is the material. A UV-curable primer and a glass-fibre-reinforced, UV-curable putty act as a hard structural filler rather than a coating, and the repair is finished with filler and a leading-edge protection topcoat.

The second is cure on demand. An integrated UV lamp cures each spot in minutes rather than hours, largely independent of ambient temperature and humidity. The process is workable from +5 °C, which extends the repair season.

The third is robotic application. After robotic grinding prepares the surface, the putty is trowelled onto the leading edge by a robotic applicator with a custom spatula. No rope access is needed.

The sequence runs in five steps: grind and prepare the surface, apply the UV primer, rebuild the laminate with fibre-reinforced putty, UV-cure spot by spot, then apply filler and the LEP topcoat. Each spot is fully cured before the next step begins, and every step is photographed, so the operator receives a complete record of the repair.



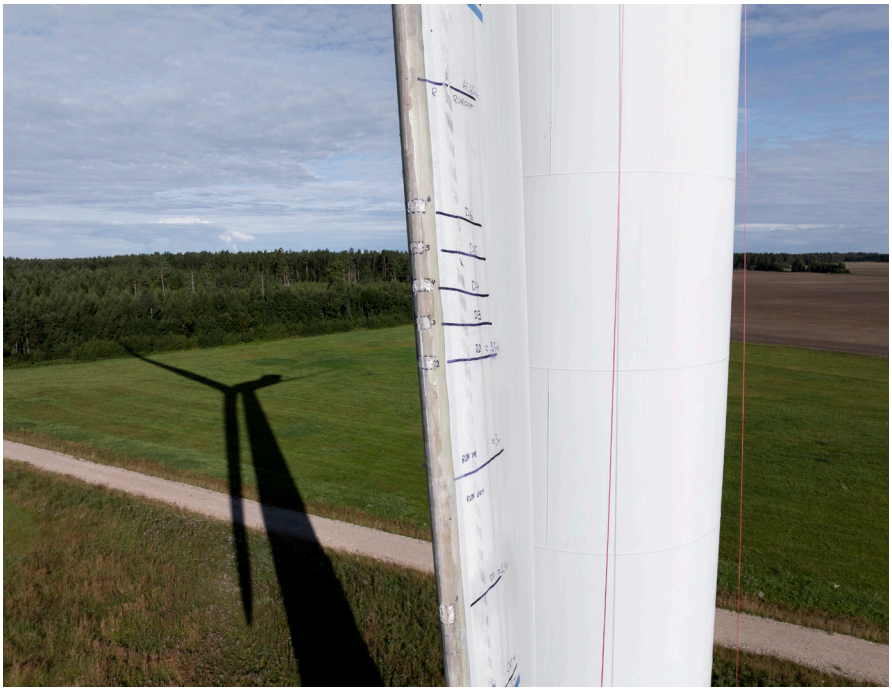
Severe leading-edge erosion on a wind turbine blade

The challenges we solved in field tests

The concept is simple. Making it work on a robot was not, and the first trials surfaced a set of problems that had to be solved before the process could go to a customer site.

The first was the spatula, which turned out to decide whether the repair works at all. In early versions, ribs that were too shallow let material leaving the applicator be pulled upwards so it never reached the blade surface. A longer material accumulation area scraped the material back off, and a thicker foam wasted material instead of holding more. Rib depth proved to be the governing dimension, and the team settled on a design evolved from Aerones' proven LEP spatula, with taller ribs and repositioned inflow.

The second was application angle and layer thickness. Too steep an angle left a lump on the leading edge with trapped air, and thick layers could not be fully cured in one pass. The answer was a shallower angle that scrapes the material and pushes it into the damage, combined with building the repair up in thinner, fully cured layers. With those settings, an entire damaged length could be repaired in a single pass.





Field-test blade photographs showing marked repair areas and the blade following treatment

These solutions were validated on Aerones' test turbine in Latvia in August. Severe erosion damage roughly 3–4 mm deep was created on the leading edge in three configurations: a single damaged area, a cluster and damaged areas spread along a section. Each was repaired with the robots and taken through to filler and topcoat.

From the test turbine to the wind farm

With the process proven on the test turbine, Aerones took it to operating wind farms in September. In the United States, the team repaired real severe erosion on all three blades of an operating turbine. The damage was typical of what operators see in the field: multiple distinct severely eroded areas spread over several metres, which the robot worked through spot by spot.

Field work also sharpened the process. The team standardised the extrusion and travel-speed settings that give the cleanest finish, and introduced practical steps that make each repair faster and more predictable: mapping every damaged area before material application so the right number of spatulas is prepared in advance, coarser abrasives for bulk shaping, and leading-edge-specific grinding blocks. Technicians have been trained intensively on the severe erosion workflow so the service can scale.

Repeatable quality in a fraction of the time

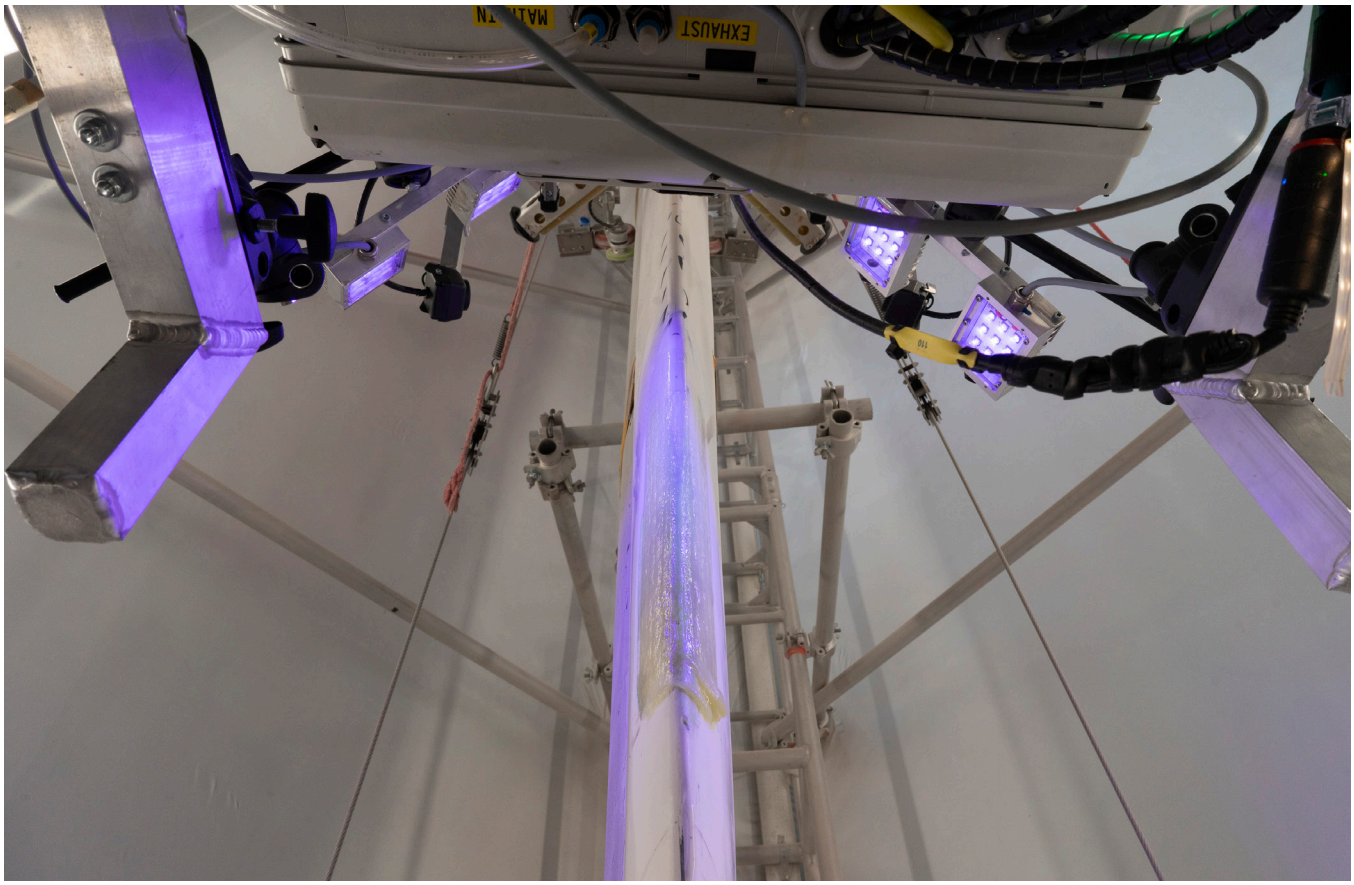
The robot follows a controlled application path, while each layer is cured on demand rather than left to ambient conditions. Every step is photo-documented, with before, during and after images and a final report available to the operator in Aerones' customer portal.

Manual severe erosion repair at height can take several days per blade once preparation, layer build-up, cure times and coating passes are included. Aerones reports a current repair rate of one blade per day using its robotic process. The company says this can shorten turbine downtime and reduce dependence on changing weather conditions.

The consistency of the final profile also matters. The article cites material testing by Catapult suggesting that application method, particularly onsite, can be more significant than the material in determining erosion performance. A smooth, accurately restored leading edge is therefore an important part of the repair.

Aerones also reports a longer-term comparison from an earlier robotic leading-edge repair: on one blade, an upper section was repaired robotically and a lower section by rope access technicians. After two and a half years, the company says the robotically repaired section retained an even profile while

Severe erosion repair has moved from largely manual intervention to a controlled, materials-led robotic process.



Robotic repair head and UV curing equipment in operation

erosion had returned to the manually repaired section. This comparison concerns earlier leading-edge repair work and does not establish the long-term durability of the newly introduced Category 4 process.

A clearly defined scope

Aerones has deliberately defined where the service delivers its best results. It covers individual severe erosion spots in the 0.4–12 m blade section, several of them on one blade if needed, but not continuous full-length erosion. The damage must sit within a leading-edge band under 120 mm wide (within ±60 mm of the leading-edge centre) and be up to 3–4 mm deep without full-depth damage. Polyester laminate blades are the preferred blade type, where adhesion is best validated.

The blade tip, Category 5 structural damage, erosion deeper than 3 to 4 mm and damage on the trailing edge or shell follow separate repair processes. Tip repair is the next development step, and each completed, monitored repair extends the envelope towards longer sections and more damage types.

Monitoring the repair

Aerones says it plans follow-up drone inspections at one week, one month, six months and twelve months, assessing adhesion, condition under operating loads and performance across seasons. Longer-term findings from the new Category 4 process will become available as these inspections are completed.

What it means for fleet planning

With severe erosion repair now available as a robotic, UV-cured and fully documented service, operators have a genuine option between slow manual structural repair and blade replacement. It also changes the timing of decisions: instead of waiting until enough turbines justify a heavy repair campaign, operators can intervene earlier on individual blades and stop erosion before it progresses further.

Severe erosion repair has moved from largely manual intervention to a controlled, materials-led robotic process. For owners of ageing fleets, that changes how they can think about blade replacement, lifetime extension and the cost of keeping turbines turning.

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