Bladena Stronger blades, **More energy**

BLADE ENABLER

Bladena

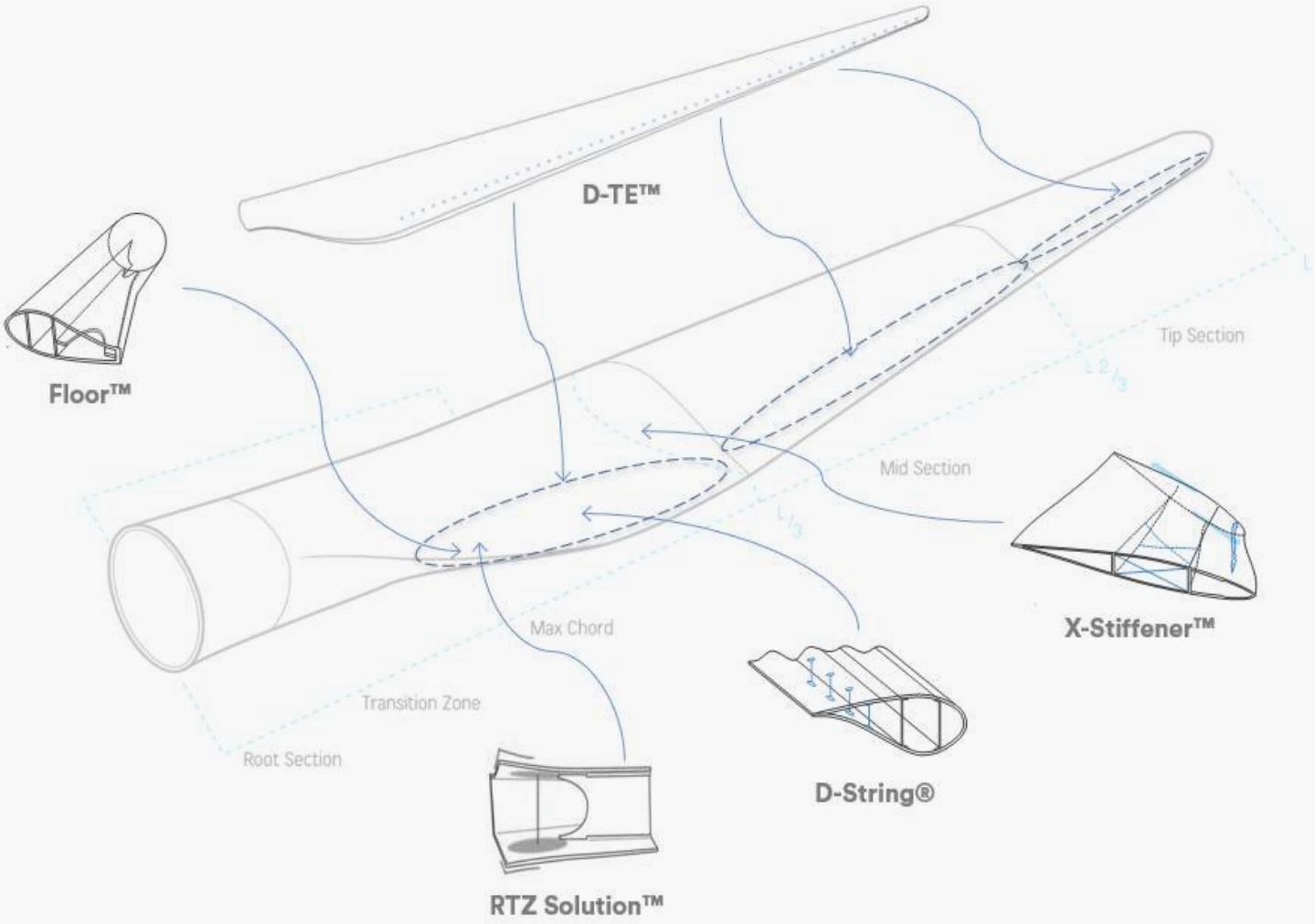
Experts in blades

Retrofit/repair solutions
(Structural upgrades)

Technical documentation

bladena.com

Bladena's retrofit/repair solutions (structural upgrades)



The Bladena retrofit/repair solutions (structural upgrades) are suited to any blade design and solve the specific root cause(s) for the damage(s) to the blade.

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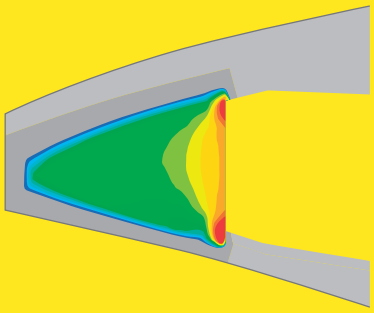
Root cause and failure mode

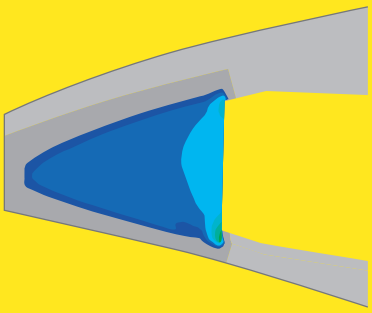
The D-String® prevents breathing of the trailing edge (TE) panels thereby reducing the peeling stresses in the adhesive bondlines in the blade's max chord area and eliminates cracks in the trailing edge max chord area.

There is a direct correlation between breathing and the peeling stresses in the adhesive bondlines: the higher the magnitude of the breathing, the higher the peeling stresses.

The two figures below illustrate a FEM simulation of the reduction of the peeling stresses in the trailing edge (TE) adhesive bondline, with and without the D-String® installed.



without D-String®



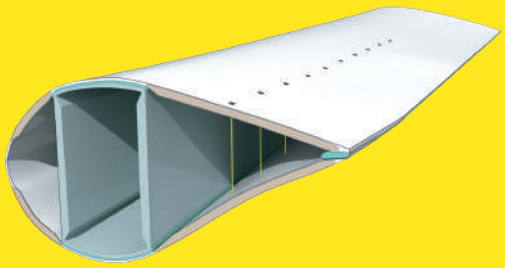
with D-String®

Field measurements show that the installation of D-String® results in a 95-97% reduction of the breathing.

Technical description

The D-String® technology is made out of three main components: two cones, a fuse and a Vectran Ø2.5 mm string. The solution can be installed up-tower using simple tools from a rigged platform.

The D-String® connects the two traling edge (TE) panels, thus reducing the peeling stresses in the blade, thereby eliminating cracks developing in the TE max chord area. Unless otherwise specified, 12 D-String® need to be installed per blade.



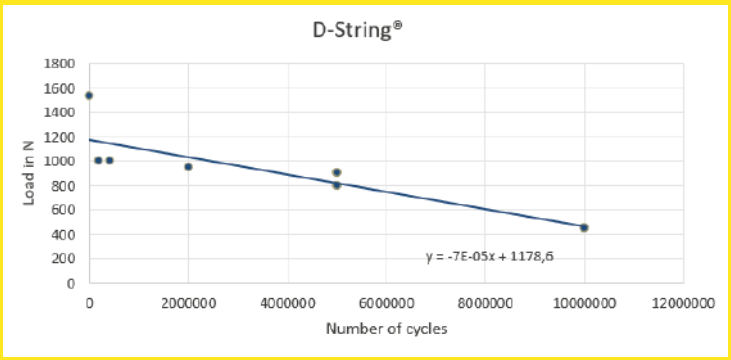
Main benefits

1. Commercially viable solution that eliminates the occurence of cracks on aging blades.
2. Significantly increases the anticipated life-time of the blade.
3. Secures operation of the blade without added maintenance cost.
4. Decreasing time for maintenance, in turn reduces the LCoE increasing the profit margin.
5. The cost of a single repair equals the cost of a D-String® kit for 3 blades (including installation).

Testing campaign

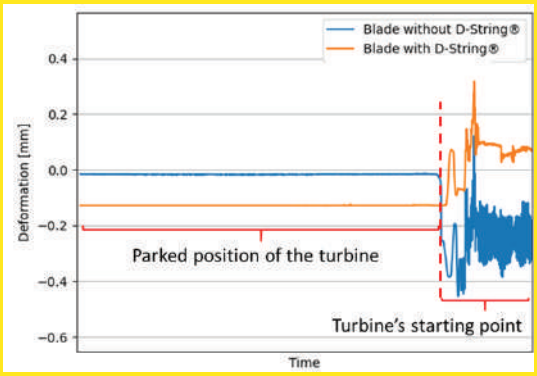
The D-String® has been thoroughly tested at the Technical University of Denmark to demonstrate the performance under normal and extreme operating conditions.

High enough loads do not exist in field which could damage the panels around the cones. The test results have verified that the D-String® has the necessary properties to remove breathing, without causing any risk to the blade.



The presented S/N curve shows that the solution can run through 2 million cycles under the pre-determined ultimate loading.

During full scale testing, the displacements measured from the posiwire were reduced from 10-12 mm down to 3-4 mm by adding 10 D-Strings®.

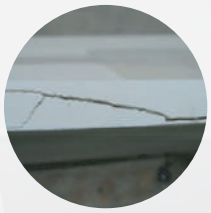


Blade references

Installation of the D-String® will positively impact the operation of your wind turbines by reducing cost for O&M, hence lowering the LCoE:

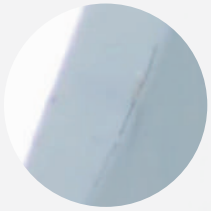
Blade model	V80
Year	2013
Failure	Transverse crack in Trailing Edge panel

Blade model	GE37
Year	2017, 2022
Failure	Bond line crack, Trailing Edge



Blade model	LM45.3
Year	2015
Failure	Transverse crack in Trailing Edge panel

Blade model	V90
Year	2016, 2017
Failure	Longitudinal crack in Trailing Edge



Blade model	AW56.7
Year	2017
Failure	Transverse crack in Trailing Edge panel

Root causes and failure modes

The D-TE™ solution eliminates two different root causes of the possibly occurring damages. Or it can be used as a temporary repair solution in the tip section.

Root Cause 1. - Breathing

Breathing in turbine blades is caused by edgewise loading due to gravity and induces peeling in the adhesive bondlines directly causes cracks, which may lead to severe failures in the blade.

Root Cause 2. - Buckling (mid-span)

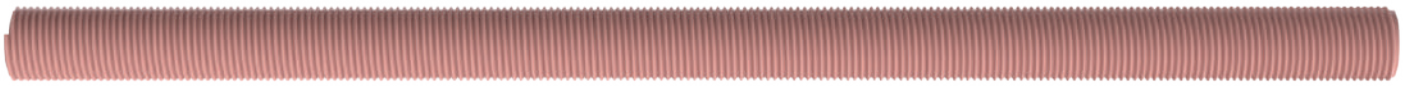
The bending of the blade due to extreme aerodynamic forces and reduced buckling capacity of the blade in mid-span and mid-span towards the tip creates premises for failure.

Temporary repair - Tip opening due to lightning

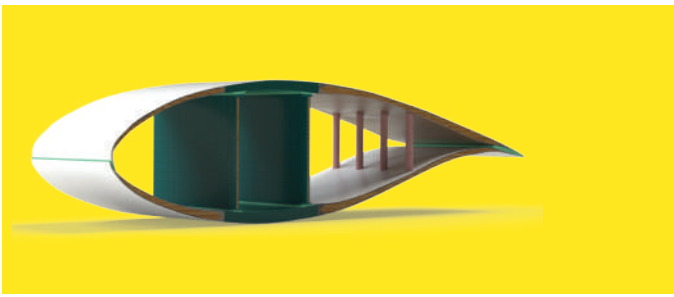
Lightning strikes in the tip area can cause opening on the tip. The solution prevents the detachment of the two shells in the area

Technical description

The D-TE™ consists of one main component which is a simple engineered threaded rod. The rod is made out of a fiber reinforced epoxy resin system with special additives. The solution is offered as a kit which includes specifically designed installation tooling with optimized maintenance being the main focus.



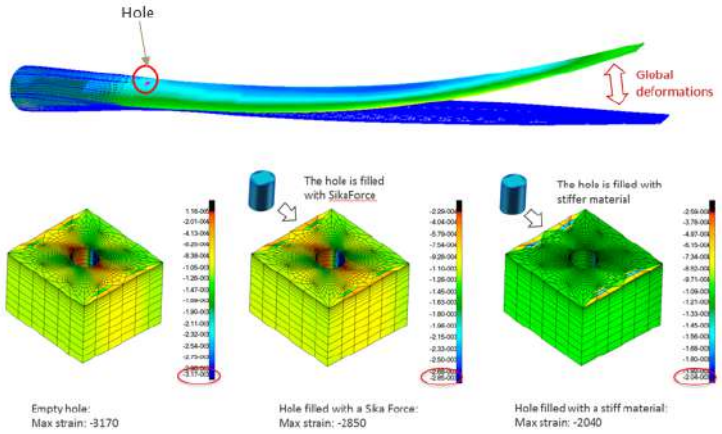
The D-TE™ increases the buckling capacity of the trailing edge (TE) of the blade by increasing the stiffness of the blade panels. It connects the two TE panels, reducing breathing thereby eliminating crack development in the TE section of the blade from max chord to tip.



Main benefits

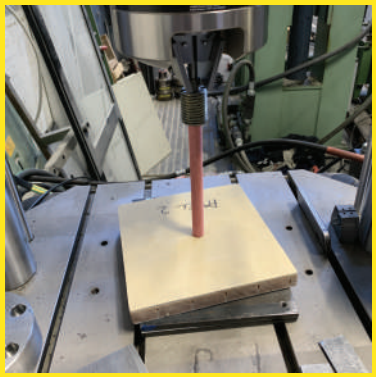
1. The D-TE™ solution eliminates the occurence of cracks and open TE panels on blades.
2. Significantly increases the anticipated life-time of the blade.
3. Reduces the buckling tendency during events with extreme edgewise loading.
4. Decreases time for maintenance, in turn reduces the LCoE increasing the profit margin.
5. Makes it possible to keep a blade in operation with a lightning damage in the tip area.

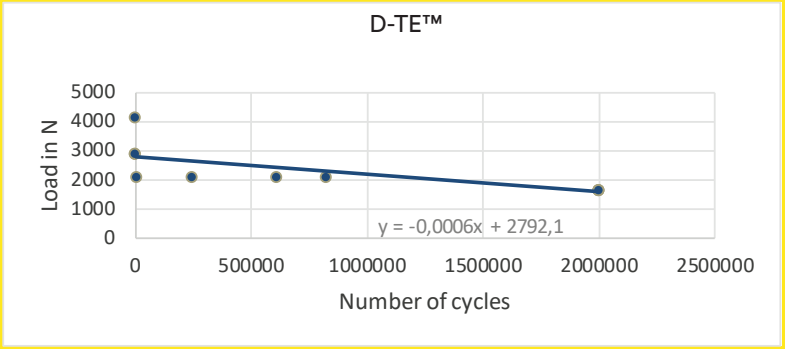
Testing campaign



The effect of drilled holes on wind turbine blade panels were investigated and the conclusion of a FE simulation was that the material area around the holes is not reaching the material strength limits.

High enough loads do not exist in field which could damage the panels around the holes. The test results have verified that the D-TE™ has the necessary properties to remove breathing, without causing any risk to the blade.



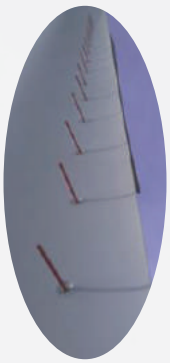


The presented S/N curve shows that the solution can run through 2 million cycles under the pre-determined ultimate loading.

Blade references

Installation of the D-TE™ will positively impact the operation of your wind turbines by reducing cost for O&M, hence lowering the LCoE:

Blade model B53
Year 2021
Failure Crack on Trailing Edge panel, mid-span
Open Trailing Edge, tip



Blade model LM42.2
Year 2015
Failure Open Trailing Edge, tip

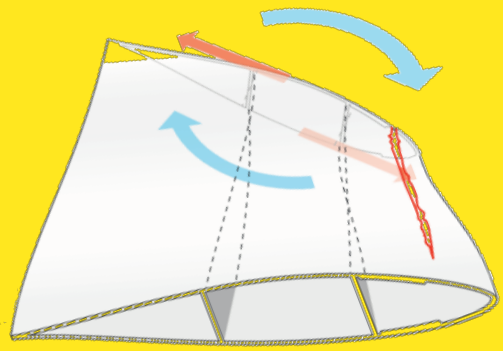
Blade model G97
Year 2017
Failure Crack on Trailing Edge panel, mid-span

Blade model G58
Year 2018
Failure Crack on Trailing Edge panel, mid-span

Blade model Vestas V47
Year 2017
Failure Crack on Trailing Edge panel, mid-span

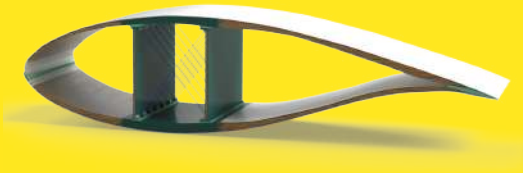
Root causes and failure modes

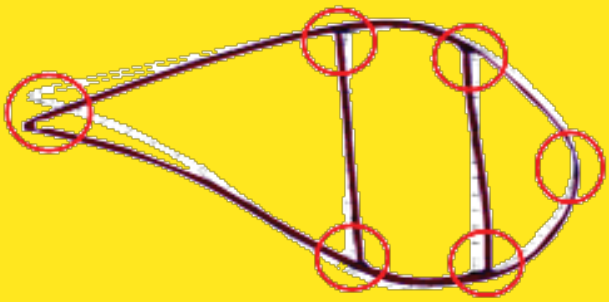
The X-Stiffener™ is an advanced solution developed to eliminate failures in the bondlines of the main shear webs or the aft shear web and flatback trailing edge (TE) by removing twisting as the root cause.

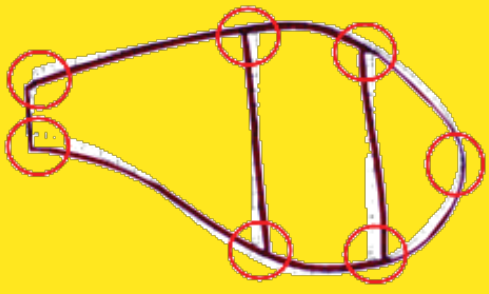


During operation twisting of the main box, increases the peeling stresses in the adhesive bondlines of the blades, as can be seen in the sketches below. The stress concentration in the adhesive bondlines will, if not discovered, develop into cracks, which in time becomes visible on the exterior surface of the blades.

The X-Stiffener™ eliminates twisting in the main box by increasing the cross sectional strength of the blade.





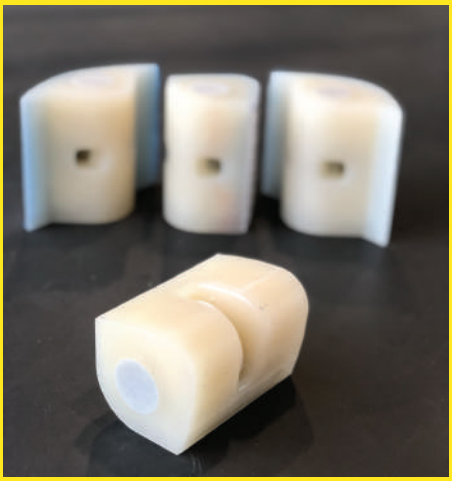


On the above illustrations the white shape present the deformation while the purple shape presents the undeformed shape.

X-Stiffener™

by Bladena

Technical description

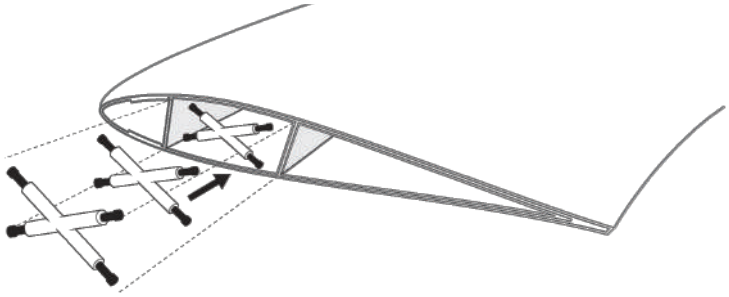


The X-Stiffener™ consists of two components; the anchoring devices and the fiber ropes connecting the corners within the blade.

The X-Stiffener™ is designed as a strong yet light weight product, which consists of respectively an anchoring device and a Dynamica DM20 pre-stretched rope. The anchoring device is attached in the corners of the main shear webs or the aft shear and the flatback trailing edge of the blade forming a cross.

Main benefits

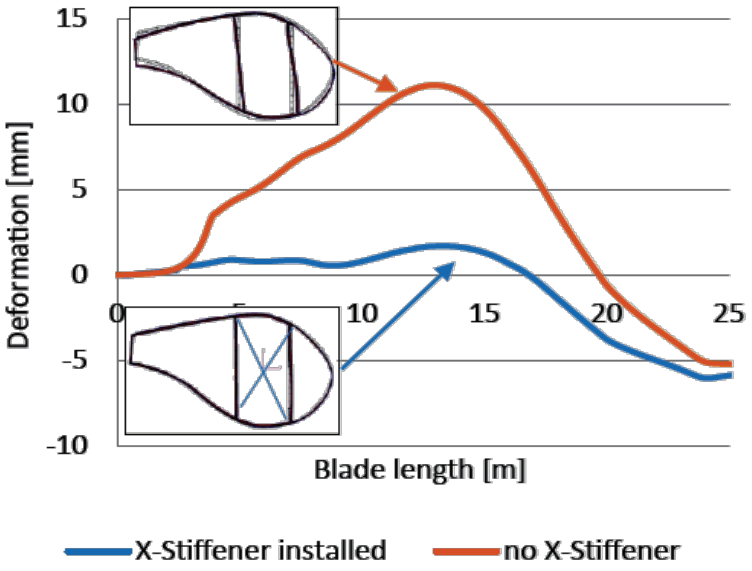
1. The X-Stiffener™ eliminates failures in the adhesive bondlines in the main shear webs or the aft shear web and flatback trailing edge (TE).
2. Helps blades with large flatbacks to avoid excess twisting.
3. Increases cross sectional strength of the blade and thereby maintaining the aerodynamic profile of the blade.
4. Significantly increases the anticipated lifetime of your blades.
5. The installation of X-Stiffener™ does not affect the integrity of your blade.



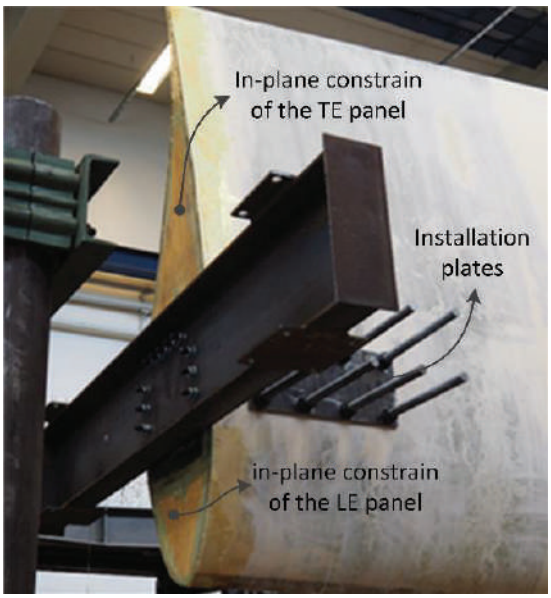
Testing campaign

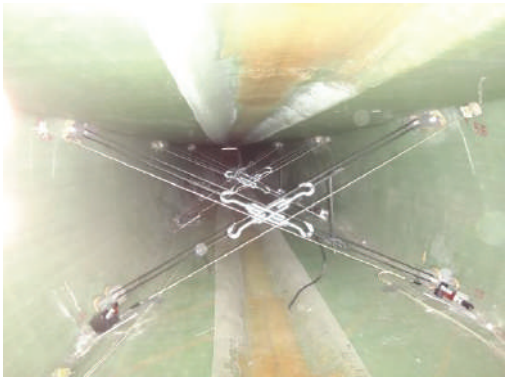
In FEM studies of a 68 m long flat-back blade the deformation of both rear-and main box was significantly reduced by the installation of the X-Stiffener™.

FEM modelling shows a 80-85% reduction of twisting after the installation of the X-Stiffener™. The twisting increases with the length of the blade. A simple comparison between a 34m and a 68m blade showed an increase of more than 250%.



Results from both the test and FEM shows that when a pure torsional moment is applied on a cross-section of a blade, this will develop a cross-sectional shear distortion on a different cross section, in this case towards the root.





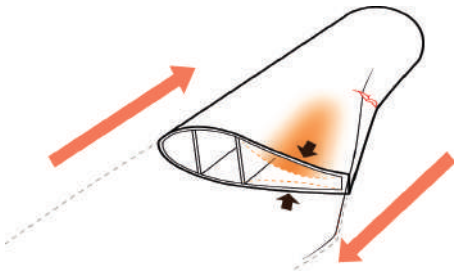
Blade references

Installation of the X-Stiffener™ will positively impact the operation of your wind turbines by reducing cost for O&M, hence lowering the LCoE:

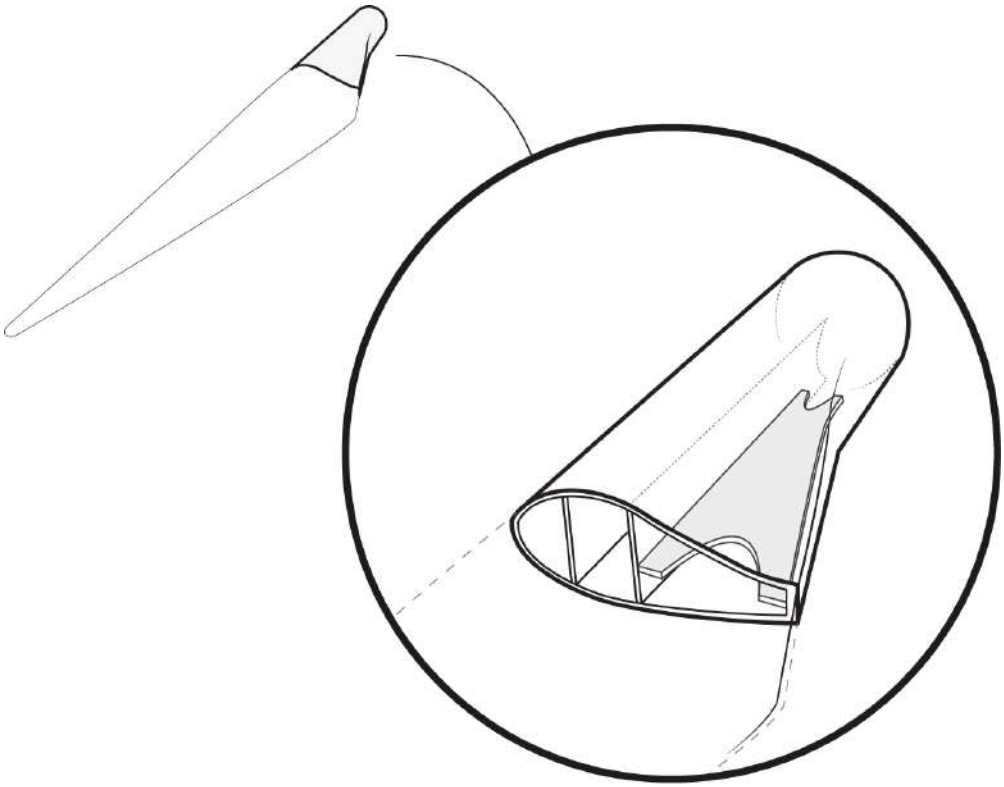
Turbine	Levenmouth 7MW
Year	2019
Failure	No issues, validation purposes

Root causes and failure modes

The Floor™ is an advanced solution developed to eliminate failures in the transition zone area towards the cylindrical root due to the heavy out-of-plane deformation caused by the curved geometry and the high loads.



The Root-Transition zone features a complex geometry with tapering panels in different directions. This makes the trailing edge (TE) transition zone vulnerable to out-of-plane deformations especially on medium-sized to large blades.



Floor™
by Bladena

Technical description

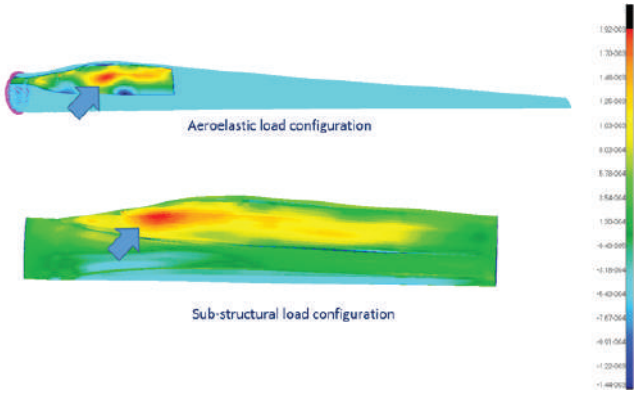
The Floor™ is a one-component solution aiming to prevent damages in the trailing edge (TE) transition zone. The solution must be designed specifically for the blade design as the sizes could differ from blade to blade. It can be installed both for box bar and non box bar designs. In the case of box bar designs, a man-hole has to be bored in the box bar to access the trailing edge (TE) region of the blade.

Main benefits

1. The Floor™ mitigates damages in the trailing edge (TE) transition zone area by reducing panel breathing.
2. Significantly increases the anticipated lifetime of your blades.
3. The installation of Floor™ does not affect the integrity of your blade.

Testing campaign

Non-linear FEM simulations resulted in significant increase in strain levels in the TE transition zone under combined loading level. The installation of the Floor™ solution would support in large load transfers mitigating the risk of fatigue damages.



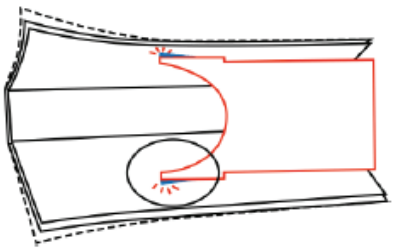
For performance demonstration of the Floor™ technology and the positive effect of the Floor™ solution in the Root-Transition zone, three wind turbine blades have been tested in fatigue with and without the Floor™ technology:

- Large-scale testing of a **SSP34m** blade with fatigue loads at DTU
- Full-scale testing of a **SSP34m** blade with fatigue loads at Blaest
- Full-scale testing of a **LM58.7m** blade with fatigue loads at Blaest

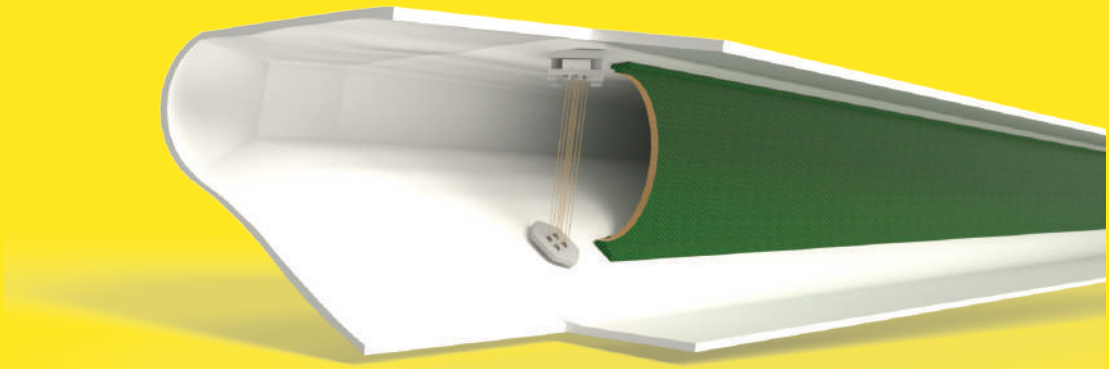
In the two full-scale tests, comparison testing was performed with and without the Floor™. In both tests damages appeared and expanded in the root-transition zone. Then the Floor™ was installed and the damage progression stopped.
On the third blade, the Floor™ was installed before the blade test. Also, this test successfully showed the effect of the Floor™, since no failure was observed neither in the transition zone or in the adhesive connection between the Floor™ and the blade structure.

Root causes and failure modes

The RTZ Solution™ is developed to eliminate aft shear web disbonding around the web's fish-mouth geometry. Peeling stresses in the adhesive joint occuring due to out-of-plane deformation (or breathing) cause the disbonding of the aft shear web.



The RTZ Solution™ significantly reduces the peeling stresses in the transition zone area where the aft shear web starts and eliminates defects occuring in the region.



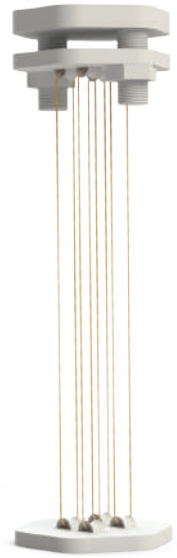
The solution connects the two shells and reduces out-of-plane deformations.

RTZ solution™
by Bladena

Technical description

The RTZ Solution™ consists of four main components; a bottom plate, a top plate, Vectran rope, and a fixing mechanism. The installation takes place inside the blade without any drilling involved on the blade shells. The mounting of the solution is performed with the use of a Bladena approved adhesive.

A strong focus of the design is to make it easy to install up-tower in a safe way without altering the aerodynamic profile of the blade.



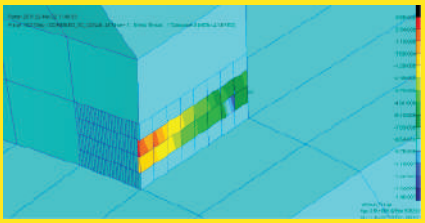
Main benefits

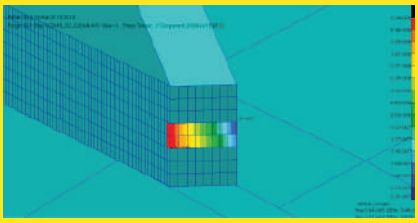
1. The RTZ Solution™ eliminates failures in the aft shear web foot connection.
2. Helps large blades with aft shear webs to avoid excess out-of-plane deformation in the root transition zone area.
3. Significantly increases the anticipated lifetime of your blades.
4. The installation of RTZ Solution™ does not affect the integrity of your blade.

Testing campaign

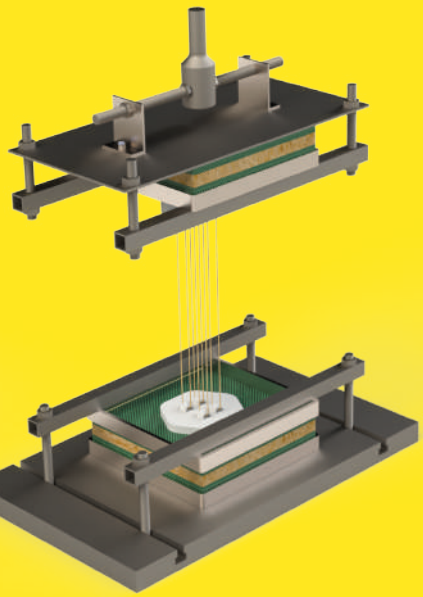
It was verified through FEM analysis that the impact of blade length is significant on peeling stresses magnitude at the aft shear web's bondline. Connecting the two shells mitigates the peeling stresses.

	Peeling Stresses (Mpa)
34 m blade	3.5
65 m blade	8.0
Change (%)	125





A testing campaign is designed to investigate the solution's performance on sub-component and large scale levels. Tests are being performed under both static and fatigue conditions at the Technical University of Denmark.



Bladena

BLADE ENABLER

Get in touch to learn more about our solutions and their application onto your blades.

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