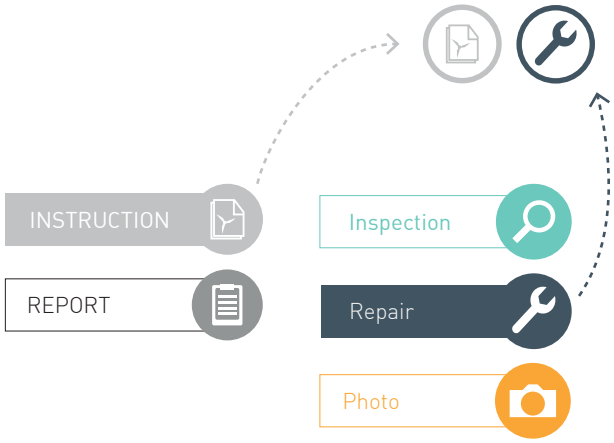
INSTRUCTION Blade Repair



INDEX

0 | INTRODUCTION

INTRODUCTION

The purpose of this document is to communicate the minimum requirements and documentation for blade repairs.

NAMING CONVENTION

The Inspection report must be named after the following naming convention. All naming information can be found on the front page of Inspection Report.

Filename = **sitename_turbine no_blade_report type_insp.type_date**
(1) (2) (3) (4) (5) (6)

Example

1. Site name — Axeltofta
2. Turbine no. — 12345
3. Blade — B
4. Report type — INSP (in report REP)
5. Inspection type — EX or IN (external or internal)
6. Inspection date — 7. December 2015

This will give the following filename
Filename = **Axeltofta_12345_B_INSP_EX_20151207.doc**

HSE

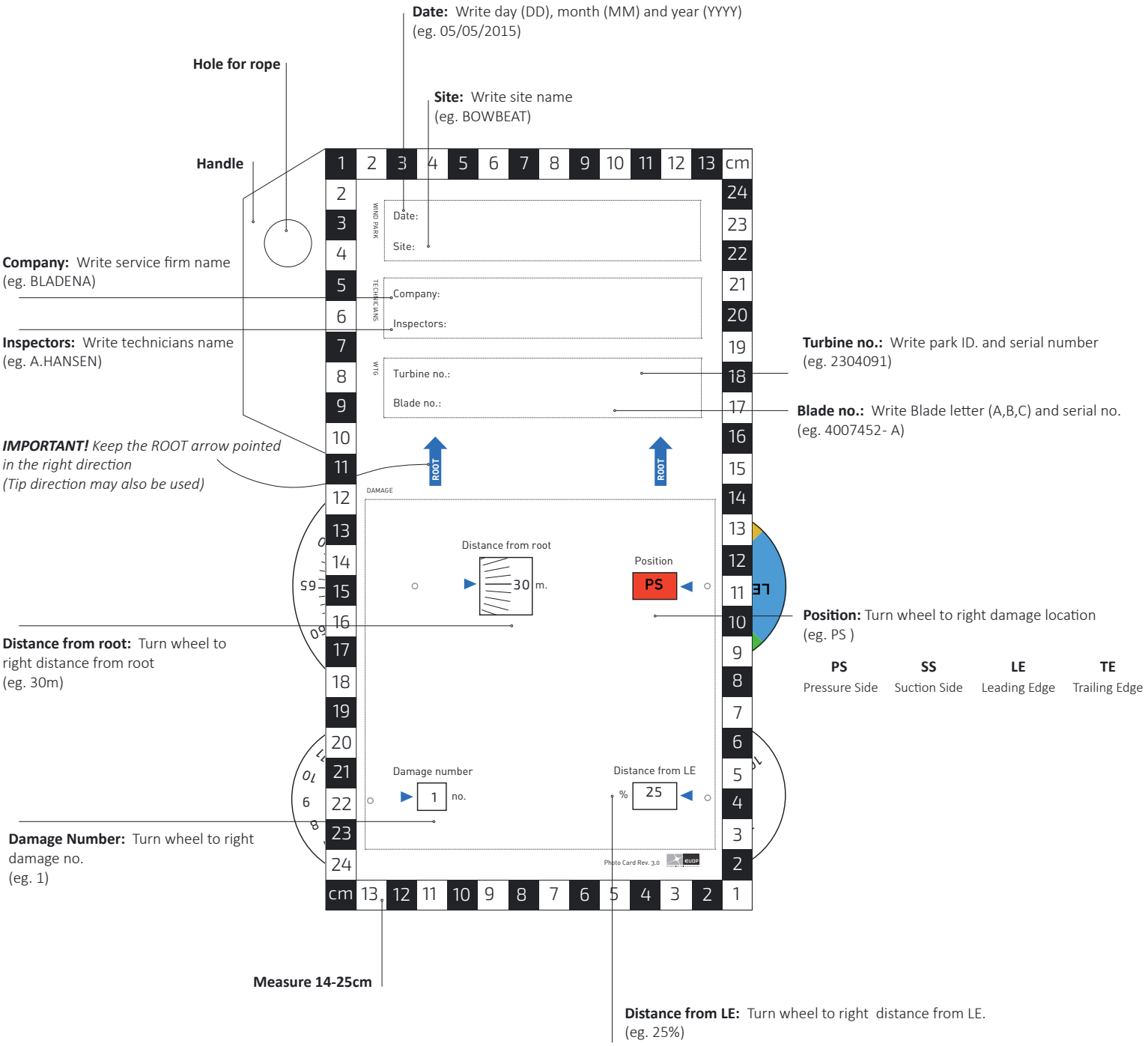
Before starting the work, the service technician shall be familiar with the hazards and risk assessment related to the work. Use the HSE guidelines and minimum requirements stated by your respective company.

PHOTO REQUIREMENTS

All findings must be documented with photos and put into the inspection report. Refer to Instruction - Blade Photos for the minimum requirements on how to take a photo.

1 | PHOTO CARD

When a damage on a blade is detected, the photocard must be placed next to the damage and documented with a picture. For in depth description on the minimum requirements of taking a picture, please refer to “Instruction – Blade Photos”.



2 | PHOTO REQUIREMENTS

All finds must be documented with photos and out into ‘Report Repair’. Refer to ‘Instruction Photo’ for the minimum requirements on how to take a photo.

It is expected that high-quality images of the observations are provided when ***inspecting*** a turbine.

When ***repairing*** a turbine it is expected that a very thorough description of the process is provided. It is expected that pictures are taken for every step of the repair including:

- Before repair process begins (overview of whole repair area and close up if needed)
- Whilst going through the layers
- When all layers have been grinded/sanded (bottom of defect has been reached)
- When chamfering has been performed and area is ready for lamination
- Foam application if applicable
- Glue application if applicable
- When all laminate/foam/glue has been performed
- When the repair is complete and paint has been applied

On all pictures involving lamination, gluing and painting environmental conditions temperature and humidity must be shown on photo or noted in documentation.

The documentation of damage repair is crucial and we expect minimum the following information:

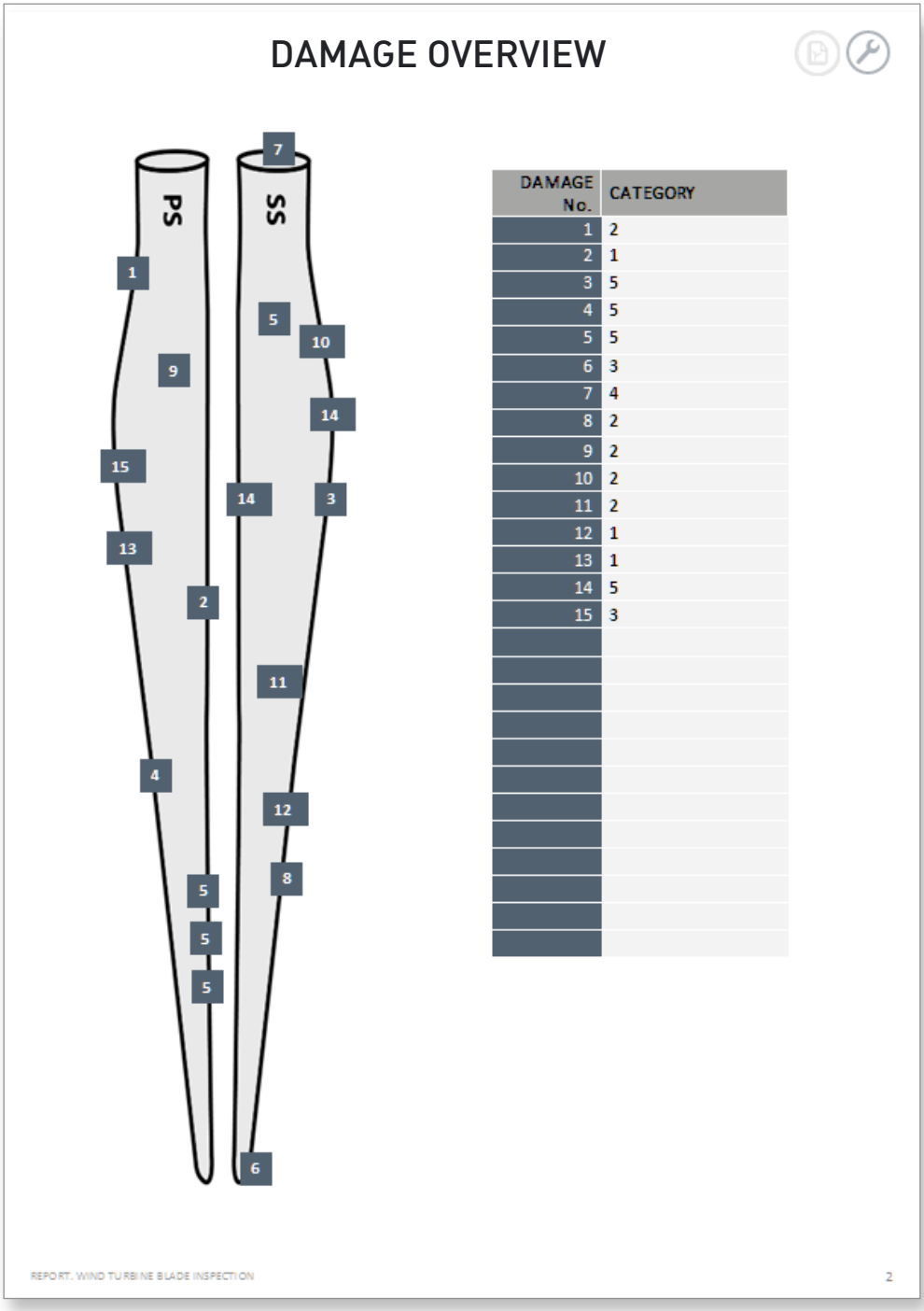
- Size of defect (longitudinal/transversal) before grinding
- Position of defect (longitudinal/transversal position and SS/PS shell)
- Damage description
- Chamfering area (size and chamfering rate)
- Curing time for resin/glue
- Amount of glass layers removed/replaced
- Type of glass/glue/resin used/replaced
- Environmental conditions (humidity, temperature)
- Name of technician performing the repair

If observed damage is located close to bondlines it is important to investigate if the damage moves into the bondlines. Often cracks in bondlines start from inside and will not be visible until penetrating through the paint. Tapping on the affected area can give an indication of the extend of the damage.

3 | HOW TO FILL OUT THE REPAIR REPORT

In the section “Damage Overview” is an overview figure of the blade showing PS and SS. Next to the figure is a table where all damages must be listed by damage number and given a damage category depending on the damage. The number boxes can be moved out on the blade figure by dragging to show in which area the damage appear on the blade. Make copies of the boxes if more are needed.

On the following pages in the repair report one photo per each page is inserted in the page table. Damage number, category and a short damage description are added. If more pages are needed, copy and paste empty table pages.



DAMAGE No.	CATEGORY
1	2
2	1
3	5
4	5
5	5
6	3
7	4
8	2
9	2
10	2
11	2
12	1
13	1
14	5
15	3

4 | PROCEDURES FOR REPAIR DOCUMENTATION

All photos must include measurements. This can e.g. be done by using the phot card or measurement tape in the photo.

BONDLINE

For cracks or other damages in the bondlines, the following documentation must be provided:

1. A photo of the damage.
2. For damages in the glue distance blocks must be visible.
3. For any cracks or opening in the bondlines, a photo showing the opening size with measurements must be taken.
4. A photo of the activated surface before any new substances are applied.
5. A photo after new glue has been applied. Documentation on temperature, humidity and curing time must appear on the photo or in written documentation.
6. A photo after the matting of the surface, before the laminate is grinded.
7. A photo after the surface has been grinded.
8. A photo showing the surface after it has been painted. *If the surface must be grinded and painted several times, a photo is taken for every step.*

LAMINATION

For repair in the laminate the following documentation must be provided:

1. A photo of the damage.
2. Mark on the blade the direction of the fibres on the blade and take a photo showing the damaged area after the paint has been grinded away.
   If the damage is not extending into the glass, the area can painted again and a photo taken.
3. A photo showing the bottom of the defect. By this means the material has been removed to the full depth of the damage.
4. A photo after the damage has been chamfered.
5. For each re-applied laminate a photo must be taken. For each laminate documentation on temperature, humidity and hardness achieved over a certain amount of time must appear on the photo or in written documentation. The hardness of each laminate must be measured and documented. Batch numbers must be noted in documentation.
6. A photo after the matting of the surface, before the laminate is grinded.
7. A photo after the surface has been grinded.
8. A photo showing the surface after it has been painted. *If the surface must be grinded and painted several times, a photo is taken for every step.*

LEADING EDGE

If the damage in the leading edge region appears in the laminate, the leading edge damage has to be filled out with appropriate material after the surface has been grinded and before the surface is painted, see point 8 below.

1. A photo of the damage.
2. A photo showing the damaged area the paint has been grinded away.
   If the damge is not extending into the glass, the area can be painted again and a photo taken.
3. A photo showing the bottom of the defect. By this means the material has been removed to the full depth of the damage.
4. A photo after the damage has been chamfered.
5. For each re-applied laminate a photo must be taken. For each laminate documentation on temperature, humidity and hardness achieved over a certain amount of time must appear on the photo or in written documentation. The hardness of each laminate must be measured and documented.
6. A photo after the matting of the surface, before the laminate is grinded.
7. A photo after the surface has been grinded.
8. A photo showing how the damge has benn filled out with an appropriate substrate.
9. A photo showing the surface after it has been painted. *If the surface must be grinded and painted several times, a photo is taken for every step.*

ADD-ONS

1. A photo must be taken of the damage before repair.
2. A photo must be taken after the surface has been grinded.
3. A photo must be taken after the repair.

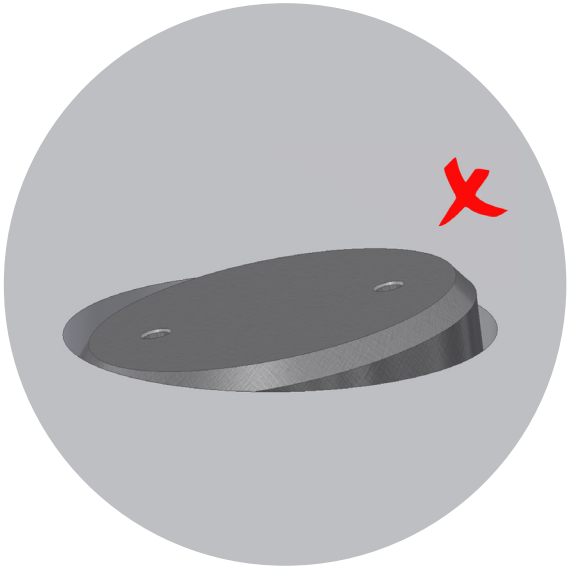
5 | MISCELLANEOUS

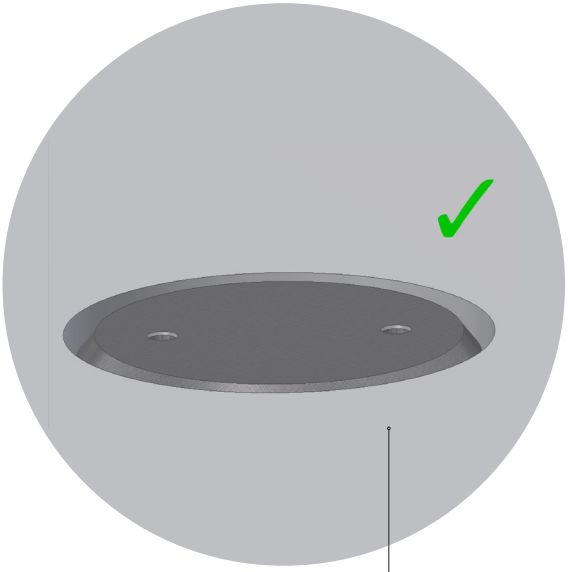
PAINT REPAIRS

Repairs must not differ much compared to the surrounding blade surface with regard to color, finish adhesion, layer thickness and smoothness.

LIGHTNING SYSTEM BLADE

Check that the blade surface 1.5mm from the conical part of the receptor, also check that the receptor is aligned with the blade surface (see figures below)





Receptor: The receptor must have a maximum outward offset of 2mm from the blade surface.

Appendix A | **TERMS AND DEFINITIONS**

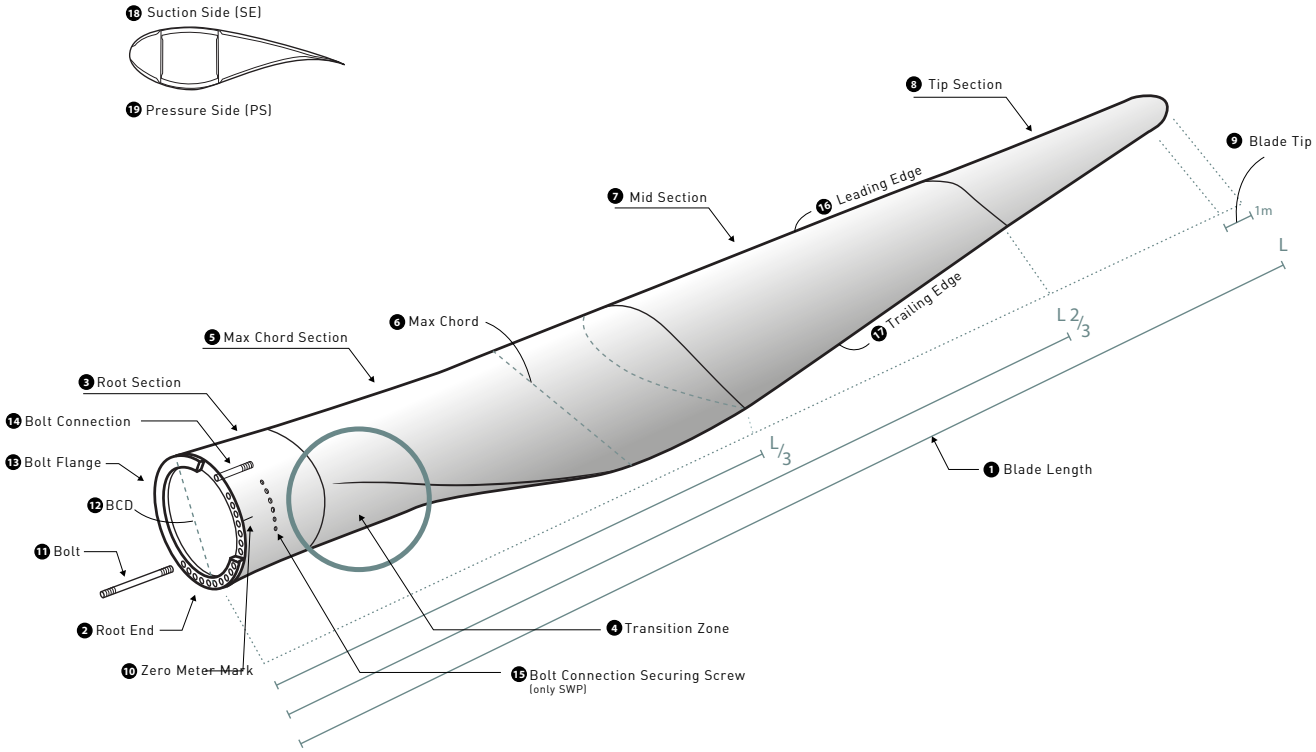


Figure 1 Illustration: KIRT x THOMSEN

BLADE OVERVIEW

1. BLADE LENGTH: Length of the blade from blade root to blade tip.
2. ROOT END: The end of the blade on which the blade is attached by bolts (bolted) to the blade bearing.
3. ROOT SECTION: The cylindrical section of the blade at the root towards the Blade tip. The root is attached by bolts (bolted) to the blade bearing.
4. TRANSITION ZONE: The flat back at the root zone on blades, where the transition from round to profile is done by use of third surface.
5. MAX CHORD SECTION: The section of the blade between the Root Section and the 1/3 of the total Blade Length.
6. MAX CHORD: The longest distance between the two chord wise extreme points (viz. Leading Edge and Trailing Edge Extreme Point respectively).
7. MID-SECTION: The section of the blade between the 1/3 of the blade length and 2/3 of the blade length.
8. TIP SECTION: The section of the blade between mid-section and blade tip. i.e. the last 1/3 of the blade.
9. BLADE TIP: The tip of the blade in the opposite direction of the root defined at the last meter of the blade.
10. ZERO METER MARK: Starting point of all lengthwise measurements of the blade. Placed at the root.
11. BOLT: Steel bolt used to attach to the blade to the blade bearing.
12. BOLT CIRCLE DIAMETER (BCD): The diameter between centres of opposite bolts in the root.
13. BOLT FLANGE: The steel flange placed at the root of the blade towards the hub.
14. BOLT CONNECTION: The steel bushing inserting into the root in a circular pattern, and used as a threaded connection for the bolts.
15. BOLT CONNECTION SECURING SCREW: Nut along the circumference close to the root and used to secure the bolt in the bolt connection. Used in the so-called IKEA bolt connection.
16. LEADING EDGE (LE): Rounded aerofoil part of the blade facing the rotational direction of the blade. Also, the angle of attack of the wind.
17. TRAILING EDGE (TE): The thin aerofoil rear section of the blade facing away from the rotational direction of the blade.

Appendix A | **TERMS AND DEFINITIONS**

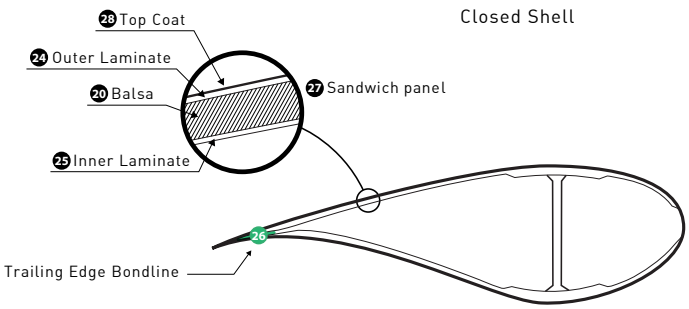
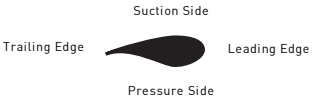


Figure 2 *Illustration: KIRT THOMSEN*



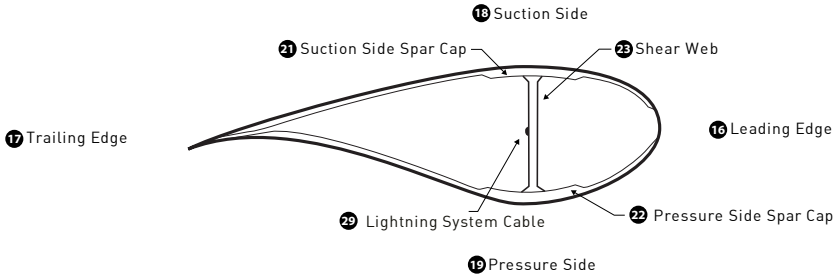


Figure 3 *Illustration: KIRT THOMSEN*

CLOSED SHELL

1. SUCTION SIDE (PS): The panel from TE towards LE (TTL) has less curvature than the other.
2. PRESSURE SIDE (SS): The panel from TE towards LE (TTL) has more curvature than the other.
3. BALSA: Core material of balsa wood.
4. SUCTION SIDE SPAR CAP: The load carrying laminate above the shear web (s) on suction side.
5. PRESSURE SIDE SPAR CAP: The load carrying laminate above the shear web (s) on pressure side.
6. SHEAR WEB: The shear web(s) running lengthwise between the two shells.
7. OUTER LAMINATE: The outer laminate layers of the sandwich panel e.g. on the shell.
8. INNER LAMINATE: The inner laminate layers of the sandwich panel e.g. on the shell.
9. TRAILING EDGE BOND LINE: The bond line bonding between the two trailing edge panels. For a Siemens blade there is no glue but still a connection.
10. SANDWICH PANEL: A panel consisting of two skins and a core material.
11. TOP COAT: The coating on the surface /outer side of the shells.
12. LIGHTNING SYSTEM CABLE: Cable connection the Lightning receptor with the grounding.

Appendix A | **TERMS AND DEFINITIONS**

Blade Box Spar Concept

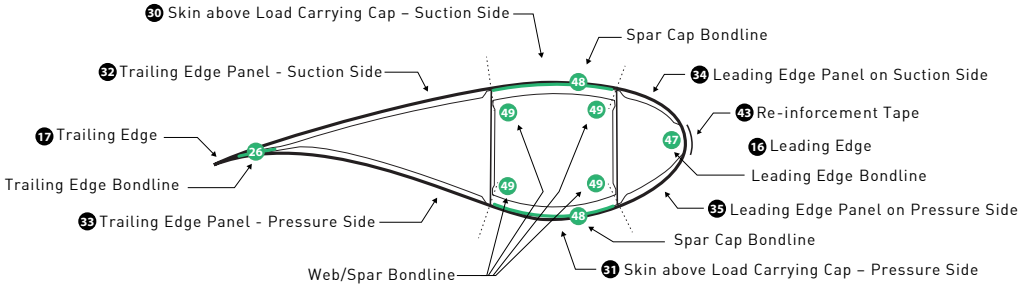


Figure 4 *Illustration: KIRT THOMSEN*

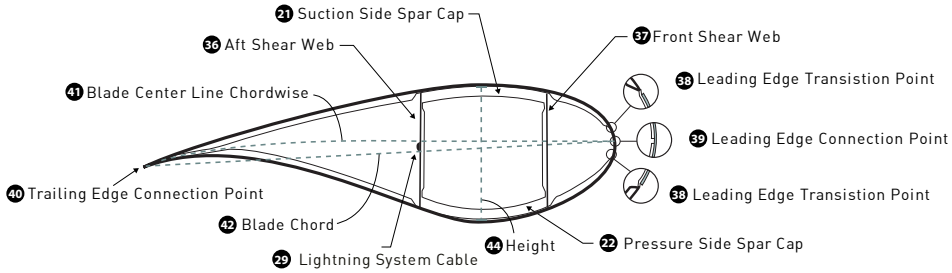


Figure 5 *Illustration: KIRT THOMSEN*

BOX SPAR CONCEPT

1. SKIN ABOVE LOAD CARRYING SHELL – SUCTION SIDE: The panel placed above the spar cap on the suction side of the blade.
2. SKIN ABOVE LOAD CARRYING SHELL – PRESSURE SIDE: The panel placed above the spar cap on the pressure side of the blade.
3. TRAILING EDGE PANEL- SUCTION SIDE: The panel placed in the area between the web(s) and the trailing edge on suction side.
4. TRAILING EDGE PANEL- PRESSURE SIDE: The panel placed in the area between the web(s) and the trailing edge on pressure side.
5. LEADING EDGE PANEL ON SUCTION SIDE: The panel placed in the shell between the web and the leading edge transition point on suction side. The panel is usually a sandwich panel.
6. LEADING EDGE PANEL ON PRESSURE SIDE: The panel placed in the shell between the web and the leading edge transition point on pressure side. The panel is usually a sandwich panel.
7. AFT SHEAR WEB: The shear web placed towards the trailing edge, if the profile consists of two webs.
8. FRONT SHEAR WEB: The shear web placed towards the leading edge, if the profile consists of two webs.
9. LEADING EDGE TRANSITION POINT: The point on the blade surface at the front end Panel (on both suction side and pressure side respectively) where the sandwich panel stops (towards the leading edge).
10. LEADING EDGE CONNECTION POINT: The point at the leading edge where the two shells are connected.
11. TRAILING EDGE CONNECTION POINT: The point at the trailing edge where the two shells are connected.
12. BLADE CENTER LINE CHORD WISE
13. BLADE CHORD: The straight line going from the leading edge dividing point to the trailing edge dividing point.
14. RE-INFORCEMENT TAPE: Tape applied on the leading edge and running along the lengthwise direction of the blade.
15. HEIGHT: The perpendicular distance between the outer side of the blade surface on Pressure side and Suction side at any point along the Blade Center line length wise.

Appendix A | **TERMS AND DEFINITIONS**

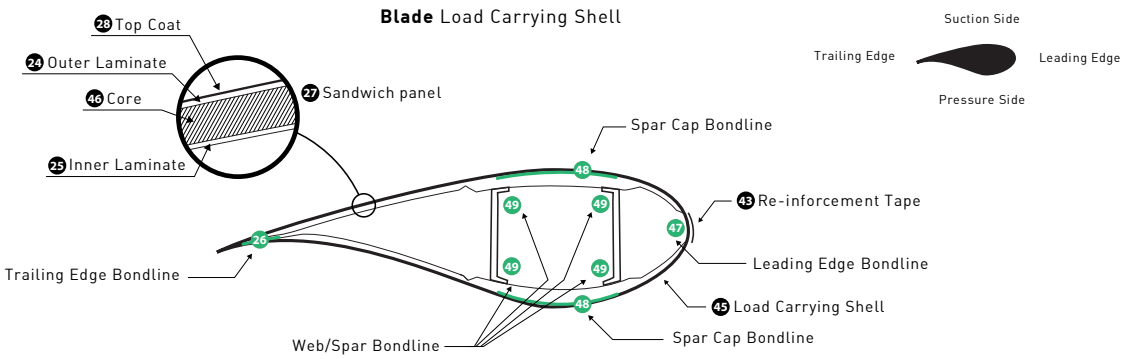


Figure 6 *Illustration: KIRT THOMSEN*

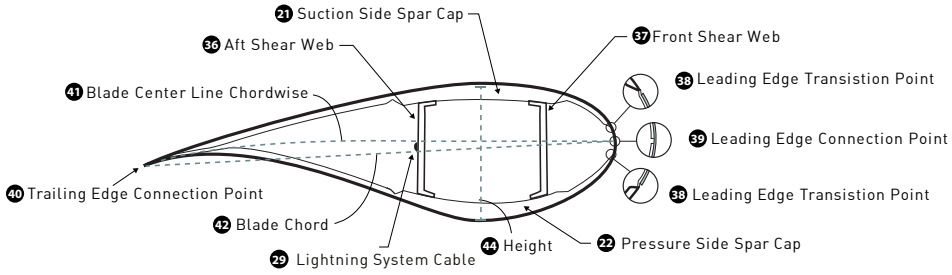


Figure 7 *Illustration: KIRT THOMSEN*

LOAD CARRYING SHELL

1. LOAD CARRYING SHELL: Sections of the aerodynamic profile of the Blade.
2. CORE: The material, typical foam or balsa, between the two layers of laminate.
3. LEADING EDGE BOND LINE: The bond line bonding between the leading edge panels.
4. SPAR CAP BOND LINE: The bond line bonding the spar cap to the panel at the suction side of the blade.
5. WEB/SPAR BOND LINE: The bond line ensuring bonding on the suction side of the blade between the front web and the spar cab, on the side facing the leading edge.

Appendix A | **TERMS AND DEFINITIONS**

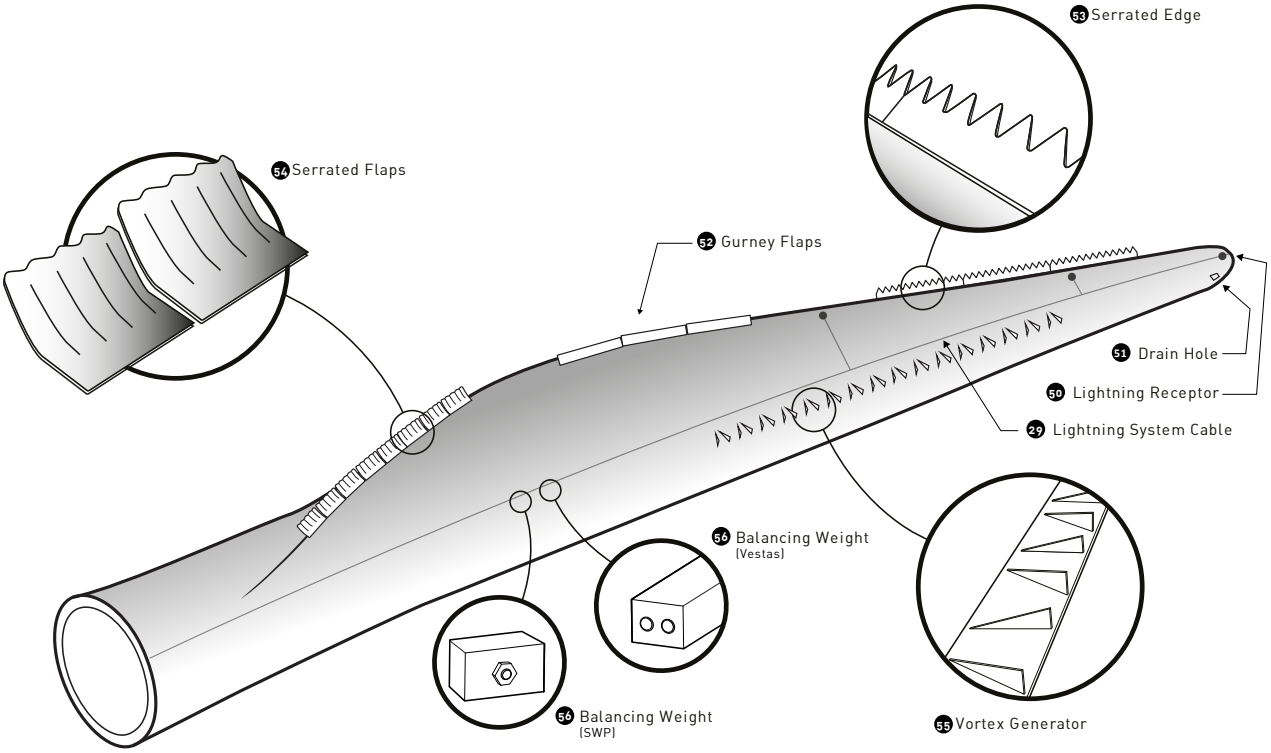


Figure 8 *Illustration: KIRT THOMSEN*

ADD-ONS

1. LIGHTNING RECEPTOR: receptor placed along the blade length designed to attract and direct the electricity via the Lighting System Cable to the ground.
2. DRAINHOLE: Angled hole near the tip or shoulder. Exit hole for water, dirt etc.
3. GURNEY FLAPS: Gurney flap are add-on placed along the trailing edge on the pressure side of the blade.
4. SERRATED EDGE: Saw-toothed TE plastic add-on placed on the trailing edge in the tip zone of the blade.
5. SERRATED FLAPS: Like the tail fin on a Stegosaurus. They are add-on placed on the trailing edge in the Tip zone of the blade.
6. VORTEX GENERATOR: Angled plastic add-ons placed on the suction side front end panel in the root section with the purpose of optimizing the lift and performance of the blade.
7. BALANCING WEIGHT: Mass typically attached to the shear webs, used for balancing purposes.

OTHER DEFINITIONS – NOT ILLUSTRATED

8. WINGLET: an add-on glued angled tip onto the blade.
9. SPOILER: Fixed control surfaces attached at or near the trailing edge in the root section. They are given a spoiler effects and resembles the spoiler of a racing car.
10. ANTI ICING: System using either hot air or carbon heating up the blade on the LE to avoid ice build-up.
11. DE-ICING: System using either hot air or carbon heating up the blade on the LE to remove ice during icing events.
12. LIGHTNING PROTECTION SYSTEM (LPS): One cable going from tip to root connecting the receptors with the root area.
13. SHOULDER AREA: The TE part of the max chord section where the blade geometry forms a “shoulder”.
14. BLADE CENTER LINE LENGTH WISE: The line going from the center of the root end to the very tip of the blade starting at the zero meter mark and halving the Blade Center Line Chord wise at any point.
15. BOND LINE: Line of adhesive bonding two parts together.
16. LE PROTECT TAPE: Leading edge impact-resistant (Polyurethane) protective tape covering LE, usually on the outer 1/3 of the blade.
17. LE PROTECTIVE PAINT: Leading edge impact-resistant paint applied to the outer 1/3 of the blade.
18. TC MARK: The location of the appointed mark from where the installation can be performed.
19. LPS ROOT TERMINAL: The transition between the cable in the root area to the hub.

Appendix B | **DAMAGE TABLE**

DAMAGE TABLE FOR GENERAL BLADE TYPES

(1/2)

LOCATION	DAMAGE	CATEGORY	BOX SPAR CONCEPT	LOAD CARRYING SHELL	CLOSED SHELL
Tip	Open tip	5	X	X	X
	Damage that penetrates the laminate layers	4	X	X	X
	Surface damage, not in the laminate	3	X	X	X
	Coat/paint damage, surface. Missing more than 15 cm2	3	X	X	
	Coat/paint damage, surface. Missing less than 15 cm2	2	X	X	
	Paint damage, surface. Missing more than 10 cm2	3			X
	Paint damage, surface. Missing less than 10 cm2	2			X
	Chip in paint/coat	2	X	X	X
Trailing edge (TE)	Open TE more than 10 cm within 5 meters of the tip	5	X	X	
	Open TE less than 10 cm within 5 meters of the tip	4	X	X	
	Open TE more than 20 cm beyond 5 meters of the tip	5	X	X	
	Open TE less than 20 cm beyond 5 meters of the tip	4	X	X	
	Cracks parallel to the TE longer than 1 meter	5	X	X	X
	Cracks parallel to the TE shorter than 1 meter	4	X	X	X
	Surface damage, not into the laminate	3	X	X	X
	Coat/paint damage, surface. Missing more than 20 cm2	3	X	X	
	Coat/paint damage, surface. Missing less than 20 cm2	2	X	X	
	Paint damage, surface. Missing more than 10 cm2	3			X
	Paint damage, surface. Missing less than 10 cm2	2			X
	Chip in paint/coat	2	X	X	X
	TE discoloration	1	X	X	X
Leading edge (LE)	Open LE	5	X	X	
	LE erosion, through laminate	5	X	X	X
	LE erosion, down to laminate and first layer laminate	4	X	X	X
	LE erosion, down to laminate	3	X	X	X
	Damaged leading edge tape	3	X	X	
	Damaged leading edge protection	3			X
	Coat/paint damage, surface. Missing more than 10 cm2	3	X	X	X
	Coat/paint damage, surface. Missing less than 10 cm2	2	X	X	X
	LE discoloration, paint or bugs	1	X	X	X

Appendix B | **DAMAGE TABLE**

DAMAGE TABLE FOR GENERAL BLADE TYPES

(2/2)

LOCATION	DAMAGE	CATEGORY	BOX SPAR CONCEPT	LOAD CARRYING SHELL	CLOSED SHELL
Shell	Shell is open, any size	5	X	X	
	Shell is buckled	5	X	X	
	Crack into laminate, more than 20 cm	4	X	X	
	Crack into laminate, less than 20 cm	3	X	X	
	Cracks in transversal direction	3	X	X	X
	Cracks in diagonal direction	4			X
	Cracks in longitudinal direction	2	X	X	X
	Glue between spar and shell contains air bobbles (Thermografi)	2	X		
	Coat/paint damage, surface. Missing more than 25 cm2	3	X	X	
	Coat/paint damage, surface. Missing less than 25 cm2	2	X	X	
	Paint damage, surface. Missing more than 100 cm2	3			X
	Paint damage, surface. Missing less than 100 cm2	2			X
	Discoloration from lighting/bugs	2	X	X	X
	Chip in paint/coat	2	X	X	X
Add-on	More than 5% or 1 meter missing, total length of VG's	3	X	X	X
	Less than 5% or 1 meter missing, total length of VG's	2	X	X	X
	More than 50% damaged or missing fins on VG panel	2			X
	Crack in sealing around serrogated edge	2			X
	Two VG's consecutive panel missing	3	X	X	X
Lightning	Lightning impact on carbon spar	4	X	X	
	Lightning damage on laminate	4			X
	Missing sealer or cracks around receptor	3			X
	Discoloration from lighting	2			X
	Discoloration from lighting	2	X	X	X
	>25% of lightning receptor surface damaged	3	X	X	X
	Lightning conductivity test above 30mΩ	3		X	
	Lightning conductivity test above 50mΩ	3	X		X
Blade collar	Misaligned	2	X	X	X
	Separated from blade	3	X	X	X

DOCUMENT DEVELOPED BY

Bladena, Vattenfall, EON, Statkraft, ENGIE & KIRT x THOMSEN

in EUDP Project LEX (2014-16) and EUDP Project RATZ (2016-18)

Energiteknologisk udvikling og demonstration

Revision 1.0