Managing Blade Integrity – Guidance on Allowable Defects

13/02/2019 | Kirsten Dyer
Agenda

• Introduction
• Blade anatomy and structure
• Failure modes
• Root causes
• Defects
• Allowable defects
• Summary
Introduction

• This presentation will explain the different types of defects which can occur on wind turbine blades, and touch on ways to determine if it is safe to continue operation of the turbine

• This presentation borrows heavily from the *Wind Turbine Blades Handbook* developed by Bladena – [www.bladena.com](http://www.bladena.com)

• The handbook can be obtained in digital form if you email Bladena – it is an excellent resource which covers much more than what is in this presentation!
Anatomy of a Blade

[Diagram of a wind turbine blade with annotations for Wind, Flap, Gravity, and Edge forces]
Anatomy of a Blade

BLADE SECTIONS

A wind turbine blade is divided into different sections as shown

Root Section
Max Chord Section
Transition Zone
Root
Shear web(s)
Shell 2
Shell 1
Spar caps (1+2)
Leading Edge (LE)
Suction Side (SS)
Pressure Side (PS)
Tailing Edge (TE)
Tip Section
Mid Section
Leading Edge
Anatomy of a Blade - Shells

SS

PS

Adhesive joint

Core

Core

Adhesive

Skins
Anatomy of a Blade – Spar Caps

Diagram showing the distribution of compression and tension forces on a wind turbine blade. The root of the blade is labeled as "Root," and the tip is labeled as "Tip." The diagram illustrates the flow of wind and the corresponding compression and tension forces. The blade is divided into sections labeled as "Spar cap 1," "Spar cap 2," and "Spar cap 3."
Anatomy of a Blade – Shear Webs

- Root
- Core
- Biax
- Tip
Anatomy of a Blade – Blade Root
There are 5 main failure modes which occur on wind turbine blades:

1. Buckling
2. Bondline failure
3. Skin debonding
4. Interlaminar failure
5. Strain based failure
Root Causes

- Typically, the blade will be very strong in-plane along the axis of loading because of the high proportion of $0^\circ$ fibres.
- However, bending of the blade induces non-linear transverse stresses which cause the panels to ‘breathe’, causing failure of the bondlines and skin debonding on panels.
- Highly concave aerodynamic shapes and flatback aerofoils with low resistance to shearing exacerbate this issue.
• **Damage** - Harm or physical change that impairs the normal function of a blade. This could be from an impact, and extreme load or fatigue.

• **Defect** - A flaw or a weakness in a blade that cause failure

• **Failure** - The loss of an intended function due to a defect

The following are some examples describing how these terms are used:

• Defects are faults in the blade that might come from manufacturing

• Failures are faults in the blade that have occurred during the lifetime of the blade, due to outside events such as excessive loads

• The failure of a root bolt creates a defect in the root

• A dry spot in an adhesive joint is a manufacturing defect

• The failure of an adhesive in a joint due to an excessive load is a defect in a blade, and a failure of the adhesive joint
This document was compiled by Bladena, Vattenfall, EON, Statkraft and KIRT x THOMSEN.

It was compiled as part of the EUDP Project LEX (2014-16) and EUDP Project RATZ (2016-18).

It aims to create an industry standard for categorisation and documentation of blade damage.

Damages are given a rating of 1.
## Damage Categorisation

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>DAMAGE</th>
<th>CATEGORY</th>
<th>BOX SPAR CONCEPT</th>
<th>LOAD CARRYING SHELL</th>
<th>CLOSED SHELL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tip</td>
<td>Open tip</td>
<td>5</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Damage that penetrates the laminate layers</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Surface damage, not in the laminate</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Coat/paint damage, surface. Missing more than 15 cm²</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Coat/paint damage, surface. Missing less than 15 cm²</td>
<td>2</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Paint damage, surface. Missing more than 10 cm²</td>
<td>3</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Paint damage, surface. Missing less than 10 cm²</td>
<td>2</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Chip in paint/coat</td>
<td>2</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>TE discoloration</td>
<td>1</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Trailing edge</td>
<td>Open TE more than 10 cm within 5 meters of the tip</td>
<td>5</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>(TE)</td>
<td>Open TE less than 10 cm within 5 meters of the tip</td>
<td>4</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Open TE more than 20 cm beyond 5 meters of the tip</td>
<td>5</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Open TE less than 20 cm beyond 5 meters of the tip</td>
<td>4</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Cracks parallel to the TE longer than 1 meter</td>
<td>5</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Cracks parallel to the TE shorter than 1 meter</td>
<td>4</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Surface damage, not into the laminate</td>
<td>3</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Coat/paint damage, surface. Missing more than 20 cm²</td>
<td>3</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Coat/paint damage, surface. Missing less than 20 cm²</td>
<td>2</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Paint damage, surface. Missing more than 10 cm²</td>
<td>3</td>
<td></td>
<td></td>
<td>X</td>
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<td>Paint damage, surface. Missing less than 10 cm²</td>
<td>2</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Chip in paint/coat</td>
<td>2</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>TE discoloration</td>
<td>1</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
## Decision Making

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>DAMAGE</th>
<th>ACTION</th>
<th>TURBINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cosmetic. Readings of lightning system below 50mΩ</td>
<td>No need for immediate action</td>
<td>Continue Operation</td>
</tr>
<tr>
<td>2</td>
<td>Damage, below wear and tear</td>
<td>Repair only if other damages are to be repaired</td>
<td>Continue Operation</td>
</tr>
<tr>
<td>3</td>
<td>Damage, above wear and tear. Readings of lightning system above 50mΩ</td>
<td>Repair done within next 6 months</td>
<td>Continue Operation</td>
</tr>
<tr>
<td>4</td>
<td>Serious damage</td>
<td>Repair performed within next 3 months. Damage monitored</td>
<td>Continue Operation</td>
</tr>
<tr>
<td>5</td>
<td>Critical damage</td>
<td>Immediate action required to prevent turbine damage. Contact technical support</td>
<td>STOP Operation safety is not ensured</td>
</tr>
</tbody>
</table>
Industry Standard Photocard

- **Hole for rope**
- **Handle**
- **Company**: Write service firm name (eg. BLADENA)
- **Inspectors**: Write technicians name (eg. A.HANSEN)
- **Date**: Write day (DD), month (MM) and year (YYYY) (eg. 05/05/2015)
- **Site**: Write site name (eg. BOWBEAT)
- **Turbine no.**: Write park ID. and serial number (eg. 2304091)
- **Blade no.**: Write Blade letter (A,B,C) and serial no. (eg. 4007452-A)
- **Position**: Turn wheel to right damage location (eg. PS)
- **Distance from root**: Turn wheel to right distance from root (eg. 30m)
- **Distance from LE**: Turn wheel to right distance from LE. (eg. 25°)
- **Damage Number**: Turn wheel to right damage no. (eg. 1)
- **Measure 14-25cm**

**IMPORTANT! Keep the ROOT arrow pointed in the right direction. (Tip direction may also be used)**
Summary

- We covered:
  - Blade structural design 101
  - What structural failures are common?
  - Why do they occur?
  - How can they be categorised and documented?
  - How do we take decisions on when to stop the turbine?
- More Information is available in:
  - Bladena Wind Turbine Blades Handbook
  - Next Generation Inspection Report
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