DeWind Blade Experiences

Wind Turbine Blade Workshop hosted by Sandia National Laboratories

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Presentation Overview

DeWind
Aerodynamics
Structure
Lessons Learned on Hybrid Carbon & Glass Blades
Manufacturing
Material Properties
Prepreg Processing
DeWind Background

- Founded in Lübeck, Germany 1995
- FKI take-over June 2002
- EU Energy take-over June 2005
- EU Energy joined CTC of Irvine, CA July 2006
- Renamed DeWind December 2006
- Assembly line at Teco-Westinghouse Round Rock, TX in November 2007
- Currently offering two product ranges: D6-1250 kW and D8.2/D8-2000 kW.
- Approximately 600 turbines installed which represent about 500 MW
- World highest turbine installed at over 4000m above sea level – 50 Hz D8.2
DeWind Turbines

DeWind D4
600 kW
Rotor diameter: 46-48 m
Hub height: 45-70 m
First installation 1996
265 units in operation

DeWind D6
1250 kW
Rotor diameter: 62-64 m
Hub height: 60-91.5 m
First installation 1999
250 units in operation

DeWind D8/D8.2
2000 kW
Rotor diameter: 80 m
Hub height: 80-100 m
First installation 2002
49 units in operation
**General Blade Series Data**

<table>
<thead>
<tr>
<th>Wind Turbine:</th>
<th>D8/D8.2</th>
<th>D6</th>
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</thead>
<tbody>
<tr>
<td><strong>Blade Designation:</strong></td>
<td>DW80</td>
<td>DW62</td>
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<tr>
<td><strong>Blade length:</strong></td>
<td>39.1 m</td>
<td>30 m</td>
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<tr>
<td><strong>Maximum chord length:</strong></td>
<td>2.9 m</td>
<td>2.8 m</td>
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<tr>
<td><strong>Laminate weight:</strong></td>
<td>6.1 t</td>
<td>3.6 t</td>
</tr>
<tr>
<td><strong>T-bolt weight:</strong></td>
<td>350 Kg</td>
<td>160kg</td>
</tr>
<tr>
<td><strong>Bolt circle diameter:</strong></td>
<td>2.0 m</td>
<td>1.6m</td>
</tr>
<tr>
<td><strong>Blade root bolts:</strong></td>
<td>48 x M36</td>
<td>44 x M30</td>
</tr>
<tr>
<td><strong>Carbon fiber:</strong></td>
<td>800 kg (included in 6.1 t)</td>
<td></td>
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Design strategy for blade design

- Blades are source of power and loads for the turbine
- Blade looked at as part of complete wind turbine system
- Strategy is to find reasonable compromises between power, loads and manufacturing issues
- Use experiences of other industries and provide close support of production
Aerodynamics

- Airfoils used:
  - DU airfoils in the first half of the blade
  - NACA 63-6xx airfoils in tip area
DW80 Blade Geometry Optimization

Blades at DeWind

- Absolute optimum, 4.894m, 6.727GWh
- Optimum linear geometry, 3.6m, 98.8%
- Linear, root-chord limited, 3.2m, 98.7%
- 80% of Optimum linear, 2.88m; 98.2%

Chord [m]

Radial position [m]
Cross Section of a Blade

- Upper Girder (CFRP)
- Sandwich Shell
- Main Shear Web
- Lower Girder (CFRP)
- Sandwich Shell
- Sandwich Shell
- Trailing Edge (CFRP)
- Second Shear Web
- Sandwich Shell
Why Carbon Fiber?

- High specific stiffness
- Very good fatigue properties

Graph showing specific stiffness of different materials:
- Carbon / Epoxy
- Glass / Epoxy
- Carbon / Epoxy Vf=0.6
- Glass / Epoxy Vf=0.6
- Kevlar / Epoxy Vf=0.6

Materials compared:
- Mild steel
- Aluminium alloy 2024
- Titanium alloy
- Carbon / Epoxy
- Glass / Epoxy
- Kevlar / Epoxy
Lightning Protection

Copper mesh transfers energy and shields Carbon girders
Solid aluminium tip offers high electrical potential
Lightning Protection

- Energy transfer from blade to hub by arcing and draggle contacts
- Energy transfer from hub to nacelle and nacelle to tower by arcing and draggle contacts

**Advantage:**
- Receptor attracts the lightning only, if the blade is going to be struck
- Lightning doesn't enter nacelle were electric sensitive components are located
Major Lessons Learned

1. Manufacturing → Development of a process to manufacture a hybrid blade

2. Material Properties → New method of testing to obtain repeatable compression values for large tow carbon

3. Prepreg Processing → New Prepreg Type
General Manufacturing Process DW80

- Shearweb (VARTM)
- Inner skin (VARTM)
- Foam (sandwich)
- Pre manufactured TE girder (Prepreg)
- Pre manufactured main girder (Prepreg)
- Outer skin (VARTM)
- Mould
Why Vacuum Infusion?

- High quality surface
- Good use for thick laminates and big components
- Relatively High Fiber volume fraction
- Relatively high properties
- Good reproducibility
Why Prepreg?

• High strength component (girder)
• High tech material (carbon fiber)
• Highest quality standard needed

• Well defined fiber volume fraction
• 100% soaked fiber
• Very accurate fiber orientation
• High material properties
Manufacturing of the Prepreg Girder

Why external manufacturing?

• Easy access to the mould
• Accurate lay up
• High degree of reproducibility
• High temperature heating
• Option to automate the process
• Operational time of the mould can be reduced significantly
Material Property Tests

Blades at DeWind
Compression Properties

Big influence on standard deviation of tested compression values due to:

- Over proportional effects of misalignments
- Surface roughness of specimen
- Micro ondulation of fiber
- Geometry of specimen (edge effects)
- Testing method / testing fixture

Characteristic design value acc. to GL guideline

\[ R_k(5\%, 95\%, \nu, n) = \bar{x} \left[ 1 - \nu \left( 1.645 + \frac{1.645}{\sqrt{n}} \right) \right] \]

- \( \nu \) deviation coefficient
- \( n \) no. of samples
- \( \bar{x} \) mean value

Characteristic value depends very much on the deviation coefficient
Standard Compression Test Fixtures

- Closed design, limited access and coupon geometry
- Restricted strain measurements with gauges or optical tools
- Celanese Test Fixture doesn’t guarantee material orientation
- Influence of the buckling support of the Wyoming Test Fixture is not predictable
- Standard geometry of coupons is not suitable for heavy fabrics and/or heavy tow fiber
Improved Material Test Fixtures

- Open design
- Design with parallel guidance (1,2)
- Friction reduced guidance by roller bearings
- Hydraulic clamping of the coupons (5)
- Force introduced via shear and front end (3,4)
- Variable geometry of specimen
- Width of specimen 35 mm

Reduction of variation coefficient for compression strength:

12% \(\rightarrow\) 3%

\(\rightarrow\) Properties increased by 30%
Component Tests

Bearing stress underneath T-bolts

Tensile Test in blade root

Fatigue Tests in area of highest damage
Objective:
 evacuation of a stack of 50 layers in one shot

– How can we be sure that the air is not trapped?
– How can we ensure that the handling is right?
– How can we optimise the process for heavy tow?
Prepreg Details

PA (Polyamid) mesh on top of each

Stack of Prepreg layers

Channels for air to travel

Mesh
Prepreg process

• Prepreg rolls contain defined amount of layers acc. to lay up. → reduce waste

• PA mesh ensures that the roving stay in place

• Smaller tapes are used for the trailing edge to be able to place them in shape

• Heavy tow fibres are used for the Prepreg

• Intensive testing of the manufacturing process and material properties guaranteed an equal or even better performance of the Prepreg

For handling the right tack is the key issue
Ready for shipment