Welcome

• Trends in Utility-Scale Wind Turbine Production
• Trends in Blade Fabrication
• Research in Blade Technologies at Sandia
• Future Research Needs
Industry Trends

• Most significant trend in market place is the tight supply situation.
  – Trend of 25% increase in world-wide installation continued in 2007 (actually was 40%).
  – It’s a Seller’s Market - prices for wind turbines have increased and delivery time is longer.
  – Installed Cost Now – $1600-2200/kW.
    • $1000 used to be the goal only a few years ago.
  – Component suppliers costs are rising.

• U.S. production tax cuts expire at end of 2008.
  – Legislation stilled being worked on.
  – China is 2\textsuperscript{nd} in installed capacity (3287MW - 2007).

• Offshore installations - 2008 forecasts significantly lowered, but expected to grow to 4.7% by 2012.

Data from BTM Consults 2007 and web
Industry Trends

• U.S. has largest number of turbines worldwide (25,667) and 1st in installed capacity in 2007 (5244 MW).
• Average turbine size delivered in 2007 was 1.492 MW about 70kW above 2006.
• 1.5-2.5MW turned into “Main Stream” position – 48% of 2007 capacity – perhaps less larger models on market.
• Two of top ten turbine suppliers are now Chinese.
• Smaller turbines preferred in Asian markets.
• 90% of turbine use pitch as the control feature – 10% use active stall.
• Amount of materials required to support blade production growing bigtime.

Fiberglass reinforcement: 51% 30 x 10^6 kg
Resin: 33% 20 x 10^6 kg
Sandwich Core: 4% 2.5 x 10^6 kg
Bonding Adhesive: 7.5% 4.5 x 10^6 kg
Miscellaneous (primarily T-bolts and Lightning Protection): 4.5%
# Leading Manufacturer’s Model Sizes

<table>
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<tr>
<th>Turbine Size</th>
<th>200-300 kW</th>
<th>600kW</th>
<th>800-900 kW</th>
<th>1.0 MW</th>
<th>1.3-1.65 MW</th>
<th>2.0 MW</th>
<th>2.3-2.5 MW</th>
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<td>~Blade Size (m)</td>
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Blade Size Constraints

• Gravity Loads
• Transportation
• Large Crane Availability

LM 61.5m
Blade for 5MW
Offshore
Blade Manufacturing Processes

- Infusion –
  - TPI, LM Glasfiber, Siemens, GE
- One shot Infusion
  - Siemens
- Pre-preg
  - Vestas, Gamesa
- Wet lay-up
  - GE, K&C
Current U.S. Manufacturing

[Map of the United States showing current U.S. manufacturing locations for various companies involved in blade manufacturing, tower fabrication, and turbine assembly.]

Legend:
- Blade Manufacturer
- Tower Fabrication
- Turbine Assembly

2008 Sandia Blade Workshop
Ongoing Blade Research

Many countries have ongoing research in labs, universities

- U.S. NREL, SNL
- Denmark
  - Risoe (DTU)
- Netherlands
  - TUDelft
  - WMC/ECN
- Universities
- Industry

Wind industry performing more & more independent research

LM Glasfiber Blade and Lightning Testing in Lunderskov, Denmark.
Blade Research Items at Sandia

- Materials & Manufacturing
- Load Control – Active & Passive
- Innovations for Blade Enhancement
  - Very thick airfoils, including flat backs
  - Trailing edge treatment
- Blunt trailing edges – noise, wind tunnel
- Codes
  - Aerodynamic and Structural
  - NuMAD
  - CFD
- Sensor Applications for Lab & Field
- Reliability
Materials & Manufacturing

- Fatigue Characterization of New & Conventional Materials and Forms
- Effects on Manufacturing Process
- Effects of Discontinuities

References
- MSU/DOE Data Base – see www.sandia.gov/wind
Passive Load Control
Bend-Twist Coupling Using Off-axis Material
(TPI/SNL)
Passive Load Control
Bend-Twist Coupling Using Sweep (K&C/SNL)
Active Load Control
Tabs & Flaps (UCDavis/SNL)

Aerodynamic lift, drag and moment during microtab deployment

Pressure contours over the airfoil and instantaneous streamlines over flap region during deployment
RISOE (Buhl, Gaunaa & others)
Flatback Noise & T.E. Treatment

Reference:

2008 Sandia Blade Workshop
Innovations in Research Blades

- Improved manufacturing processes
- Remote build demonstration
- Carbon spar cap
- Off-axis material for bend-twist coupling
- Very thick airfoils (flatbacks)
- Slenderized profile
- Threaded rod (manufactured in place) for inexpensive attachment
Testing of Research Blades – Laboratory & Field
Design Codes

Aeroelastics
- FAST – NREL
- BLADED – commercial (GH)
- FLEX5 – DTU (Academic)
- ADAMS – commercial – (MSC)

Structural Analysis
- NuMAD/BPE (Sandia)
- Focus (WMC)
- Pre-Comp (NREL)

Aerodynamics
- AeroDyn (NREL)
Sensors Applications for Lab and Field

- Detection of de-bonds or no adhesive, dry spots, delaminations
- SBlade & active load control

Acoustic Emissions

Strain Gauges
Future Research Needs

- Materials
  - Coatings
  - Adhesives
  - Thick Laminates
  - Core
- Joints
- Reliability

- Lean Blade Manufacturing
  - Labor Reduction
  - Automation
- Load Control
- More Efficient Designs
  - Optimize material usage
Adios and Thank You