The Effects of Black Blades on Surface Temperatures for Wind Turbines

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Presentation Outline

• Introduction: Rime Ice and Wind Energy
• Experimental Setup
• Goals
• Results
Problems with Ice Accretion

- Altered Aerodynamics
- Ice Shedding
- Control
Types of Ice Accretion

- Glaze Ice
- Rime Ice
YEC’s Icing Treatments

- Leading Edge Heaters
- StaClean (Black) Coated Blades
Experimental Setup
Experimental Setup

- **Two Sets of Data**
  - Comparing 3 *root* temperatures:
    - Manufacturer’s Blade Coating (White)
    - StaClean White
    - StaClean Black
  - Temperatures along length of Black Blade
    - Tip Temperature
    - Root Temperature
Vestas Blade Root Temperatures - November 2000

<table>
<thead>
<tr>
<th>Date</th>
<th>Temperature Inside Nacelle (°C)</th>
<th>Blade 1 - Root, Manufacturer's Gelcoat (°C)</th>
<th>Blade 2 - Root, StaClean White (°C)</th>
<th>Blade 3 - Root, StaClean Black (°C)</th>
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Vestas Blade Root Temperatures - November 2000

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<th>Temperature (°C)</th>
<th>Ambient Temperature (°C)</th>
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<th>Blade 2 - Root, StaClean White (°C)</th>
<th>Blade 3 - Root, StaClean Black (°C)</th>
<th>Temperature Inside Nacelle (°C)</th>
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Heating of entire blade due to lack of wind
Ice acts as an insulator after an icing event.
Heat Transfer

Leading Edge Heater – 0.25 W/in\(^2\)
(Wrap Length = 12"")

Airfoil (not to scale)
Heat Transfer

\[ u_\infty = 5 \text{ m/s} \]

\[ x = 6 \text{ in} = 0.15 \text{ m} \]

\[ \overline{N_u} = \frac{\bar{h} \cdot x}{k} = 0.664 \, \text{Re}_x^{1/2} \, \text{Pr}^{1/3}, \quad \text{Pr} > 0.6 \]

\[ q'' = \bar{h} \Delta T = 300 \, \text{W/m}^2 = 0.2 \, \text{W/in}^2 \]
Vestas Blade 3 Temperatures - July 2001

T_{max} = 25.9 °C
Discussion & Conclusions

- Heaters are not able to heat blades beyond themselves even in modest winds (>5 m/s)
- Black blades appear to add minimal solar gain in windy areas, in neither summer nor winter
- Black blades do not overheat in the summer