Retractable Wind Turbine Rotor Blade

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Abstract

Although wind power can currently compete with fossil fuels, Clipper Windpower is interested in further reducing the cost of wind energy. To do this, Clipper partnered with our group to increase the efficiency of their Liberty turbine. Our objectives were to develop a proof-of-concept that could be installed into the Liberty turbine and increase power production at lower wind speeds. Our team built and tested a proof-of-concept that validated our design and met our objectives.

Design Overview

Tip Extension (Fig. 2 Left)

→Provides extra lift when blade is extended and reduces stress when retracted.

→Forks provide structure for extension and utilize rollers for smooth, laterally constrained motion.

Ribs and Stringers (Fig. 2 Left)

→Replaces box-beam support structure for last part of blade and provides extra space for extension blade.

→Stringers double as extension blade guide rails.

Pulley Mechanisms (Fig. 2 Right)

→Mechanism must withstand 6g load and offer simple design, be relatively light weight, and operate quickly.

→Weight located closer to hub, reducing blade stress

Material Selection and Testing

Rope – Spectra Rope (Fig. 3 Left, Center)

→1.5x stronger and 8x lighter than steel cable

→Low wear, highly corrosion and creep resistant

→Synthetic ropes tested for loading and creep properties

Fiberglass Attachment Method – Lap Shear (Fig. 3 Right)

→Three attachment methods tested to failure to understand loading properties – epoxy bonded, bolted, and combination bolt and epoxy.

→Fiberglass is the standard, cost effective material used in turbines

Results and Accomplishments

FEA analysis was conducted on the pulley bracket and pulleys to insure these proposed parts can withstand the calculated maximum full scale load of 98 kN (22,000 lbs).

Analysis of rope testing helped choose Spectra rope for our design. Lap shear tests showed that bolted attachments would withstand the necessary scaled loads of 1089 N (244 lbs) (Figure 4).

Cliper Windpower provided us with performance specifications that our design needed to achieve when installed on a Liberty Turbine. Our team scaled down these specifications to demonstrate design feasibility with our prototype. By achieving these performance specs, our prototype has proven design robustness and reliability at scale. This establishes the potential for our design to provide the same robustness and reliability for a full-scale prototype.

Testing (Figure 5) of our prototype was completed and the results are compared with performance criteria as follows:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Spec</th>
<th>Tested</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. operating accel. (force)</td>
<td>6 g’s (1089N)</td>
<td>7 g’s (1330 N)</td>
<td>22% Better</td>
</tr>
<tr>
<td>Total mass added</td>
<td>≤ 45 kg</td>
<td>38.66 kg</td>
<td>14% Reduction</td>
</tr>
<tr>
<td>Extension travel distance</td>
<td>1.5 m</td>
<td>1.5 m</td>
<td>Success</td>
</tr>
<tr>
<td>Time required for full extension</td>
<td>&lt; 1 min</td>
<td>45 sec</td>
<td>25% Faster</td>
</tr>
<tr>
<td>Power input required</td>
<td>&lt; 1.5 kW</td>
<td>600 W</td>
<td>60% Reduction</td>
</tr>
<tr>
<td>Min. wind speed (max power)</td>
<td>12 m/s</td>
<td>≤ 12m/s</td>
<td>Approved</td>
</tr>
</tbody>
</table>

Acknowledgements and References

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