The role of wood in wind turbine blades: A feasibility study of wooden blade components in ANSYS (R).

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Wood for use in wind turbine blades

It is paradoxical that wind turbines, a renewable and green energy resource, are built with materials that are manufacturing intensive and hard to recycle. Turbine blades are subjected to large and multidirectional forces, and as such, are built with fiberglass and carbon fiber reinforced plastics, composite materials that are stiff and have high strength-to-weight ratios. However these materials also produce carbon dioxide and other pollutants during manufacturing. With recent advances in engineering wood composites, it is now possible to replace components of these blades with biomaterials. Engineered wood has competitive strength-to-weight ratios and is a natural carbon sink. Building partially wooden turbine blades will reduce the cost of manufacturing, produce recyclable blades, and reduce atmospheric carbon. It is also speculated that wooden blades may have a longer fatigue life.

Figure 1: Example of static testing on turbine blades

Figure 2: Static loading scenario

The static loads in ANSYS (R) simulated real life static testing of blades as seen in Figure 1. The end of the blade was constrained and the loads applied at the red highlighted areas in Figure 2. The ultimate load is 7.2 MPa which corresponds to a wind velocity of 70 m/s (highest wind speed recorded).

Figure 5: Tip deflection of blades under gravitational and static loads

Table 1: Comparison of the mass and amount of wood in each blade build

<table>
<thead>
<tr>
<th>Build</th>
<th>SNL blade</th>
<th>Shear Web</th>
<th>Skin</th>
<th>Spar Cap</th>
<th>All Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (kg)</td>
<td>17,699.00</td>
<td>18059</td>
<td>11906</td>
<td>15004</td>
<td>9650.7</td>
</tr>
<tr>
<td>(% by mass) wood</td>
<td>0</td>
<td>52.4</td>
<td>22</td>
<td>11.9</td>
<td>63.5</td>
</tr>
<tr>
<td>(% by volume) wood</td>
<td>0</td>
<td>18.4</td>
<td>17.2</td>
<td>11.9</td>
<td>40</td>
</tr>
</tbody>
</table>

Figure 5 demonstrates a lack of stiffness in the wooden spar cap as it deflects about 5X as far as the Sandia blade. However the wooden skin and shear web preform as well as, if not better than the control blade in terms of tip deflection. This suggests that the lighter weight of wood in conjunction with the stiffness of traditional spar caps can yield a better preforming blade than traditional composites alone.

Figure 6 displays the stiffness (modulus) for each material direction of the shear web and skin rebuilds in comparison with the original blade. The skin rebuild is competitive across the board, and due to wooden skins dramatically reducing the weight of the blade (Table 1) this suggests that a wooden skin is more competitive than a traditional fiberglass skin.

The wooden shear web is not as stiff in the Y component, however the majority of this stress component is seen by the spar caps. The shear webs resist shear stresses, for which the wooden shear web is competitive with and in the case of the XZ component superior to traditional composites.

These results indicate that turbine blades would be competitive with wooden skins and shear webs and more in depth analysis should be taken to design for those components.

Future Work

• Import real life wind loads into ANSYS (R) using FAST/WINDS to produce a more accurate stress profile within the blade builds.
• Run fatigue simulations in ANSYS (R)
• Design optimal blade geometry to produce a mechanically competitive blade containing as much wood components as practical

Objectives

• Assess mechanical feasibility of wooden blade components
• Determine success

Methods

Model turbine blades were built using the Numerical Manufacturing and Design tool produced by Sandia National Laboratory (SNL). The SNL 61.5 meter blade, modeled after the National Renewable Energies Laboratory SMW turbine, was used as a control blade (Figure 4). The three major blade components: spar cap, skin, and shear web (figure 3) were volumetrically replaced (or as close as possible) with laminated veneer lumber composites. These four blades along with an entirely wooden blade were then subjected to static and inertial loads through finite element analysis in ANSYS (R). APDL. The blades were then evaluated by their tip deflection and by comparing the maximum stress of the rebuilt component to the stresses at the same location in the SNL 61.5 m blade.

Figure 4: A 61.5-m, SMW turbine blade in NuMAD

Results

Figure 3: Major components of a wind turbine blade

Carbon spar cap, fiberglass skin, bladed or foam core, shear web, tips and root cap

Figure 6: Stiffness in each material direction for shear web and skin builds compared to control blade

Shear Web Rebuild

<table>
<thead>
<tr>
<th>Component</th>
<th>Modulus (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>Wood shear web</td>
<td>3.00E+10</td>
</tr>
</tbody>
</table>

Skin Rebuild

<table>
<thead>
<tr>
<th>Component</th>
<th>Modulus (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>Wood skin</td>
<td>2.00E+10</td>
</tr>
</tbody>
</table>

| Fiberglass | 4.00E+10 | 3.50E+10 | 2.50E+10 | 1.50E+10 | 1.00E+10 | 5.00E+09 |

References

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