PROJECT SPECIFICATION

Project Name: Recyclable Wind Turbine Component
Project Number: 494201743
Project Sponsor: MAE494
Date: February 9, 2017

Specification Review and Approval

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Editor</td>
<td>Vincent Vu</td>
<td>2/9/17</td>
</tr>
<tr>
<td>Project Coordinator</td>
<td>Tai Ho Wong</td>
<td>2/9/17</td>
</tr>
<tr>
<td>Prototype Manager</td>
<td>Brandon Lee</td>
<td>2/9/17</td>
</tr>
<tr>
<td>Technical Manager</td>
<td>Yiu Wah Li</td>
<td>2/9/17</td>
</tr>
<tr>
<td>Webmaster</td>
<td>Lawrence Yoon</td>
<td>2/9/17</td>
</tr>
<tr>
<td>Sponsor</td>
<td>N/A</td>
<td>2/9/17</td>
</tr>
<tr>
<td>Instructor</td>
<td>John Hall</td>
<td>2/9/17</td>
</tr>
</tbody>
</table>
1.0 SCOPE

1.1 Background
At the end of a turbine’s life cycle, there are many complications. Complex components such as the blades have become a concern due to their limited afterlife. There are not many known ways to extract the materials in the blades, so they often end up as rubble. The motivation for the project is to maximize materials extracted in the blades at the end of their lifecycle for recycle purposes. Since we do not have a sponsor, our group interviewed professionals in the industry through the phone. Their need for a wind turbine include recyclable, lightweight, easily assembled and resilient. The importance of the project is that it opens new ways to recycle and extract material from a wind turbine at the end of its life cycle, which improves the sustainability of wind power.

1.2 Problem Statement
Complex components such as the blades have become a concern due to their limited afterlife. There are not many known ways to extract the materials in the blades, so they often end up as rubble. As of 2012, Zagons Logistiks was the only reprocessing plant that handled turbine blades at the end of their lifecycle. On an average month, they reprocess 400-500 tonnes of turbines into concrete filler. Due to the complexity of turbine blades, there are not many options in recycling the materials in an environmentally friendly way, which is polluting the environment and resulted in lower sustainability of wind power. In finding a solution to this issue, there are a few criteria’s we have set up in finding a feasible solution. The new turbine material must be able to withstand the forces and moments a turbine may experience. This is validated by the equations in section 3.

1.3 Proposed Concept
The recyclable wind turbine design consists of three main components. The turbine hub is the center of the turbine rotational axis with four standard rods on top and bottom. The reason this design was chosen was to create less steps in the manufacturing process which can save on the cost of production. The second component is the turbine blades which are made with an aluminum sheet with curvature on it. The group chose to create curvature on the blade in order for it to catch the wind. The last component is the standard nylon hex nuts that can lock the blades in place. Although the hex nut was not part of the design, since it is a standardized part, it can be purchased and easily assembled onto the turbine. Each of these components combine to become a simple design that can satisfy the function of being eco-friendly, lightweight and recyclable.
The assembly of our wind turbine was designed to be easily replaceable and maintainable. The blades will be able to slide out once the nuts are unscrewed and a new blade can be put back in just as easily.

Figure 1: Turbine hub with connecting rods on top and bottom

Figure 2: Turbine blade made from an aluminum sheet
2.0 Design Framework
The subsections below describe the functions of the wind turbine and the context in which it will operate.

2.1 System Definition
2.1.1 Purpose
The purpose of the proposed concept is to create a wind turbine that is able to be recycled at the end of its lifecycle.

2.1.2 Functions
The Recyclable Wind Turbine will perform the following functions:
- Lightweight turbine blades
- Recyclable
- Resilient for longer lifespan and less maintenance
- Strong blades to withstand high forces from wind speed
2.2 Application Site Characteristics
The location site where the wind turbine shall be used has the following characteristics.

2.2.1 Physical Characteristics
- Installation pad: concrete, 3000 PSI maximum loading
- Door dimensions: 5.5’ width x 8’ height (maximum opening)

2.2.2 Environmental Characteristics
- Temperature range: 65° - 75°F
- Humidity range: 10% - 40%

2.3 Application Site Resources
The following resources are available to the wind turbine, which will be operated

2.3.1 Energy
- No energy resource required for operation

2.3.2 Utilities
2.3.2.1 Compressed Air:
- Pressure: 90 psig
- Flowrate: 10 cfm

2.3.3 Data
- No data resource required for operation

2.4 Performance Requirements
The wind turbine shall meet the following requirements:

2.4.1 Allowable Stress
- Able to withstand 70 mph winds

2.4.2 Rotational Speed
- System life: 20 years

2.4.3 Operational Life
- Blade cycles: 20,000,000,000 (twenty billion revolutions)
- Piece cycles: 10,000,000 (ten million)

2.4.4 Sound
- Maximum level: 70 dBs

2.4.5 Energy required to recycle
- Specific Heat Capacity: 0.96 J/g⁻⁰°C
- Melting Point: 477 - 635 °C

2.5 Processed Materials
Not applicable
3.0 Analytical Process

3.1.1 Forces and Moments

The moment equation is used to calculate the force of the wind needed to make the blades spin. This is necessary to obtain the values needed to determine minimum wind velocity and blade rotation speeds. The mass moment of inertia would also be needed to determine if the force applied to the wind turbine blades is sufficient enough to overcome the inertia enough to spin the blades. We would first calculate the force the wind applies to the wind turbine blade and using that value, we can calculate the moment of the blade about the wind turbine hub. We can then use the force of the moment about the wind turbine hub to determine the velocity of our wind turbine blade. Finding the mass moment of inertia of our blade would provide us with a value that can be used to find the minimum value needed to force the blades to spin. This would provide us with the minimum air velocity required to make our turbine function. Although these calculations can be used to determine the efficiency of the wind turbine, the focus of our project is the recyclability of the wind turbine blades. After choosing both the design and material needed to manufacture the blade, the moments and forces will be used to determine whether or not our design will fail under loading. These values can also be used to determine the fatigue rate of the wind turbine blade under cyclical loading and the estimated lifespan of our wind turbine blade design. To do this we would need to determine the endurance strength, fatigue strength coefficient, and fatigue strength exponent before finally calculating the fatigue strength of our material.

\[
\text{Endurance Strength: } S'e = 0.5 S_{ut}
\]

\[
\text{Fatigue Strength Coefficient: } \sigma'f = S_{ut} + 50 \text{ kpsi}
\]

\[
\text{Fatigue Strength Exponent: } b = -\left(\frac{\log(S'f)}{\log(2 \cdot Ne)}\right)
\]

\[
\text{Fatigue Strength: } S'f = \sigma'f \cdot (2n)^b
\]

\[
M = F \cdot D \quad \text{or} \quad M(t) = j_0 \dot{\theta} + C_1 \ddot{\theta} + k_4 \theta
\]
3.1.2 **Finite Element Analysis**

To ensure that the wind turbine blades will not fracture or deflect due to wind forces, we can implement a finite element analysis to calculate stresses exerted on the blades from the wind and the maximum allowable stresses that the aluminum blades can handle. This can be done with the Creo parametric and the Creo Simulate software simultaneously. The 3D model of the wind turbine blade was first created on Creo Parametric and then the Creo Simulate software was used to apply the finite element analysis method. The focus of the stress using the finite element analysis is on the wind turbine blade, therefore only the blade component would be tested using Creo Simulate. With Simulate, the properties of any material may be applied to the turbine blade. The blade is tested against high wind forces while being constrained through the holes by the steel rods. Finite element analysis is used by first constraining the blade at the four mounting holes and applying the load onto the inner surface. The results of the test shows that it can withstand high velocity winds with low stress levels on it. This proves that the aluminum sheet turbine blade will not fracture and deflect under high wind loads.

Shear Stress: \( \tau = \frac{F}{A} \)

3.1.3 **Power**

To truly ensure that our wind turbine is “green,” we can calculate the power the wind turbine can produce and compare that with the energy required to fully melt and recycle the aluminum components. This would mean that the wind turbine itself would be able to generate enough energy for its own recycling process and more. This would also eliminate the need for other types of energy sources that would be needed to power the machines that melt aluminum which often has a one hundred percent recyclability rate. To do this we would need to calculate the amount of energy that the blades contain when they spin at a certain velocity. After determining how efficient the turbine is at converting energy, we would then compare the values with the values involving recycling the aluminum material. Then we can estimate a duration of time needed to generate the energy with the wind turbine. This can be determined with different wind velocities as a lower wind speed would generate less energy which would require the wind turbine to function for longer while a location with high wind velocities could generate energy much faster.

Power: \( P = F \cdot v \cdot \cos(\theta) \)
4.0 Prototype Manufacturing Framework
The subsections below describe the steps pertinent to the production of the wind turbine.

4.1 Engineering Drawings
A set of engineering drawings consisting of assemblies, subassemblies, and components shall be made prior to production. Production drawings shall conform to ASME Y14.5.

4.1.1 Commercial Components
Commercial components will be presented as shells and called out on the assembly drawings.

4.1.2 Hardware
Mechanical hardware shall not be included on drawings, but locations shall be called out.

4.2 Bill of Material
A bill of material shall be made and organized in terms of assemblies, subassemblies, and fabricated parts. Commercial components shall be identified on the bill of material as well.

4.3 Commercially Available Components
Commercial items are to be used, when available, to minimize production time and simplify replacement of failed components.

4.4 Fabrication
The wind turbine shall be fabricated in the MAE machine shop by each member of the group using the following processes as needed:
- Cutting
- Welding
- Drilling
- Sanding
- Grinding
- 3D printing

4.5 Materials
The following materials are available for building components of the wind turbine as needed:
- Steel Rods: 1 in. diameter, 30 in. length
- Aluminum 7075: 48 in. x 40 sheet, 0.125 in. thickness
4.6 Commercially Available Items
The following components are commercially available and shall be used in the assembly of the wind turbine.

- 20 Volt DC Motor, 60 RPM max speed
- Radial ball bearings
- Hex Nuts (UNC 1 ¼ - 7)

5.0 Acceptance Testing (Validation)

5.1.1 Prototype
The prototype of our recyclable wind turbine will be built in a 1:2 scale to represent the product. Using this scale allows for better simplicity when taking into consideration of loads and moment calculation. The major component that we will be focusing on are the blades. As discussed in section 2.4 and 3, the testing will help determine if the blade material qualifies for real life use. If the material is able to satisfy all the criteria presented earlier such as noise level, FEA, moment, and allowable stress, then the prototype will be acceptable.

5.1.2 Technique
The prototype will be used to test and validate each design requirement in section 2.4.

5.1.3 Operational Life
Operational Life will be calculated manually using fatigue calculation:

\[
\frac{dN}{d\sigma} = \frac{c}{2} (2N)^{\frac{1}{n}} + c_1 (2N)^{\frac{1}{m}} \quad [2]
\]

It is also possible to calculate using software, such as NREL's FAST[3] and Canadian Retscreen International RETScreen[4] which are industry standards.

5.1.4 Allowable Stress
The blades will be tested in Creo Simulate using finite element analysis. Using this program, the location for highest stress experienced on the blade may be visualized. Creo offers many materials to choose from thus allowing us to test aluminum with varying properties.

5.1.5 Rotational Speed
Rotational speed will be measured using a bike speedometer. A magnet will be placed on one of the blades that trips a reed switch, which is mounted on the an stationary frame, as it passes and tells the computer that the blade has made one revolution. We can then determine the rpm under specific wind speed under a controlled experiment.
5.1.6 Sound
The sound level will be measured to ensure the level does not exceed 70 dB by using the microphone on a laptop or phone. There are many free applications available that are able to meet our needs. It is a concern that the app may not be accurate, so we will aim for a precise measurement. We may use multiple phones with different measuring applications to test the sound level.

5.1.7 Energy Required to Recycle
The energy required to recycle can be mathematically calculated by recording the mass of the wind turbine blades and calculating the amount of energy required to completely melt down the blades to be reused in another application. The amount of energy required to recycle can be compared to the energy generated from the wind turbine by testing the power output of the wind turbine and the average amount of wind in a specified location.

6.0 DELIVERABLES
6.1 Prototype
The prototype described in 4.0 will be delivered at the end of the project.

6.2 Documentation
A comprehensive set of files will be submitted on a DVD disc as indicated below. Documentation shall also be submitted as described.

6.2.1 Computational models
All computational model files will be submitted on a DVD disc.

6.2.2 Full set of drawings
A hard copy of drawings will be submitted as assigned and according to the course schedule. The drawings will also be submitted on the DVD disc in the pdf format.

6.2.3 Design review report
A hard copy of the design review report will be submitted as assigned and according to the course schedule. An electronic version of the design review report will also be submitted on the DVD disc.

6.2.4 Final report
A hard copy of the final report will be submitted as assigned and according to the course schedule. An electronic version of the final report will also be submitted on the DVD disc.
7.0 References


