Wind Turbine Project Design

Design a Wind turbine to generate electricity efficiently from Wind

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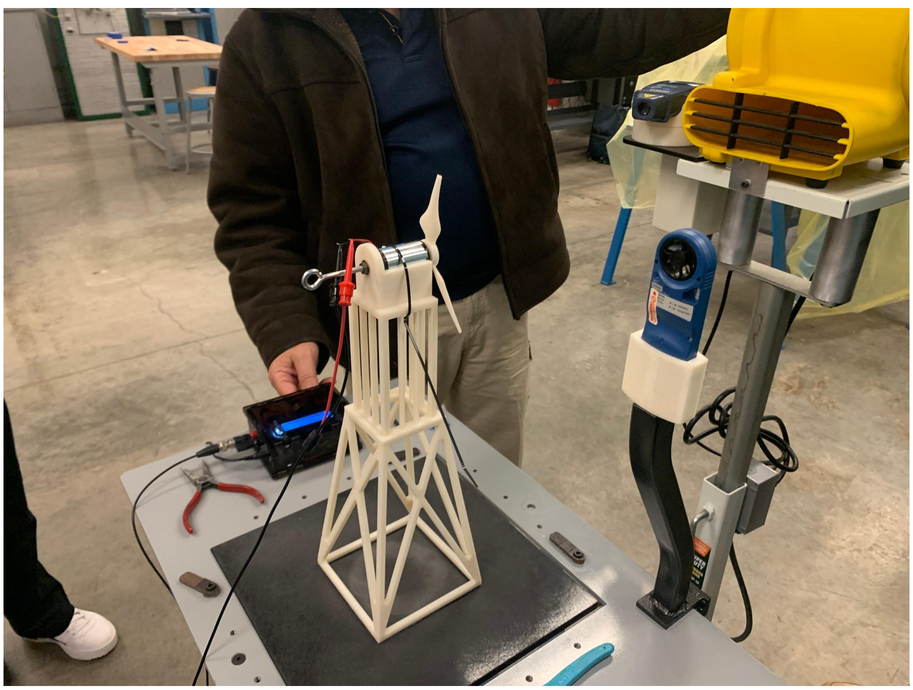
Project Summary

This project was aimed at the development of a wind turbine, with the goal of harnessing energy from the wind. A wind turbine is a system that accomplishes the conversion of wind energy to electricity.

The design process included 4 major activities, designing and fabricating the turbine rotor blades, the support tower, and determining the power output and stiffness of the wind turbine tower. Each part had specifications that needed to be met. The turbine rotor blades needed to be no more than 3 inches in radius, and the support tower required a height of 16 inches. The 3D printer had a footprint of 9x9x9 inches (width, depth, and height). The total volume of the 3D print shouldn't exceed 17 in^3. These requirements influenced the design of our wind turbine to its final shape.



(Figure 1)

Our final wind turbine design had a weight of 213.6 grams, a height of 14.25 inches, a maximum power generation of .061 Watts, and a stiffness of 0.6405lbf/mm. These measurements were taken in 28 mph wind and a motor with specifications of Maxom A-max, 6.0 VDC @80mA, 8500 rpm, 26x45 mm x3 mm shaft. In many ways, the tower successfully achieved the design objectives. The tower was able to harness energy from the wind, although not very efficiently. The tower did fail in a couple of ways due to poor

design. The significant failure was that the tower didn't reach the required height of 16 inches, only topping at 14.25 inches. This had the effect of interfering with testing. The blower was not directly blowing on the center of the turbine blades, but rather on the top portion due to the tower's shortness. This caused less air to pass through the blades and thus less electricity generated. When testing the deflection of the tower, the rope used to apply a force on the tower was touching the post which led to inflected result

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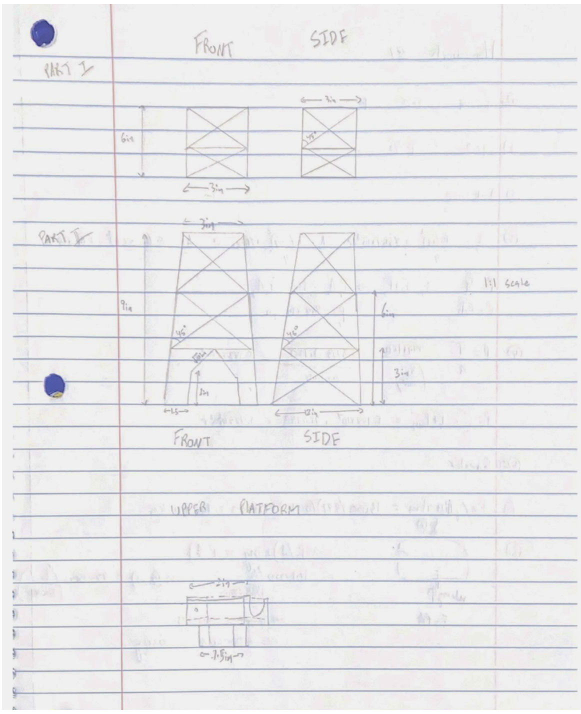
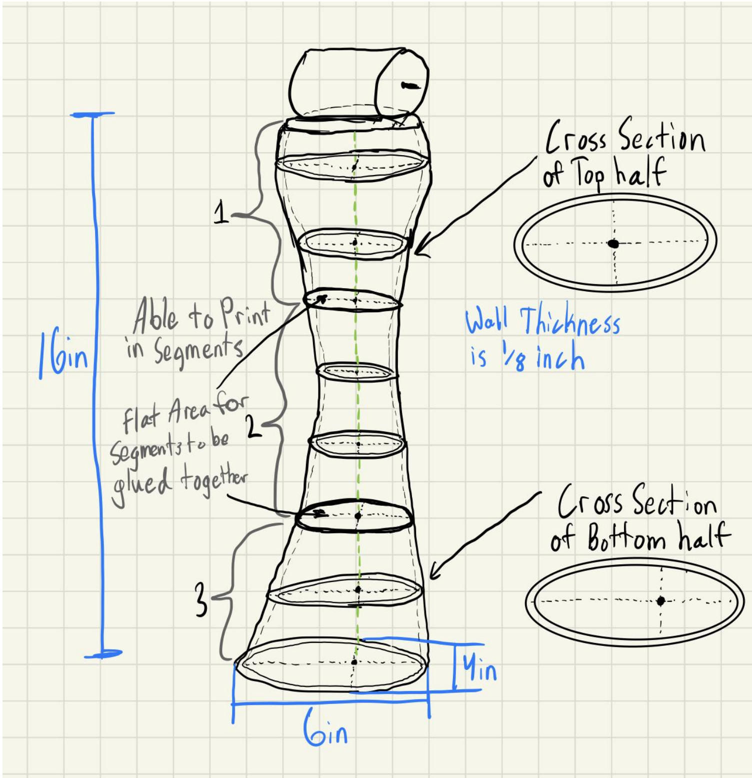
Introduction

Wind turbines are an alternative form used to generate energy. The turbines are used to create electricity/mechanical power. The way the turbine produces energy begins with the wind rotating the blades around a rotor that then spins around the generator, which creates energy that can be used in different ways. The project objective was to design and create, with the help of a 3D printer to fabricate the tower's rotor blade, the support tower, and a generator housing unit (used to hold the generator that will help create energy). Furthermore, we had to determine the power output of the wind turbine and the stiffness of the tower we created. The specifications required for the tower were a maximum height of 16 inches, a maximum volume of 17 cubic inches, a platform with the dimensions of 12x12 inches for our tower to go on, and we also had to create a platform for the motor, which was given, to go on the top of the tower in order to hold it for when we tested the tower. The tower that was designed by our group was a horizontal-axis wind turbine which is usually the most common type of turbine and usually has three blades that operate with the blades facing the wind. Our blade design had to take into account the angle of attack which we thought was the most effective, the length of each blade, and the number of blades that should be on the tower because different amounts of blades will affect the tower in their own way. For example, we decided that three blades on the tower were the best course of action because with three blades the tower will be the most stable and more reliable compared to a tower with two or four blades if we decided on a tower with two blades it would become too wobbly when the blades are facing the wind compromising the stability and risking our tower to snap. On the other hand, three blades were the best option because three blades on the tower would result in the most stable structure due to the fact that when one of the blades is pointing up, the two other blades will be pointing at an angle, allowing the blades to rotate in a smooth manner. The blades on our turbine tower had an angle of attack of 4.5 degrees. We used this angle because we thought it would be the optimal angle to produce the maximum amount of energy.

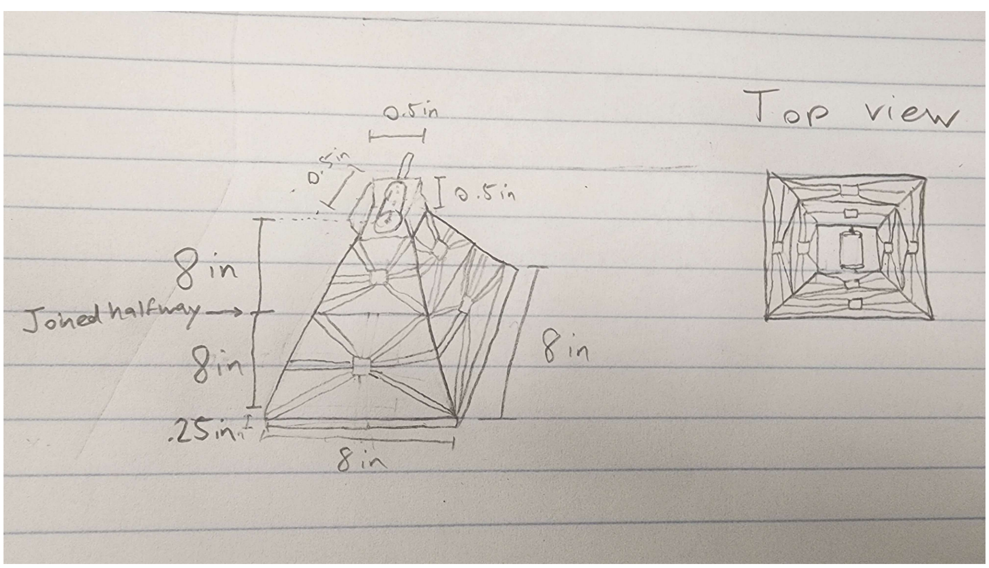
Typically, the ideal angle is between twenty to thirty degrees since an angle between those two will help the tower produce the maximum amount of power, so our angle of attack was not large enough to produce the most amount of energy. The height of the tower, once fabricated, resulted in being about 14 inches, leaving a 2-inch discrepancy from the maximum height. Our tower design was a two-story tower with thick beams on the corners of the structure and thinner beams in the center in order for the tower to be more stable and to help the structure be more supported. The two-story tower structure was what we believed to be the best design because we believed it would be the most effective in providing support for the tower in order to assure that it wouldn't snap when it is in front of the wind and when the tower is tested for its stiffness. The stiffness test is done by adding 0.1kg weights onto the tower until it reaches 1.0kg. While adding the weights there is a reader clipped to the tower and it measures the stiffness of the tower while the weights are being added. Our design plan for the tower was to make it two stories, with a strong base on each story, and to have beams running through the sides of the tower in order to have even more support just in case the outermost beams were not thick enough to keep the tower stable. Each group member created their own concept for a tower with different dimensions and aspects of the tower (figures A-E), in the end, we decided on a compromise of all of our tower concepts (figure F). The tower was created on a program named "SolidWorks" which is used to create objects or design them, which can then be used to create a 3D printed model of the drawing. We also used SolidWorks to test the tower for stiffness and to check where the tower had the most stress; once the stress was located on the tower, we were able to adjust the design in order for the stress to distribute evenly across the tower. Testing the tower for stress refers to performing a simulation on the SolidWorks program that evaluates the parts of the design that would have trouble handling weight, resulting in the tower snapping so the stress test provides us with the information needed in order to redesign the tower in order for it to be able to handle weight evenly. The tests and the different designs created were used in order to create the tower which we thought would be able to produce energy from wind and a tower that could hold 1.0kg of weight added to it and be able to hold that weight.



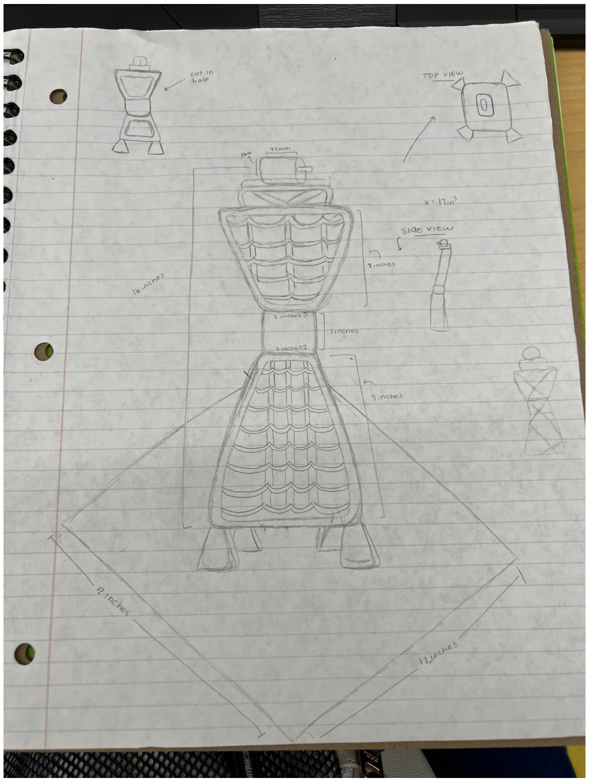
(Figure A) One tower concept by one member of the group



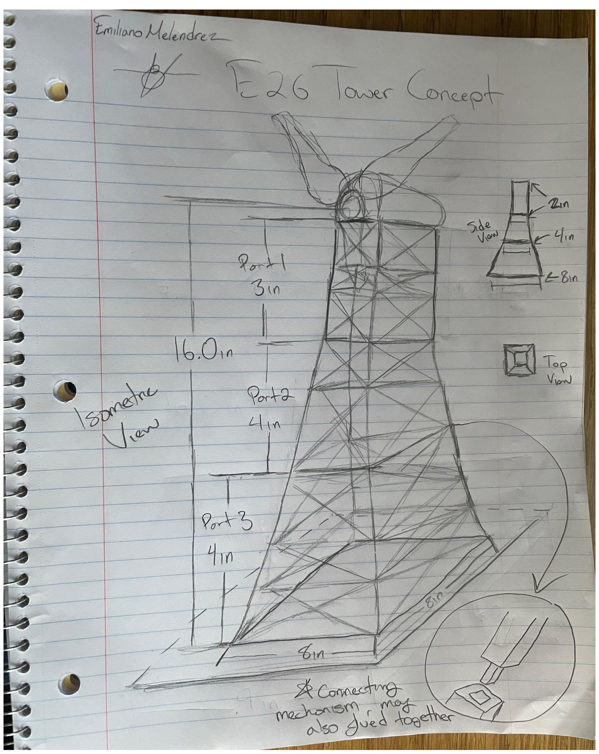
(Figure B) Concept for the tower



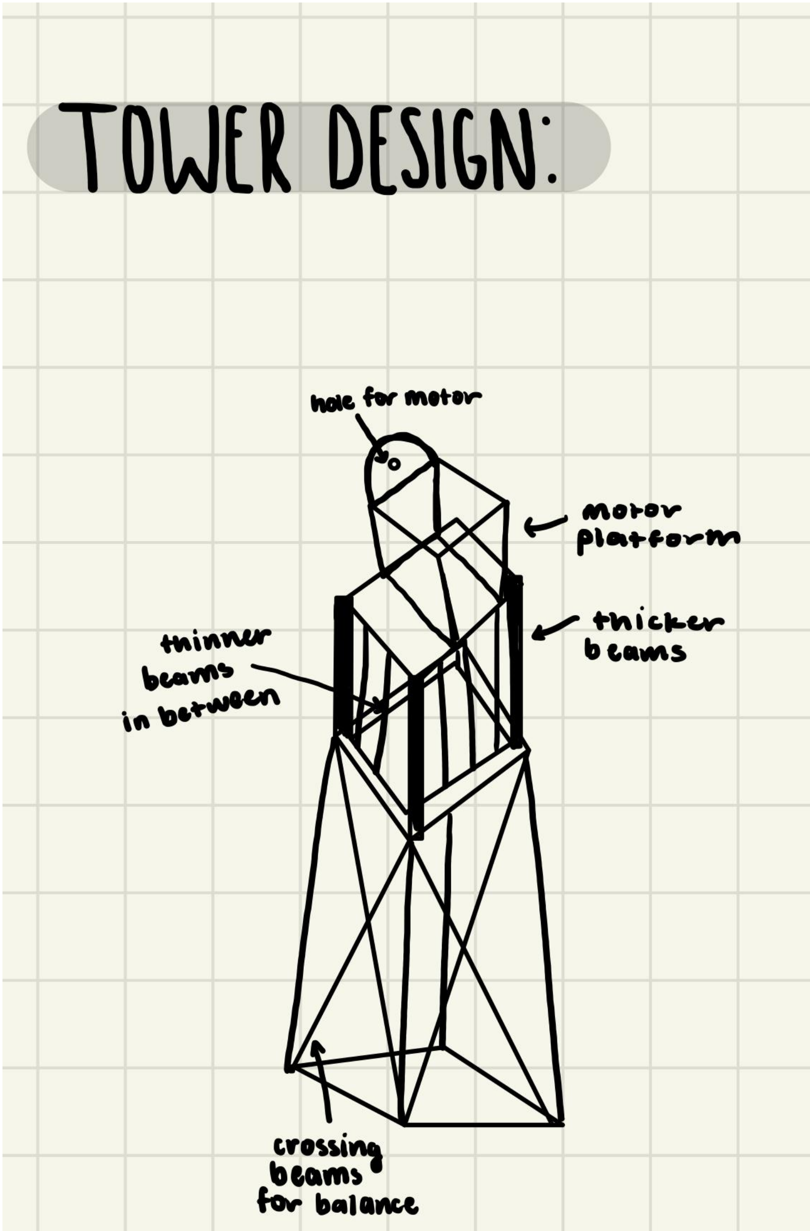
(Figure C) Tower concept



(Figure D) Tower concept



(Figure E) Concept for the tower



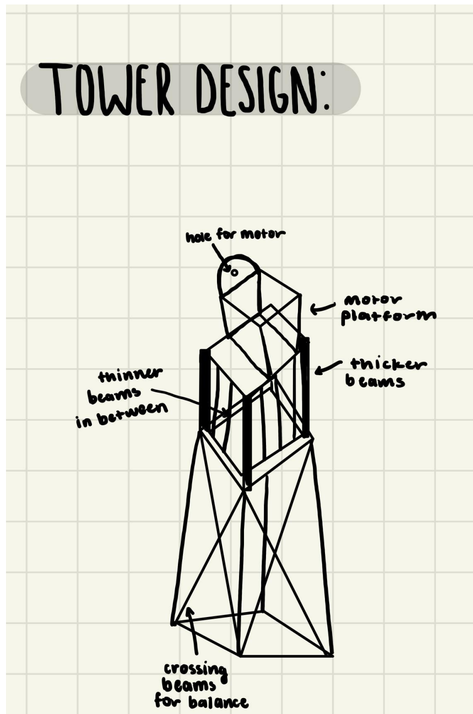
(Figure F) Sketch of the final tower design

Theory

In order to complete the project and understand the results we needed to understand the theory and equation behind the results. The equation needed to determine the power created by the turbine with aid from the wind is the power equation. The power equation is "W/△t" with the "w" referring to the work divided by an elapsed time. The equation states that power is the consumption of energy per unit of time, with the metric unit of power being a "watt." We need the equation in order to see how much power our turbine produces as time goes on and as the turbine creates energy. Energy efficiency was also something we needed to know in order to comprehend the numbers from our data from testing our tower. Energy efficiency measures how much a system is receiving from the energy source being used, for us this would be the fan. Knowing the energy efficiency is important because with that we are able to know if our tower can be producing a consistent amount of energy through the fan and if it will be able to produce that amount of energy without changing the source.

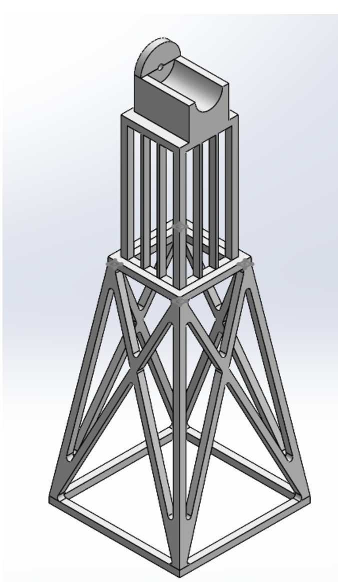
Design

The major tool used during the design process was Solidworks, a computer program used to design parts in 3 dimensions. Before we used Solidworks however, we drew sketches of the parts we wished to design.



(Figure F) Sketch of the final tower design

Once we got the basic idea of the part, we went into Solidworks to 3D model the part.

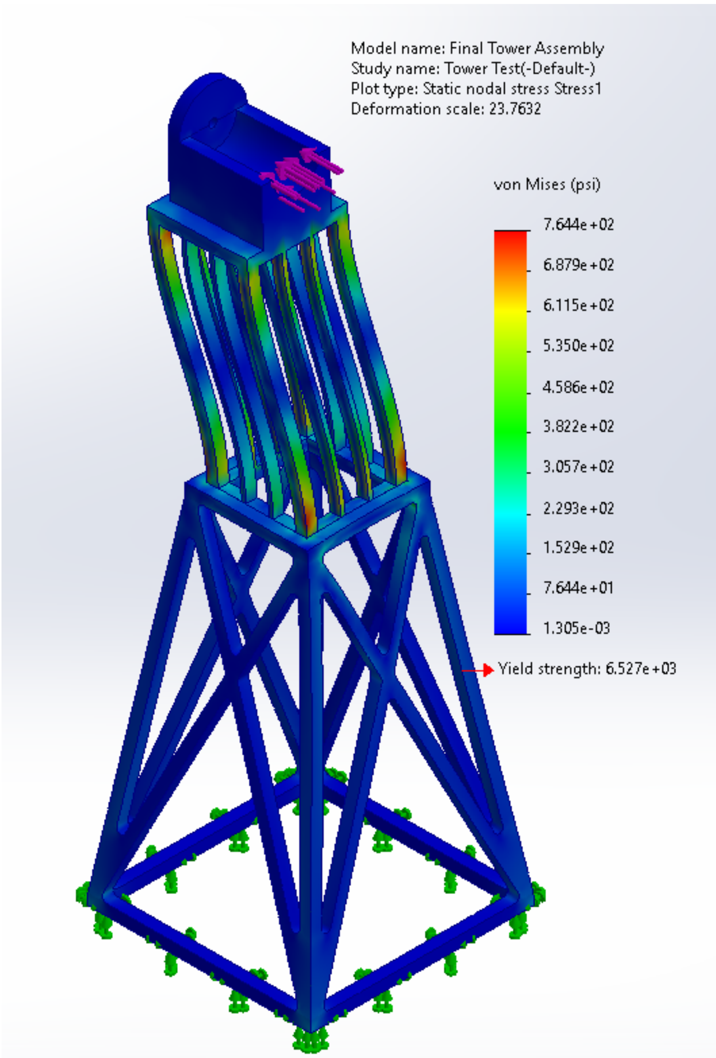


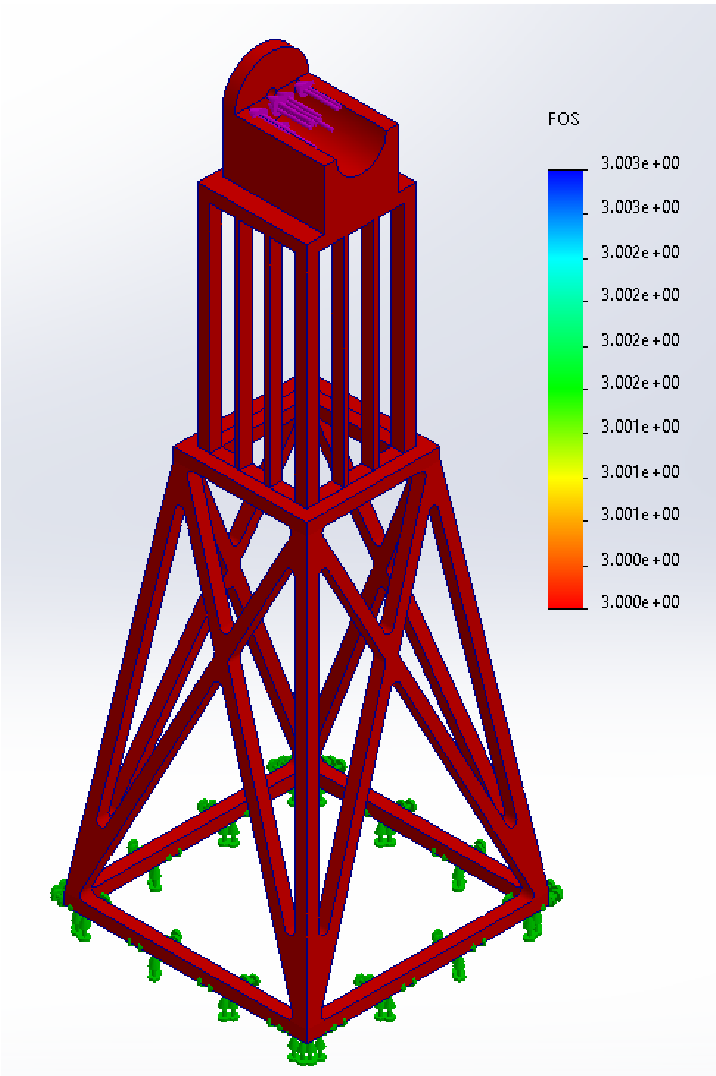
This design was made up of 3 main parts, the bottom half of the base, the middle/ top half, and the mounting bracket for the motor. The tower was split into parts as the 3D printer can only print so tall or wide, so sections were needed to construct the full wind turbine tower.

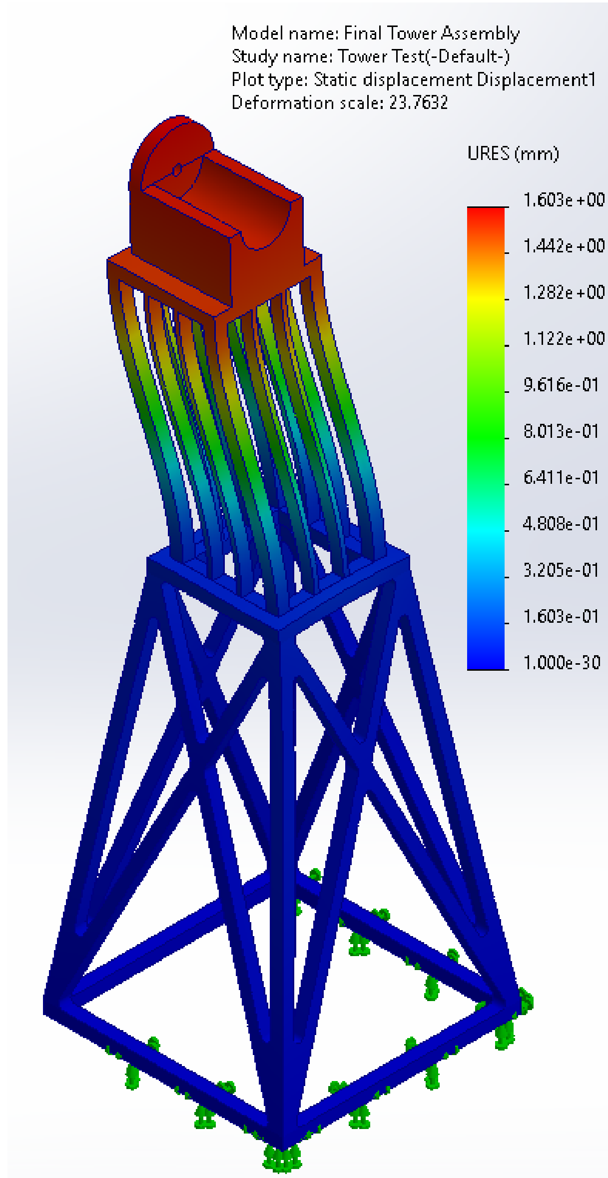
Once completed with the 3D model, we performed a Finite Element Analysis (FEA) simulation through Solidworks to determine the stiffness of the wind turbine tower. The simulation

is a computer-based engineering analysis tool used to predict how a product or material will perform in the real world. It can analyze stress, strain, temperature, vibration, and more. FEA breaks down a problem into tiny elements, solving them one by one to create an accurate 3D model of the design and its behavior under various conditions. This helps engineers to identify potential problems before the product is built, saving time and money.

Here is an image of the stress, displacement, and safety factors of the Tower.

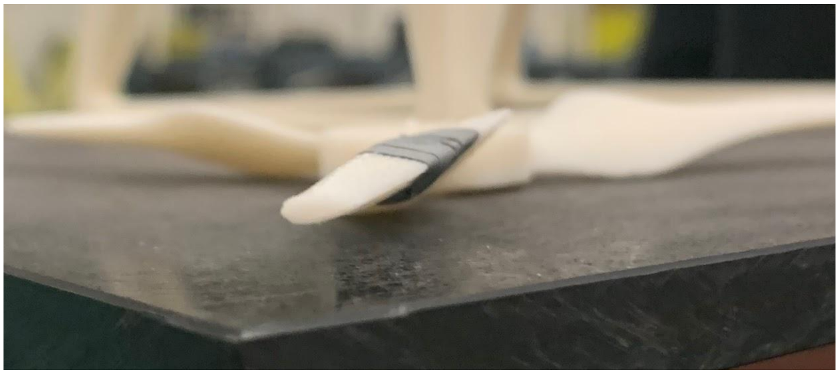




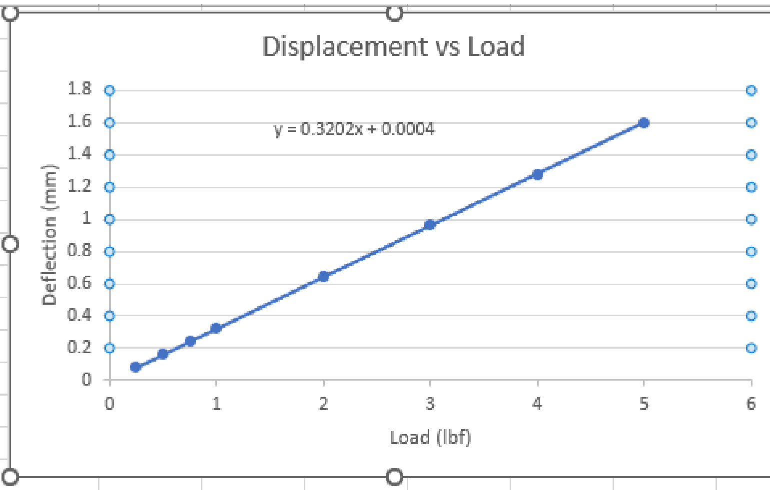


The Images above had a fixed base and a 5 lb load applied along the back face of the motor casing to simulate the force of the winds. This setup would allow us to figure out how our tower might interact in the real world with the forces of wind applied to the tower. The Factor of safety plots shows the whole tower can withstand a FOS of 3. Displacement showed that the maximum displacement of the tower would occur at the motor housing, with a displacement of 1.603mm. The highest stress occurs at the four corner supports, primarily where they meet the top and bottom plate on the faces parallel to the direction of the force.

The blade design was based on our own personal research through the internet. We found that the best profile was one that was wide close to the center of rotation, then thinned out as the blade was further from the center of rotation. The angle of attack we used was 4.5 degrees, with a minuscule amount of twist that was not very noticeable. The number of blades used was three as it allowed for a stable and efficient transfer of energy from wind to electricity.



Load (lbf)	Displacement (mm)
5	1.6
4	1.282
3	0.9616
2	0.6411
1	0.3205
0.75	0.2404
0.5	0.1603
0.25	0.08013

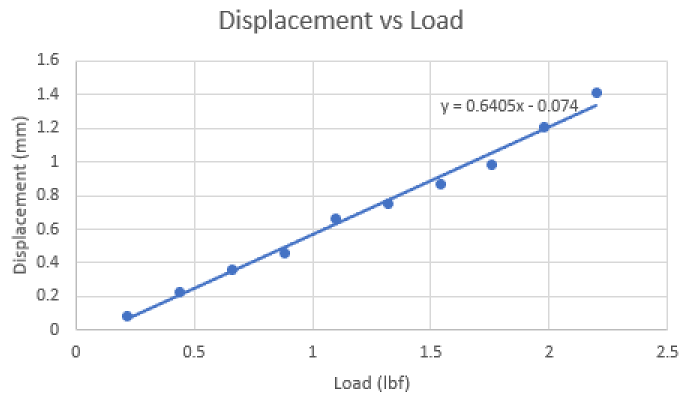


The data is from the Solidworks model and gives us the best fit line of

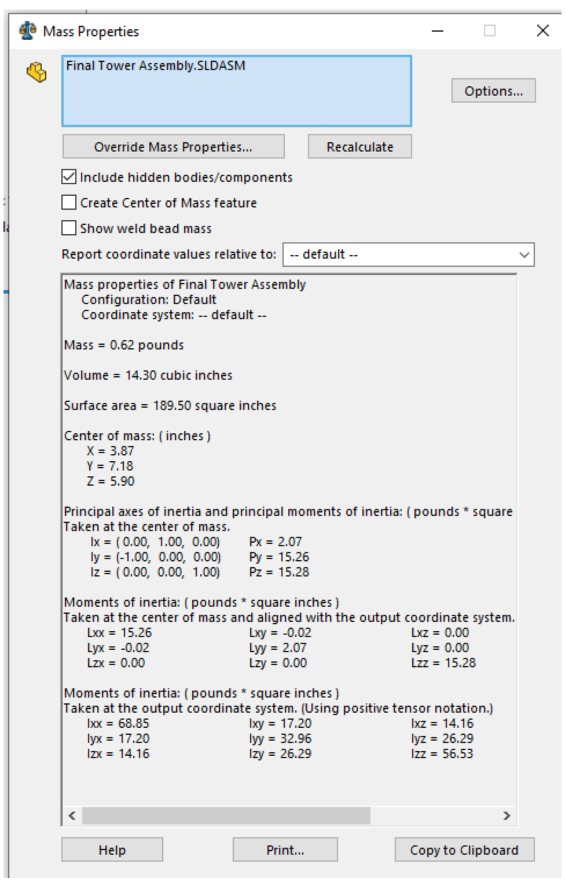
$y = 0.3202x + 0.0004$

The slope of the equation gives us the stiffness of the tower, which is 0.3202 lbf/mm or 8.133lbf/in

Load (lbf)	Displacement(mm)
0.22	0.08
0.44	0.23
0.66	0.36
0.88	0.46
1.1	0.66
1.32	0.75
1.54	0.87
1.76	0.98
1.98	1.21
2.2	1.41

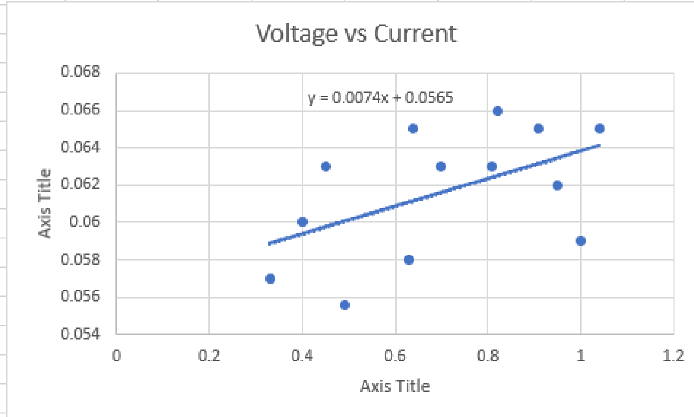


The data from our testing gave us a line of best fit y=.6405x-0.074 which results in stiffness of 0.6405lbf/mm or 16.2687lb/in. The difference between the two is about half and we believe the reasoning is that our final tower ended up being shorter than the original concept so the applied load has some angle with respect to the displacement measuring instrument, as well as a human error with the relative orientations of the tower and the load hanging off the eye-bolt.



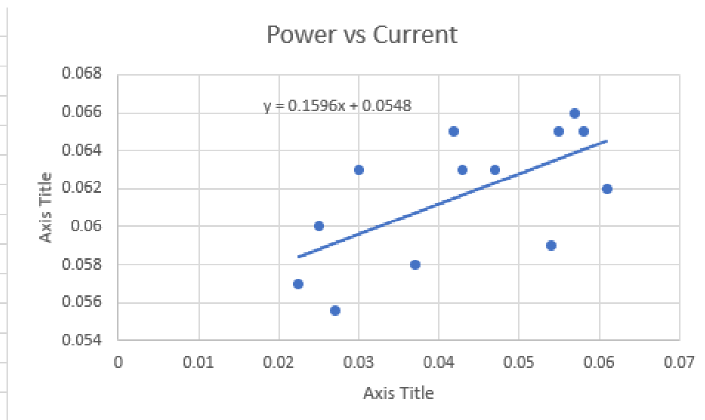
The overall weight of the tower was 0.62lb, excluding the weight of the glue and the bottom board.

Voltage (V)	Current (A)
0.33	0.057
0.4	0.06
0.45	0.063
0.49	0.0556
0.64	0.065
0.63	0.058
0.7	0.063
0.81	0.063
0.82	0.066
0.91	0.065
0.95	0.062
1	0.059
1.04	0.065



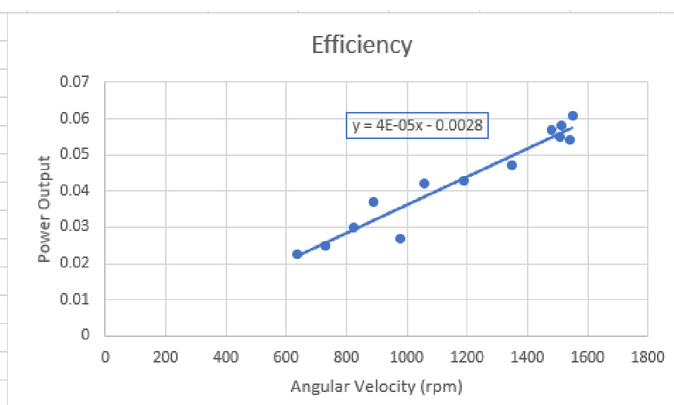
The Voltage vs Current plots shows us that as the Current increases, the Voltage begins to decrease at an increasing rate.

Power (V)	Current (A)
0.0225	0.057
0.025	0.06
0.03	0.063
0.027	0.0556
0.0419	0.065
0.037	0.058
0.043	0.063
0.047	0.063
0.057	0.066
0.058	0.065
0.061	0.062
0.054	0.059
0.055	0.065



The power and the current plot show that the Max power is about .061Volts for the wind turbine.

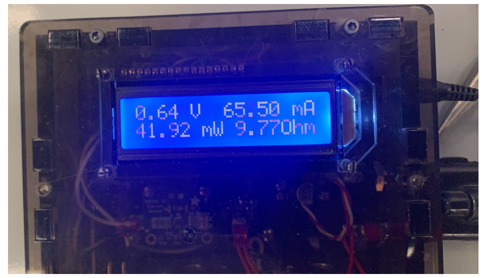
Angular Velocity (rpm)	Power (V)
636	0.0225
732	0.025
823	0.03
980	0.027
1060	0.0419
890	0.037
1189	0.043
1350	0.047
1480	0.057
1515	0.058
1550	0.061
1540	0.054
1509	0.055



The efficiency of the Wind turbine, as Angular velocity increases, so does the power output.

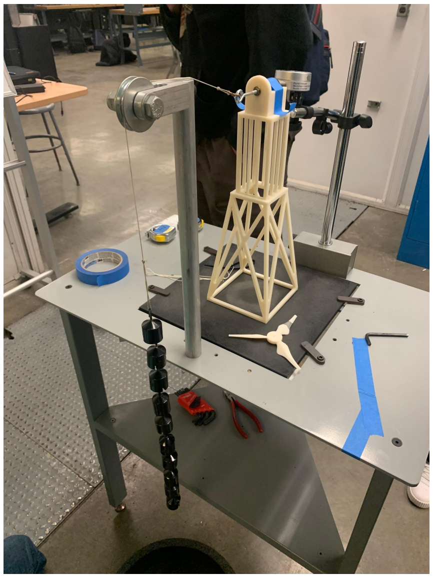
The data points through the different plots were scattered because our power output was low. The low power out was due to the poor design of the blades and also the short tower which didn't allow for the tower to be in the direct center of the blower. Sensitive equipment used to record data also leads the data set to be highly variable. In addition, human error affected the data as 4 different people read and recorded the data, having 4 different judgments influencing the data.

Testing apparatus and Procedure



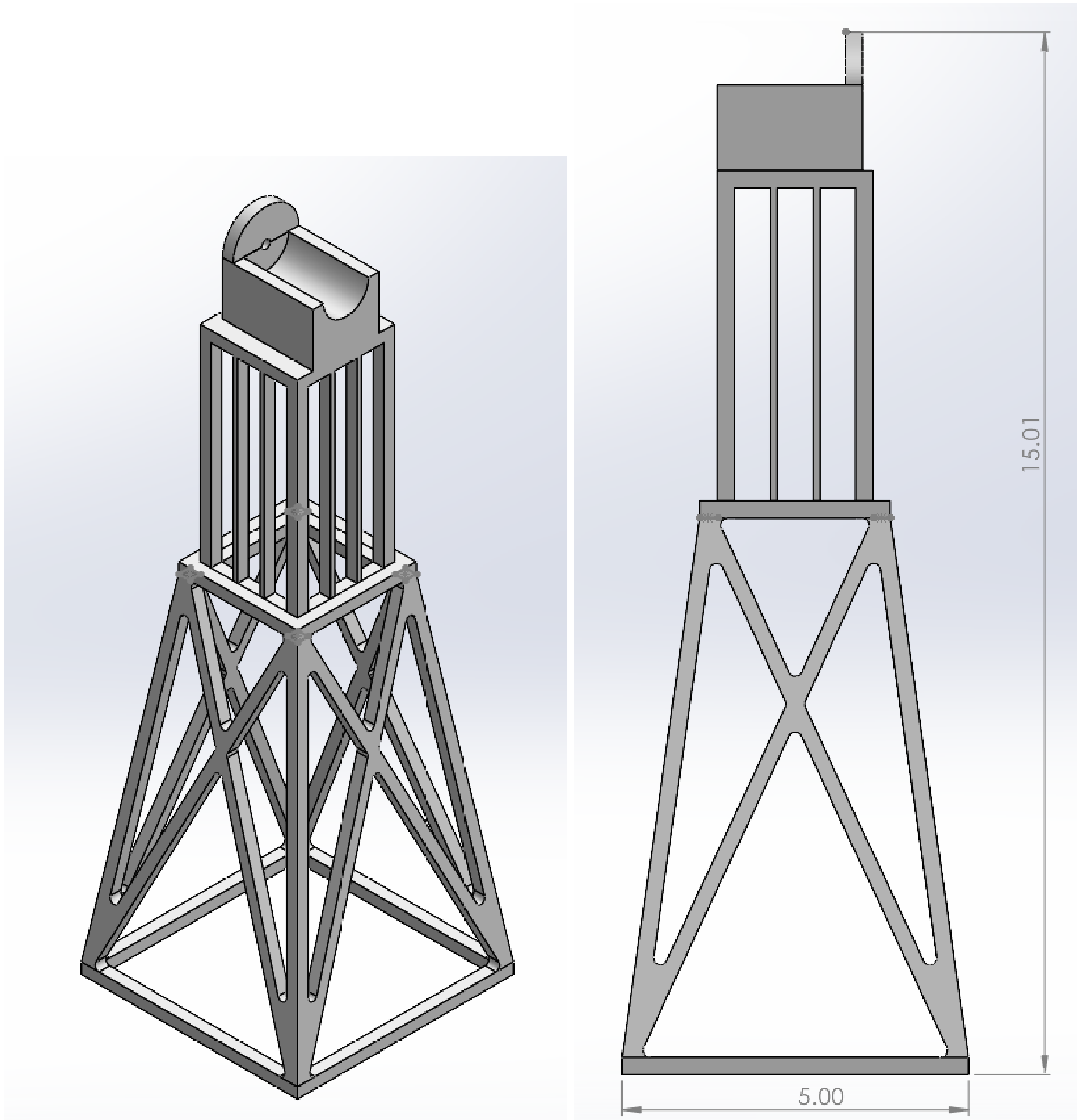
In order to test the efficiency of the wind turbine, we used a fan that was directed in front of the blade and the tower, a Tachometer,(a tool that measures how fast the blade is moving in RPMs), and another tool that measures the current, power, and voltage of the turbine. All of this data is

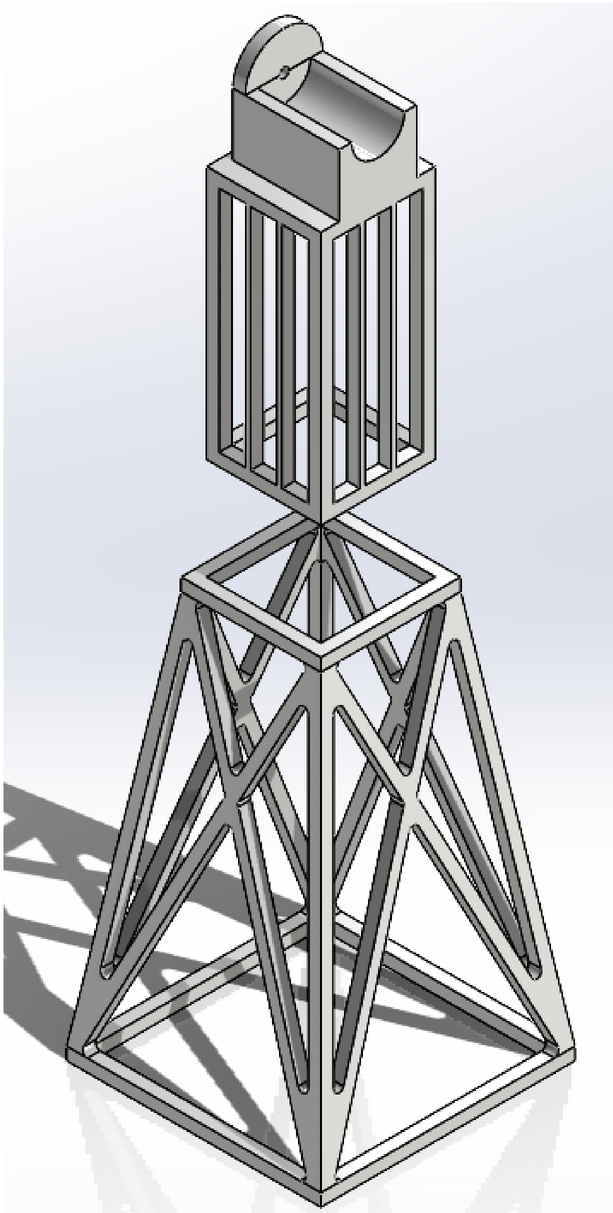
important to know when testing our turbine because the numbers that result from the tests give us the amount of power our wind turbine is producing and the maximum amount of power it can generate. The procedure of our testing began with increasing the current of the wires that are connected to the motor on top of the tower, and seeing how that affects the rest of the numbers. The first thing we did was increase the current the most we could in order to see what the maximum power our tower could generate, we got the highest power by observing the numbers on the screen of the tool and noticing where the number would settle and no longer jump from large numbers to smaller ones, which for us was 0.6 watts. As we increased the current every 10-20 seconds we would write down the voltage, power, and current; after, we would measure how fast the blade is moving with that current and write the number down. We repeated this process about twelve times in order to get enough data points for a graph with all of the data we collected. Once the data was collected for the power generated by our turbine we moved on to the deflection test of our tower, which is seeing if it would be able to withstand weight being added to it. After placing our tower down and securing it to a metal plate, a piece of string was attached to the top of our tower in order to attach the weights. The way the deflection test works is with the string, we add 0.1kg weights and the weights will then pull the string while simultaneously pulling down the tower with it. We would add 0.1kg weights until we reached 1kg and then take note of



how much our tower deflected from its original shape. Our deflections ended up being 1.41mm, we got this data from a tool that was attached to the top of our tower next to where the string was attached. The tool measured, in millimeters, how much our tower deflected as more and more weight was added to it and once 1.0kg of weight was added to our tower we took down the deflection number and finished our testing.

CAD Drawings





Conclusions

Overall, the tower project required our group to create, design, and 3D print a wind turbine tower and to test the stiffness, energy produced, and durability of the tower. Once our tower was printed, we tested it in order to see how much energy it would produce when it faced the wind. To test it we used a fan to generate a wind speed of 28mph that the blade needed in order to create enough spin, then 0.1kg weights were added to the tower in order to test the deflection of the tower.

We tested this by using a fan, lining the tower to be in the way of the wind so that the blade can rotate, then produce energy. Our blade ended up producing a maximum of 0.6 watts, which is enough to power L.E.D lights. Unfortunately, our blade did not produce the amount of power that was expected to be generated by the tower, which was 100 watts. What we learned by doing this project was how wind turbines generate power through wind, and how the different blade designs affect the power produced because of the number of blades and the size of the blades. We also learned what was an ideal concept for a tower in order for it not to snap and break, which is to have a tower with beams that are thicker on the outer edges, which aid in the stability of the tower compared to thinner beams that wouldn't be able to support the weight being added or the speed of the fan.

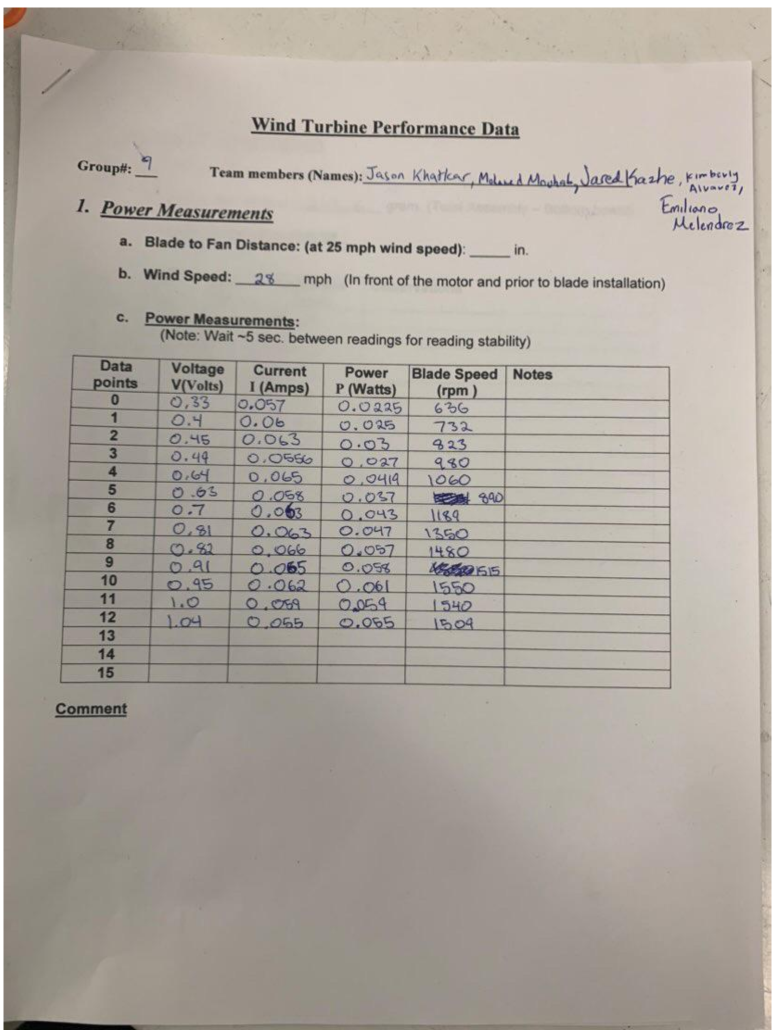
The outcome of our project was that it performed below the expected outcome for the towers. Our tower was expected to be 16 inches but ended up being 14.25 inches and our tower did not generate enough power; the tower produced a maximum of 0.6 watts when it was expected to produce 1.0 watts. The variances in the numbers that were expected and the data our tower produced could have been caused by the blade design. We learned that the angle of attack affects the amount of energy the tower can produce

Recommendations for Future Work

Some recommendations for future work/designs would be to try to create multiple designs for blades and for the tower's structure. Although our group had a tower design that included all of the specifications we all had in our initial freehand design, it would have been ideal to have different designs for the tower just in case one of them ended up printing to be the 16 inches since our tower resulted in being 14.25 inches. Or instead of creating an entirely new design, in the future, we could make the beams slightly longer in order for them to reach the height of 16 inches. An improvement we could make for a future tower would be to change the angle of the blade and make the blades have more of a twist. Since our blades didn't have that large of a twist, they did not produce a substantial amount of power. So if we were to remake a tower in the future, creating blades that twist more would help produce more energy because with a larger twist, the blade will be able to spin faster and handle more energy from the fan. A detail that could be changed for a future tower design would be the platform where the motor is placed, on our tower we were told that the platform ended up being slanted, which did not affect our data but is something that could be improved upon in a future design. Lastly, if there was enough time and material, something that could help the outcome for future designs would be to create at least two towers and have them 3D printed in order to be able to compare the towers and be able to decide which tower we believe would be able to produce the most amount of power.

Appendices

If doing a similar project, something that might be of help would be when you're testing your tower and reading/collecting the data, to be patient and write down as many points as possible in order to have an extremely accurate chart. In our data table we ended up writing twelve data points, but it ended up taking quite a bit of time because our numbers kept jumping up and down and would not stabilize on a number. So, when doing this project it is important to be patient and to use all of the given data point slots on the paper because if all of them are used then the graph of the power produced by your tower will be accurate and you will have an easier time understanding how much power your tower can produce.



Wind Turbine Performance Data

Group#: 9 **Team members (Names):** Jason Khatkar, [illegible], Jared Kazhe, Kimberly Alvarez, Emiliano Melendrez

1. Power Measurements

a. **Blade to Fan Distance: (at 25 mph wind speed):** _____ in.

b. **Wind Speed:** 28 mph (In front of the motor and prior to blade installation)

c. **Power Measurements:**
(Note: Wait ~5 sec. between readings for reading stability)

Data points	Voltage V(Volts)	Current I (Amps)	Power P (Watts)	Blade Speed (rpm)	Notes
0	0.33	0.057	0.0225	636	
1	0.4	0.06	0.025	732	
2	0.45	0.063	0.03	823	
3	0.49	0.0556	0.027	980	
4	0.64	0.065	0.0419	1060	
5	0.63	0.058	0.037	890	
6	0.7	0.063	0.043	1189	
7	0.81	0.063	0.047	1350	
8	0.82	0.066	0.057	1480	
9	0.91	0.065	0.058	1515	
10	0.95	0.062	0.061	1550	
11	1.0	0.059	0.054	1540	
12	1.04	0.055	0.055	1509	
13					
14					
15					

Comment

(Figure F) Our data sheet when testing how much power our tower produced