3D Printed Wind Turbine Design and Testing

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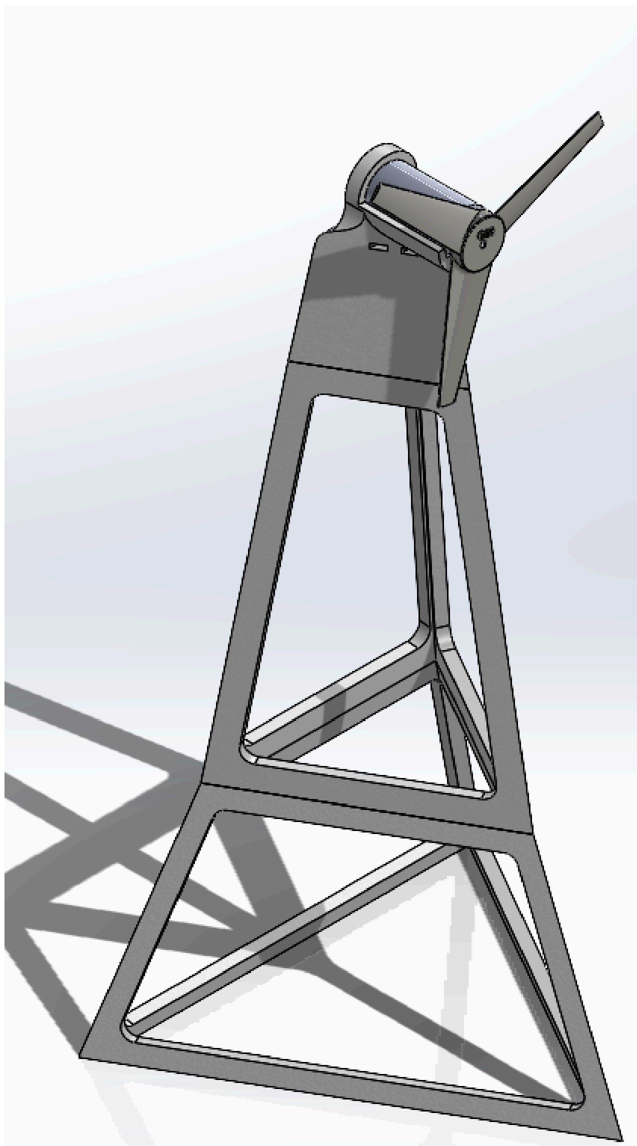
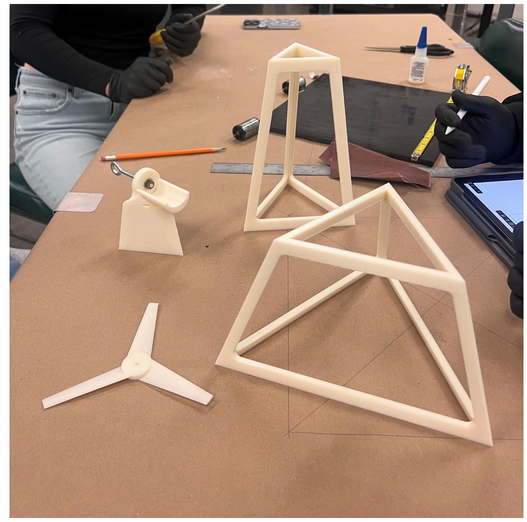


Project Summary:

The turbine tower project aims to design, print, and test a wind turbine using 3-D modeling and fabrication with the ultimate goal of using it to produce electricity. In order to maximize the performance of the wind turbine, we had to research and understand the technical concepts behind its functionality. We started off by understanding how different tower and blade designs contribute to different qualities of stiffness and electricity generation. The four key tasks that our team tackled were: designing and creating the turbine rotor blades, designing and fabricating the building the support tower and generator housing, testing the power output, and testing the rigidity of the tower.

Our project design was built according to the specific requirements and limits that were given to use, guaranteeing that the blade and tower components would not exceed certain dimensions and would be compatible with the testing set up. Some specifications and limitations included weight, size, radial symmetrical structure, correct motor housing size and the hole in the back of the motor housing.

The first designed component was the blade for which our team conducted individual research, before coming up with our final design. The key factors that were taken into account when designing the blades were the angle of attack, angle of twist and number of blades needed for the most optimal design as shown in Figure 1.1. These factors played a large role in the performance during the power output test, so each of those values were carefully chosen

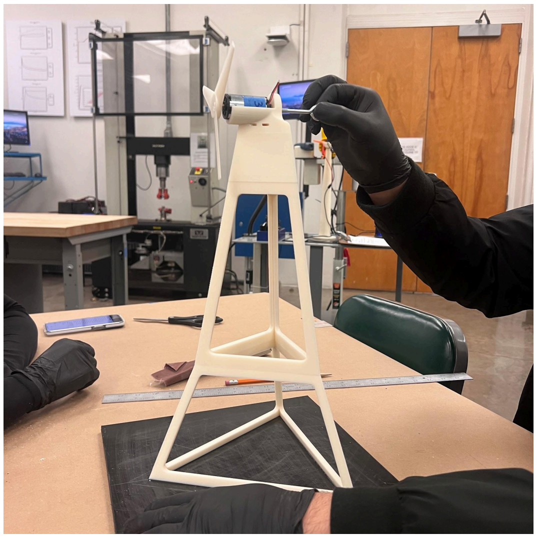


[Figure 1.1] Turbine Rotor Blade Component

[Figure 1.2] Separate Tower

The next component was the support tower and generator housing which held the motor. Our team followed a similar process as we researched support designs and motor hubs that would result in the greatest possible stiffness for testing. We decided on a wide, triangular base that would fare well to stress due to its strong, symmetrical design. The support and housing consisted of three separate parts, two of which made up the tower and the third component which was the motor housing, Figure 1.2.

The ultimate goal was to test the performance of our design through two means, the first being the power output and the second being its stiffness. Our final wind turbine weighed a total of 251.2g not including the base plate and produced a max power output of 1.823 watts, with a deflection of 0.69 mm at 1 kg. These measurements highlight how well our final design, as shown in Figure 1.3 and construction processes worked, showing how we optimized material use, structure, and power generating capabilities in an efficient manner.



[Figure 1.3] Final Assembled Tower

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1. Introduction

1-1 Introduction to wind turbines

The use of wind energy is one of the fastest growing energy sources in the world, let's talk about how they work.

[Figure 1.1] Wind turbine farm

To start, where does wind come from? Wind is solar energy that is produced when the sun unevenly heats the earth's atmosphere, by the earth's rotation, and irregularities in the earth's surface.

Different sized turbines are used for various purposes; smaller turbines can be used for chargers for vehicles and boats or provide power for a traffic light system. Slightly larger turbines can be used to produce electricity for domestic supplies. Wind farms are a large group of large turbines that are an indispensable source of occasional renewable energy. Countries around the world use them to minimize fossil fuel usage.

How does a wind turbine create energy?
Wind flow is what the turbines use to generate electricity, this is done by the wind's aerodynamic forces being applied on the blades. During this the wind flows across the blade which causes the pressure to decrease as the wind travels, this difference in pressure proceeds to result in both lift and drag on the face of the blade, resulting in the blade rotor spinning. The rotation of the rotor allows the generator, which is connected to the rotor, to produce energy.

1-2 Types of Turbines

Horizontal axis- these are the most commonly used turbines, typically using three blades. The turbine pivots around at the top of the tower so the blades are always about to adjust to the direction upwind. This design allows for a high lift to drag ratio, which allows for an optimized production of energy in different winds. Pictured in figure 1.1.

Vertical axis- these turbines tend to also have vertical blades that are swept out and attached on the ends of a fixed pitch. They can take wind from any direction and can generate more energy with less wind than the horizontal turbine. Pictured in Figure 1.2.

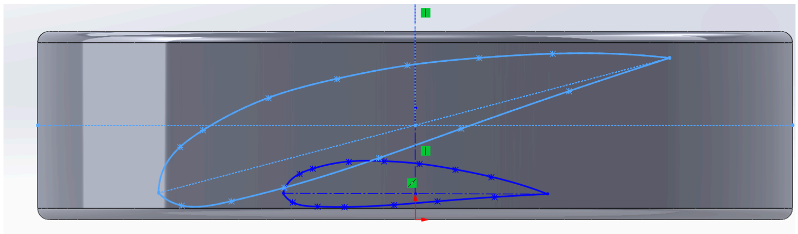
[Figure 1.2] Vertical Axis Turbine

1-3 Project Introduction

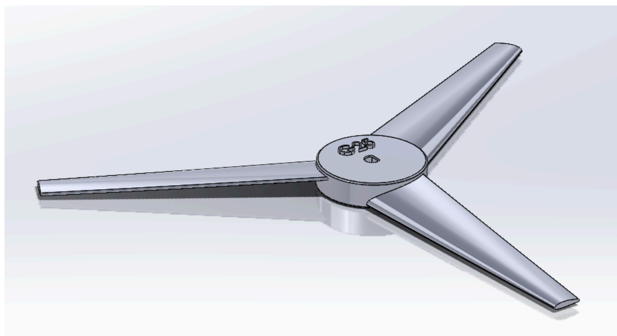
This project assigned the team with the goal of being able to design and manufacture a miniature wind turbine, with the goal of producing 2+ watts of power, the tower having a stiffness of 8+ N/mm (newtons per millimeter), and a total weight of 350 grams or less.

1-4 Blade Introduction

The first task of this assignment was to research the most effective blades and find their specific designs in order to produce one unique to the team. This meant finding the angle of attack, which is the angle between the oncoming wind and the chord line that is simply a straight line from the leading edge to the trailing edge of the blade. The team learned that the range for attack is from 1-15%, however, the higher the angle the greater loss in lift of the blade, which led to the decision for the angle to be 7.5%. Next, the angle of twist was needed to be decided, during the search the typical range of 0-20 degrees was found and the most commonly used average was around 15 degrees, which led to 15.3 degrees on the design. Finally, the number of blades needed to be found, having as few blades as possible leads to the least amount of drag, however, one blade would result in an unbalanced turbine and a two blade design is prone to gyroscopic precession which results in stability issues. This byproduct of this information guided the team to choose a three blade design, which is the most common and configures the best balance of aerodynamic efficiency and blade stiffness.



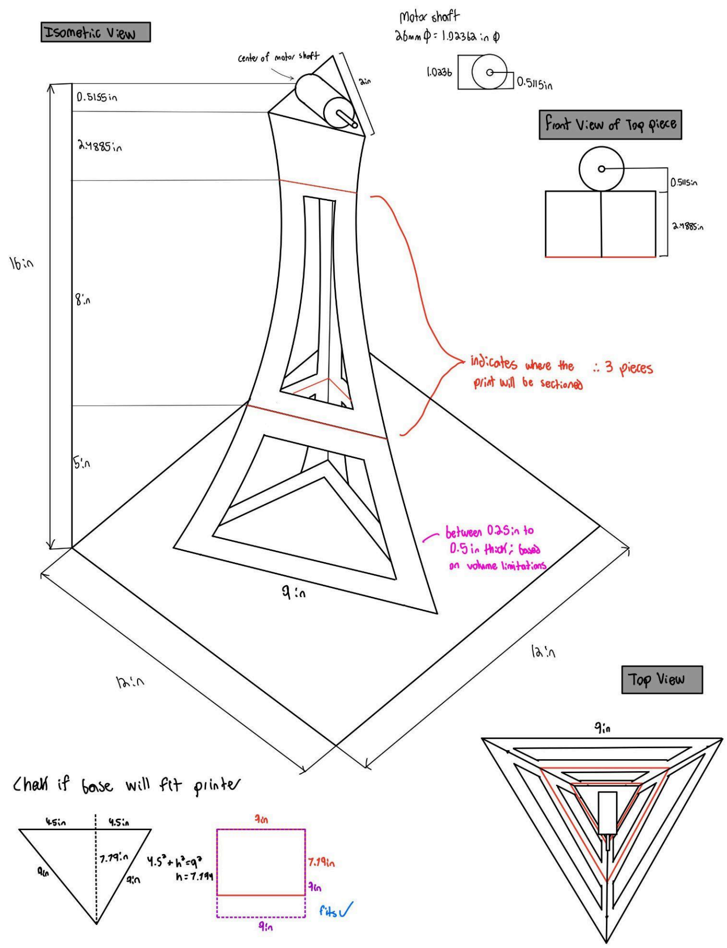
[Figure 1.3]- Angle of attack and twist



[Figure 1.4]- Three-blade design

1-5 Tower Introduction

For the tower design, the team split up and designed all their own potential towers. Everyone decided on the tower pictured in Figure 1.5. The tower had certain parameters that we needed to follow; it could not exceed a based on 12x12in which was the size of the base plate, the height could not exceed 16 inches, the tower must be split into separate parts that do not exceed 9x9x9in which was a limitation of the 3-D printer, it could not exceed 17in^3 in volume, and finally the design must have been radially symmetrical. This tower design was chosen by the thought that it would result in the best tower and realistically the best fitting design. There was also a thought that it would have the highest stiffness number. Once we had decided on the tower concept the only next step to make the tower up to the specifications, was to add a 3/16in hole in the section that houses the generator.

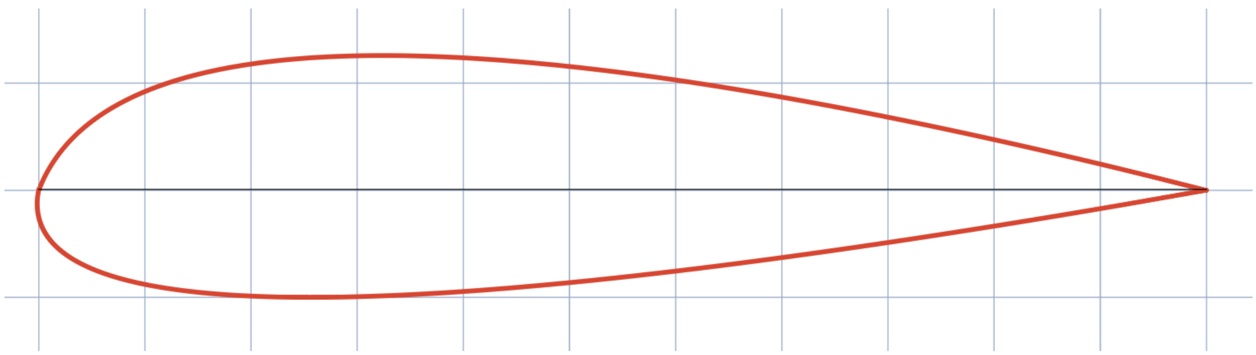


[Figure 1.6]- original drawing of the tower design

2. Design

2 - 1 Blade Design

In our effort to explore various characteristics of blade profiles and determine the most optimal parameters, we drew inspiration from a 2012 research paper titled "Aerodynamic Analysis of a small horizontal axis wind turbine using CFD." For our blade profile, we decided to adopt the NACA 4418 (see Figure 2.1), as the research paper identified optimized aerodynamic parameters/characteristics for it.



[Figure 2.1] NACA 4418 Blade Profile

For our angle of attack, we drew on insight from lectures and additional research; we learned the angle of attack typically ranges between 1.0% - 15.0%, and having a higher angle of attack would result in a loss in the lift because of turbulence. Keeping this in mind, we referred back to the 2012 research paper for the specific NACA 4418 blade profile, as the paper highlights aerodynamic characteristics such as its maximum lift-to-drag ratio as well as corresponding angles of attack. This allowed us to come to a decision on the angle of attack value of 7.5%.

To determine the angle of twist for our wind turbine blade, we consulted a research paper titled "Wind Turbine Blade Aerodynamics" by Kimerius Aircraft. This paper provided us with general information on wind turbine blades and informed us that the typical angle of twist ranges from 0-20° from root to tip. To obtain a more specific value, we revisited the previously mentioned research paper and utilized a table relating the geometry of the blade to its twist angle for the NACA 4418 blade profile (see Figure 2.2), specifically for an angle of attack of 6.5% which we did not choose and will accommodate for at the end. Using this table and considering our blade diameter is a maximum of 6 inches (radius 3 inches or 76.2 mm), we used linear interpolation to determine the specific twist angle of ≈ 11.91%. To accommodate for our angle of attack of 7.5%, from the equations used in the research paper to obtain the table we expected a variation of around 25% due to the differing angle of attack, allowing us to obtain the angle of twist should be ≈ 15.30%.

S. No	Radius (r) (mm)	Chord (c) (mm)	Twist angle (θ_T) (degree)
1	25	35.872	31.232
2	45	32.852	20.229
3	65	27.13	13.680
4	85	22.452	9.5624
5	105	18.942	6.7943
6	125	16.299	4.8246
7	145	14.267	3.3586
8	165	12.666	2.2280
9	185	11.377	1.3310
10	205	10.321	0.6027
11	225	9.4400	0

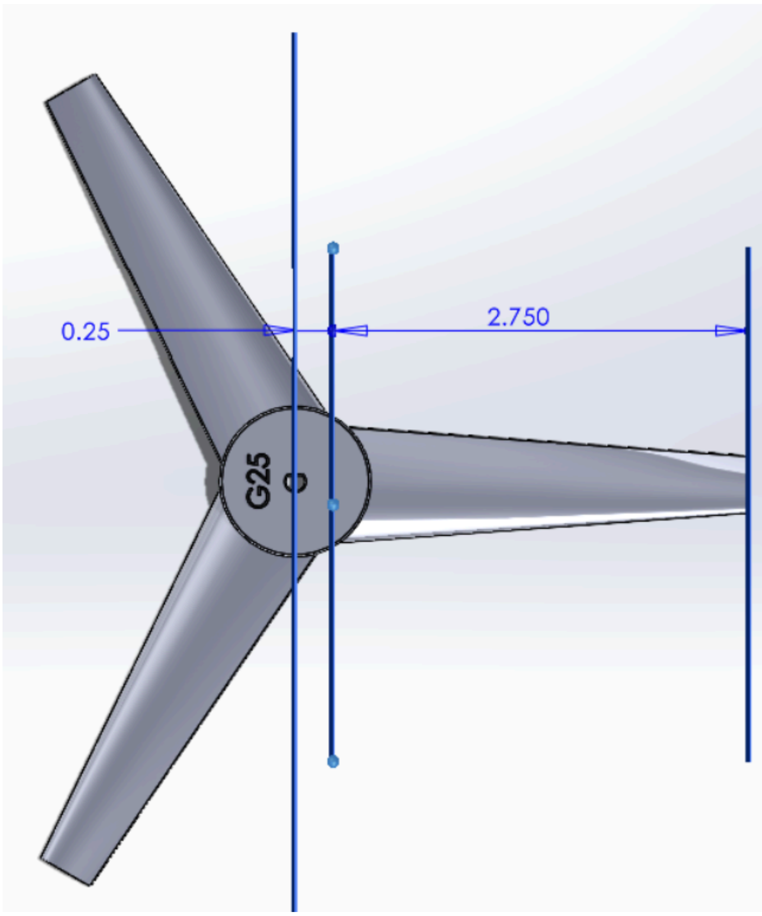
[Figure 2.2] Table of twist angle relating to the geometry of the blade

For our number of blades, using lecture material and exploring an article titled "The Scientific Reason Why Wind Turbines Have 3 Blades," we learned that minimizing the number of blades decreases drag, enhancing energy yield. However, we learned that a one-blade design would make the turbine unbalanced; a two-blade design is prone to gyroscopic precision (causing stability issues). A three-blade design is the most common, and any more than three blades would create greater wind resistance and slow down electricity generation, so we were prompted to use a 3 blade design. To solidify this decision further, the previous research paper states, “The three-bladed configuration is the best balance between aerodynamic efficiency, noise levels, and blade stiffness” (Keerthana 17).

All in all, our blade specifications included using a NACA 4418 blade profile, an angle of twist of 15.3%, and a three-blade design.

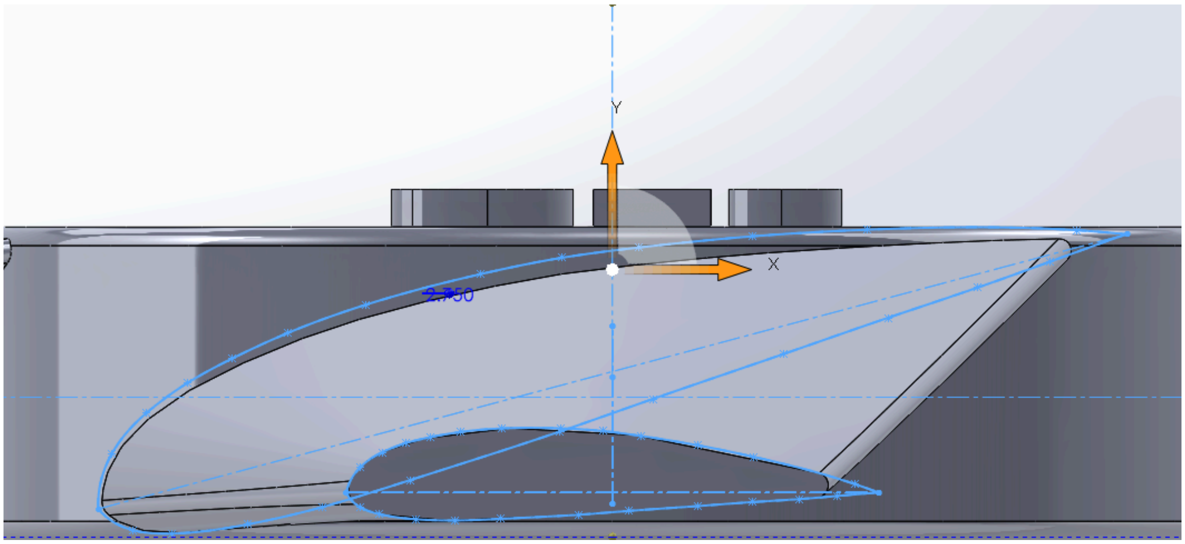
The process of designing the rotor blade involved importing the provided hub CAD into Solidworks and defining two planes. The first plane was set at 0.25 inches from the center of the hub, while the second plane was set at 3.0 inches from the center of the hub (see Figure 2.3).

These planes allowed us to define the diameter of the blade, which we chose to be the maximum diameter allowed, 6.0 inches.



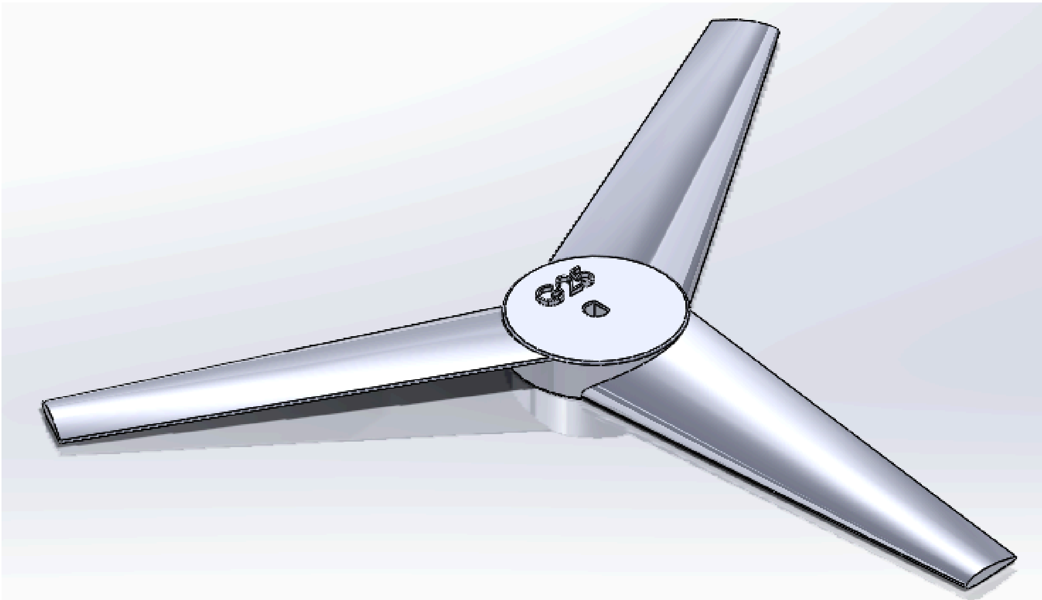
[Figure 2.3] Top view of blade design *(units in inches)*

Our next step is to sketch the NACA 4418 blade profile on each plane. For plane 1, we aim to position the profile at 15.3% relative to the top plane and maximize its cross-sectional size while ensuring it remains flush with the hub. Moving on to plane 2, we will draw the profile parallel to the top plane and scale it to 0.5 relative to the profile from plane 1 (refer to Figure 2.4). It's crucial to maintain the alignment of both profiles along their vertical center line as shown in the figure.



[Figure 2.4] Side sketch view showing blade profiles

We will lastly use our most used tools while making this entire tower/blade, the loft tool, to loft the sketches from planes 1 and 2. It's essential to keep in mind that the printer may not be able to print extremely thin sections of the blade. To address this, we can use our second most commonly used tool, the fillet, to round the back (left side in Figure 2.4) with a radius of 0.015 inches and the front (right side in Figure 2.4) with a radius of 0.01 inches. Once this is complete, we can create a circular pattern with the blade to achieve our desired three-blade design. Finally, we embossed our group number onto the top of the hub to make identification easier once printed (see Figure 2.5).

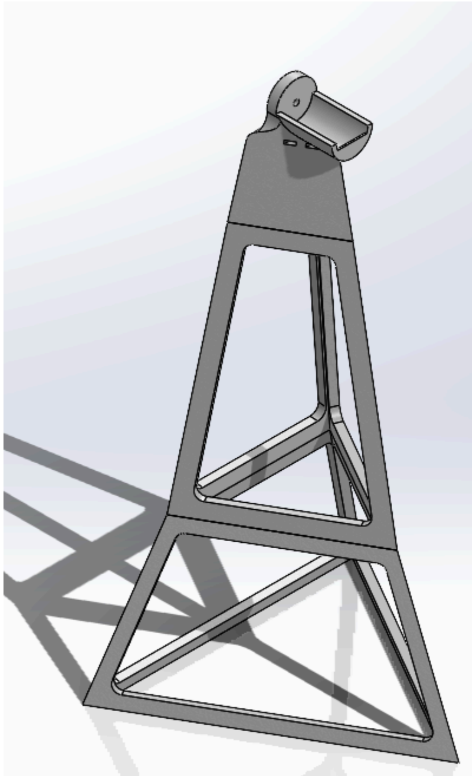


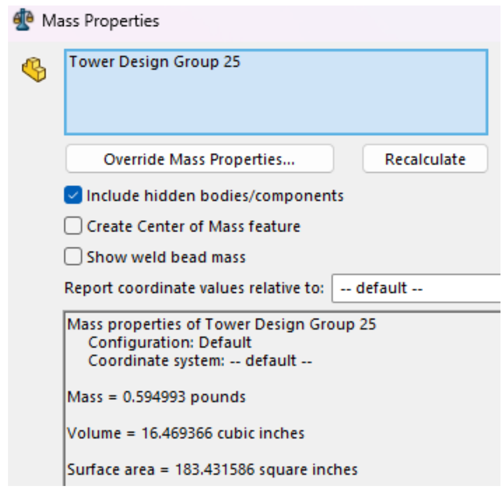
[Figure 2.5] Isometric CAD view of the blade

2 - 2 Tower Design

For our tower, we decided to stick to a fairly simple design where the base will maximize the 9x9 base plate of the 3D printer and tried to keep as few individually printed parts as possible. Additionally, during the lecture, we were told to try not to make too many trusses as it can waste a lot of support filament so we decided to create a tower that would utilize the shape of a triangle, the ‘strongest shape’ as the weight gets distributed along the three sides and is a main reason why we see so many bridges built using truss designs.

Keeping all this in mind, we came up with the design shown in Figure 2.6, where we used the shape of a triangle to maintain radial symmetry and cut out as much material as we could to minimize the weight and stay under the given volume restriction of 17 in^3.



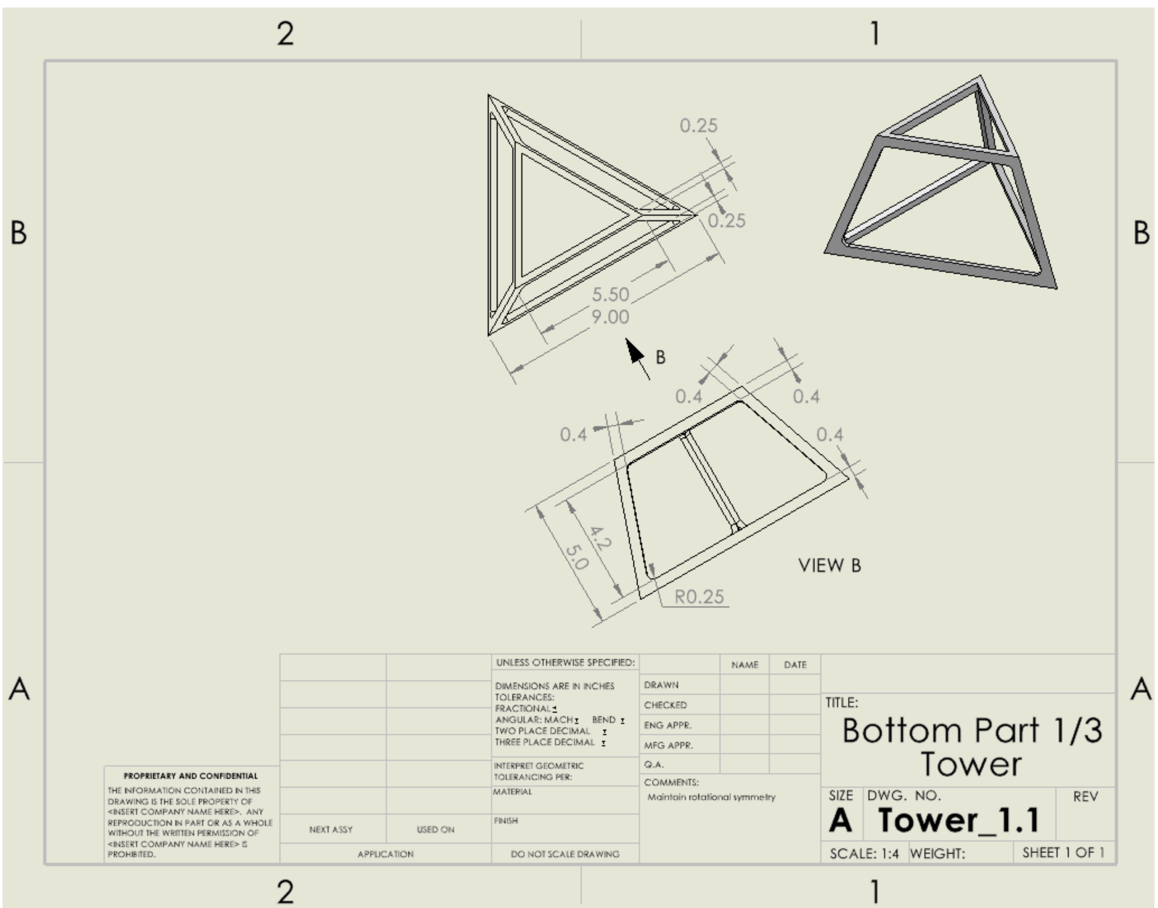


[Figure 2.6] Isometric view of the Tower **[Figure 2.7]** Mass properties of the Tower

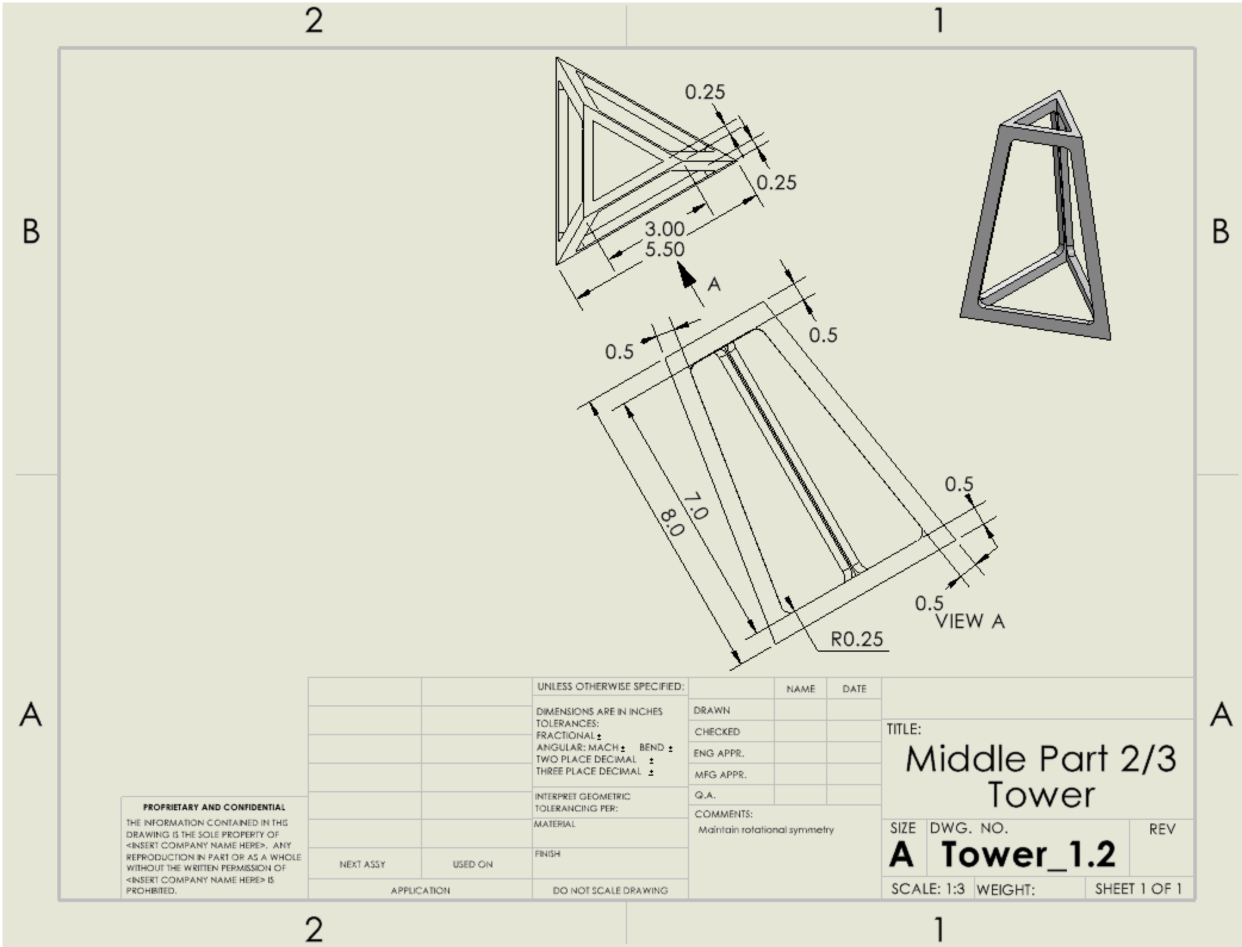
From the mass properties of our assembly, we can see how the volume of the entire tower is indeed maintained under the 17 in^3 volume constraint and if necessary we could have even taken advantage of the remaining 0.531 cubic inches of volume to further strengthen the tower.

The process of designing the rotor blade involved defining numerous parallel planes at various heights that would allow us to design our three independent parts of the tower. We had to keep in mind the 3D printer had a printing area of 9x9x9, so deciding how to divide our tower was quite crucial, which is shown later in Figure 5.5. After defining our heights, we could create the triangular cross sections onto each parallel plane, starting from a 9-inch equilateral triangle up to a $\approx$ 2.1-inch equilateral triangle. After sketching the equilateral triangles, we could use, again, our most used tool, the loft tool, to loft the sketches together. This would essentially allow us to obtain three tetrahedron pyramids with flat tops. Remembering our volume constraint, we can next use the shell tool to shell, inward, a thickness of 0.25in to reduce material. We will sketch on each face of the ‘tetrahedron pyramid’ to further cut-extrude material, which will allow us to obtain a 3D truss-like triangle. It is important to note that at the end of the sketches, we set a fillet on all the sketches of 0.25 inches as we know that filleted corners will help distribute the stress/force and decrease our chances of stress failure at the inner sketch corners.

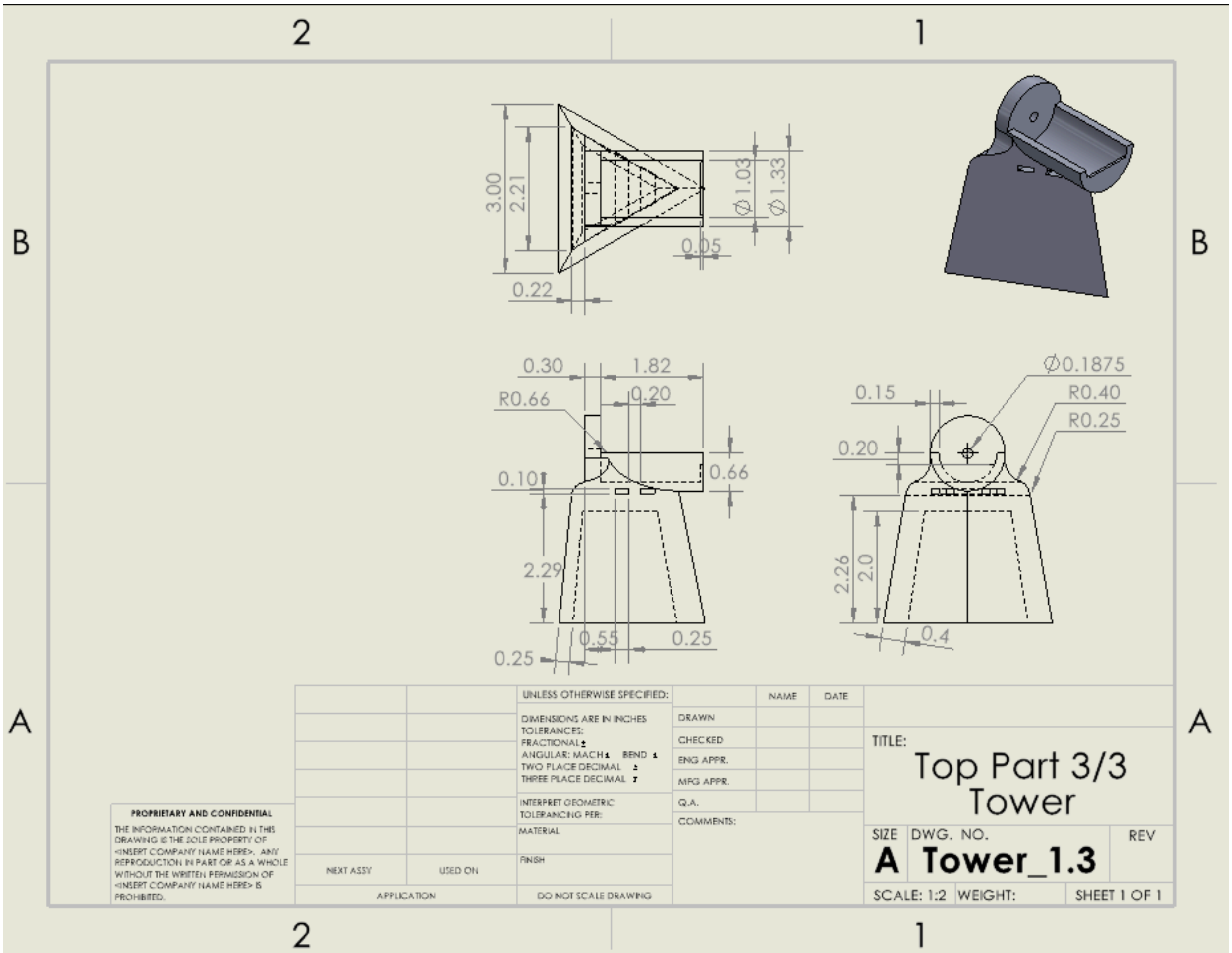
This same procedure of loft-> shell-> cut extrude was used on all three of the tower parts to obtain the basic geometry of the tower. The top part, however, we had to modify to accommodate the motor as well as create a hole for the eye-bolt which would be used for testing. A crucial design decision we made when designing the top part is that we will try to fillet as many of the corners as possible as this will help distribute the force/stress the tower will endure during our testing, increasing its stiffness. In Figures 2.8, 2.9, and 2.10 below we can see the 2D design drawings of the three tower parts



[Figure 2.8] 2D Drawing of the Bottom Part of the Turbine Tower *(Part 1/3)*



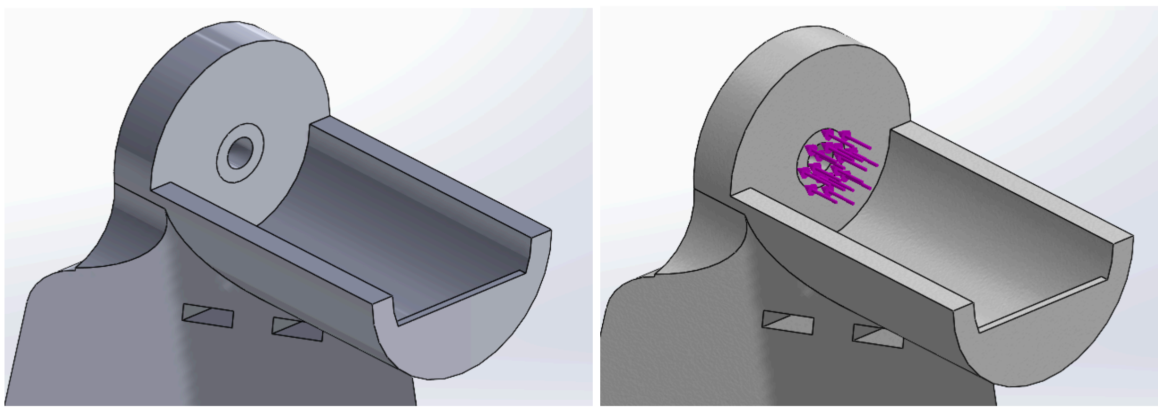
[Figure 2.9] 2D Drawing of the Middle Part of the Turbine Tower *(Part 2/3)*



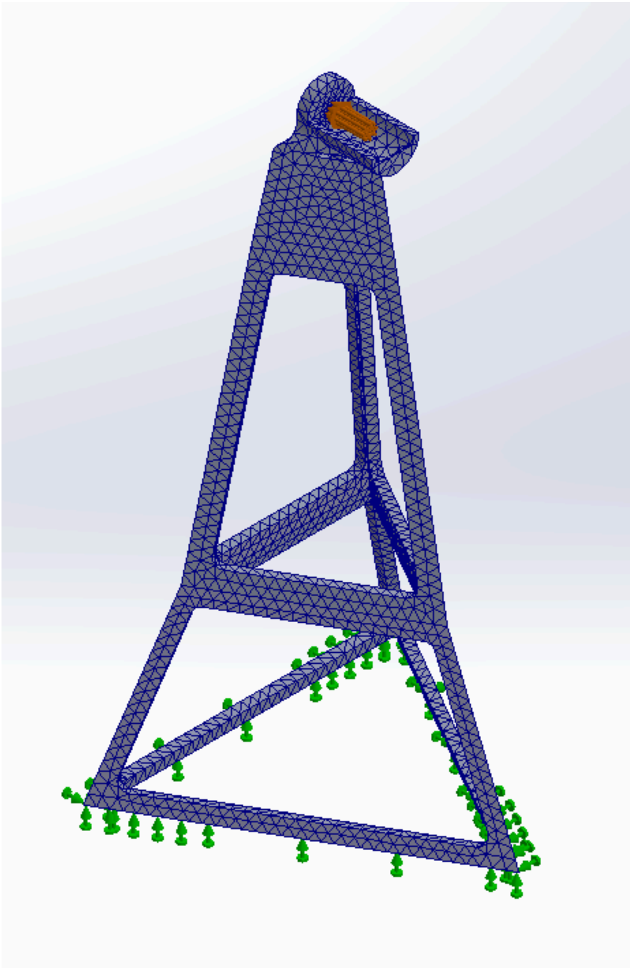
[Figure 2.10] 2D Drawing of the Top Part of the Turbine Tower *(Part 3/3)*

2 - 3 Finite Element Analysis on the Tower

We can run a finite element analysis, FEA, study on our designed tower to get an understanding of the deflection (stiffness) of the wind turbine tower as well as its displacement, stress, and safety factor. To do so, we will simply start a new static FEA study on the tower, define the material to be ABS, and set the bottom face of the tower to be fixed. We can next apply our external load of 9.81N, which is equivalent to hanging 1 kg from the eyebolt to the area of the washer of the eyebolt. I defined this area using a split line (see Figure 2.11), and this would result in a more accurate analysis as, realistically, the force from the weight will be transferred to the eyebolt, which will next be distributed to the area of the washer. We can next create our mesh, which we went with the finest possible mesh so our analysis can be more accurate and run the study (see Figure 2.12).

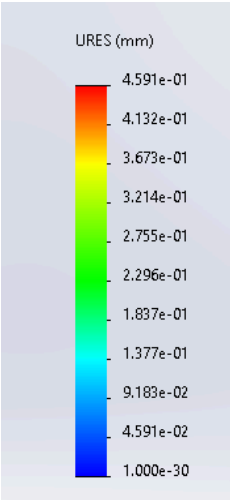


[Figure 2.11] Shows the area where the external force will be applied, the circle represents the washer.



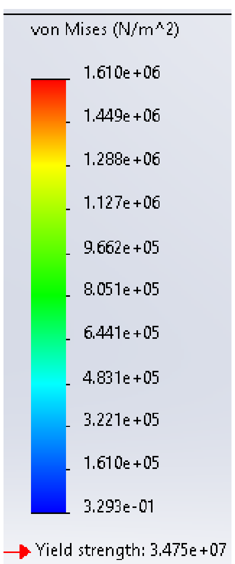
[Figure 2.12] Fully defined static study where our external load/force is applied to the area of the washer and the bottom of the tower is fixed.

Running this study, we obtain the plot of displacement (see Figure 2.13), stress (see Figure 2.14), and safety factor (see Figure 2.15). The plot of displacement in Figure 2.13 allows us to interpret that the tower will experience a maximum displacement of only 0.459 mm. Recall that we applied a force of 9.81N, we can calculate the theoretical stiffness of the tower by dividing by the maximum displacement, 9.81N/0.459mm =21.37N/mm.



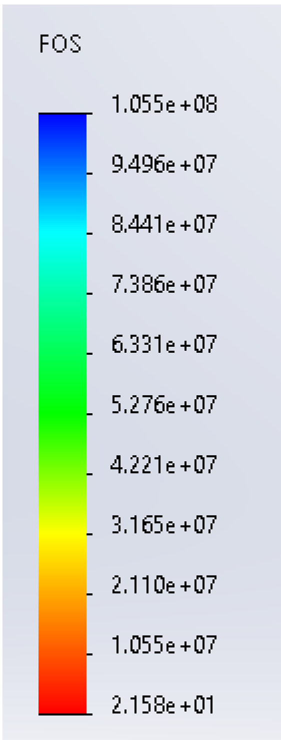
[Figure 2.13] Plot of Displacement

From the plot of stress in Figure 2.14, we can see that the maximum stress the tower will endure is 1.61 *10^6 N/m^2. Since the material property of ABS in solid work does not have a yield strength defined, we can assume to use an average yield strength value of 3.475*10^7 Pa ("Abs Material Properties…" 1). Therefore, using our understanding of solid mechanics, we know that the part will not fail since the maximum stress is less than its yield strength.



[Figure 2.14] Plot of Stress

Lastly, from the Factor of safety plot, we can see that the lowest factor of safety is 2.158. A safety of factor less than 1 indicates failure; therefore, we can conclude the part will indeed not fail as it is greater than 1.



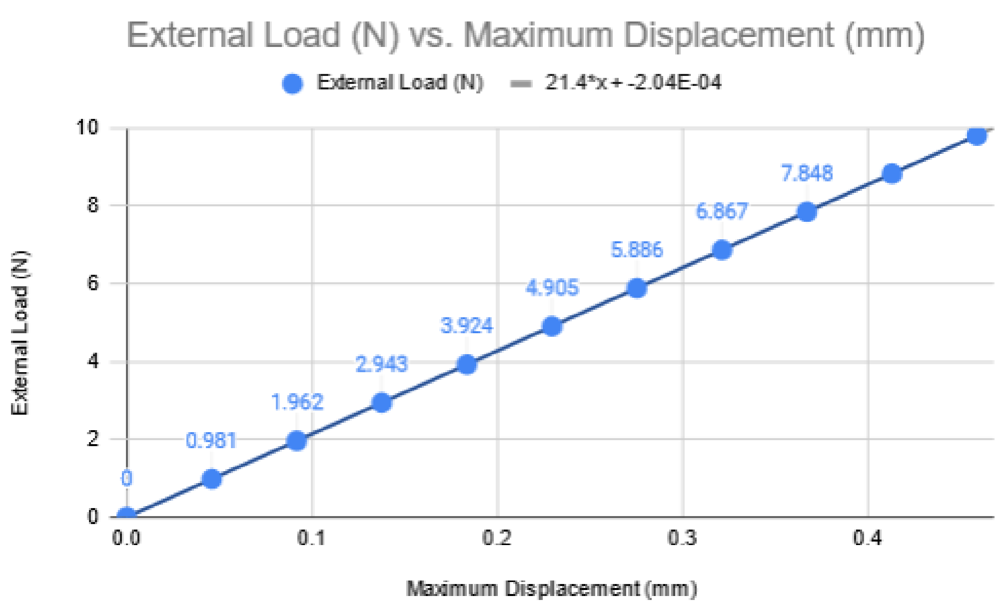
[Figure 2.15] Factor of safety plot

We can also obtain a plot of the load vs. deflection by incrementally increasing the external load set in the FEA from 0-1kg with increments of 100g and noting down the maximum displacement (see Table below).

External Load Mass (g)	External Load Force (N)	Maximum Displacement (mm)
0	0	0
100	0.981	0.04591
200	1.962	0.09183
300	2.943	0.1377

400	3.924	0.1837
500	4.905	0.2296
600	5.886	0.2755
700	6.867	0.3214
800	7.848	0.3673
900	8.829	0.4132
1000	9.81	0.4591

From the table above we can simply input the data into excel to obtain the load vs deflection shown in Figure 2.16. Additionally, we can use our linear best-fit equation where the slope of the line is actually the stiffness of the tower, 21.4 N/mm, which is essentially identical to the value of 21.37N/mm we computed early.



[Figure 2.16] Theoretical Load vs. Deflection Plot

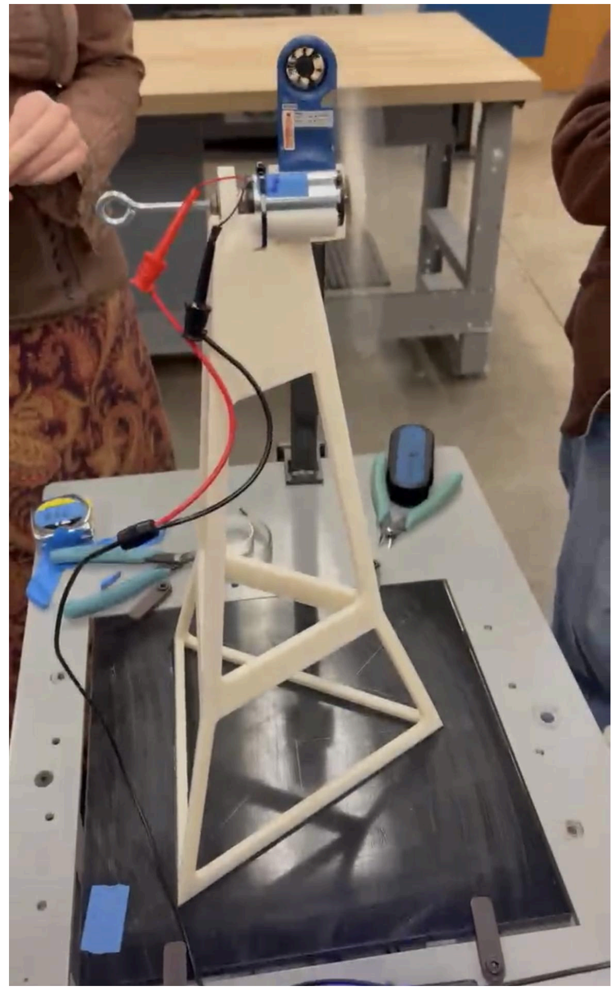
3. Testing Procedure

Once our tower design was assembled, we conducted several tests examining the structure's ability to generate power, blade speed, and deflection using equipment in the lab.

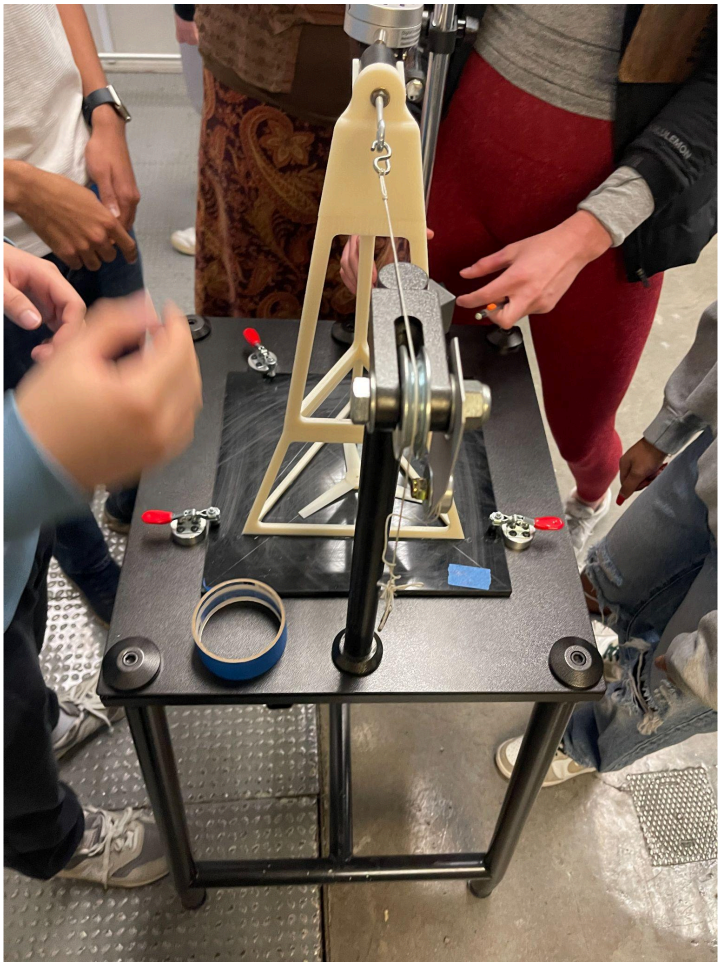
The first test we conducted measured the speed of the blade in response to the fan generating an air current directed at the windmill blade. The tower plate, which clamped to the table and measured generated wind speed from the blade, initially produced a value of 24.5 mph. We then adjusted the distance between the windmill and the fan, bringing the value up to 25 mph.

[Figure 3.1] This image depicts the wind speed test.

After we established the wind speed of 24, we connected the red and black wires to the potentiometer box. This was done in order to measure voltage (in volts), current (in amps), and power (in watts). The box functionally served as a potentiometer, which allowed for variable resistance control. This is possible through the mechanical adjustment mechanism which enables the resistance to be changed manually. This resistance is important because it gives a potential difference between two values, which allows us to see relationships between variables such as current, power, and resistance. In order to measure the speed, we used the digital anemometer and lined up the red laser with the tip of the blade. Once the windmill was in motion, the machine was able to calculate the speed of the blade in rpm.



[Figure 3.2] This image depicts the windmill actively generating power.



[Figure 3.3] This image depicts the test of deflection

The final test we conducted in the lab was deflection. Before the test, we measured that the tower height was 16 inches and its net weight was 251.2 grams, including the blade, excluding the base plate. We then tested deflection by attaching the back of the tower to a hook attached to a pulley system. The front of the tower that housed the motor was in contact with the Digital Dial Indicator that measured deflection in millimeters. We measured load in kilograms and our procedure involved attaching a weight of 100g to the pulley system and measuring the deflection in response to the new weight. We repeated this process of adding an additional 100 g and reading the new deflection until we reached 1 kg. We then adjusted our increment to 1 kg, meaning that for the eleventh data point, we initially had 1 kg and we added 1 kg to measure the deflection with a load of 2 kg. We repeated this new increment until we reached a load of 5 kg, to which our tower had a deflection of 3.17mm.

4. Results

Data Points	Voltage (Volts)	Current (Amps)	Power (Watts)	Blade Speed (rpm)
0	5.08	0.0	0.0	6700
1	4.74	83.5	0.410	6776
2	4.7	109.7	0.5112	6600
3	4.59	135.2	0.6218	6478
4	4.37	162.1	0.7066	6315
5	4.28	189.2	0.8129	6216
6	4.19	219.8	0.8956	6070
7	4.09	284.3	1.078	5984
8	3.9	301.2	1.176	5969
9	3.71	348.2	1.289	5737
10	3.53	399.8	1.428	5524
11	3.84	431.6	1.539	5410
12	3.25	501.5	1.619	5297
13	2.98	604.1	1.823	4999
14	2.67	616.8	1.709	4720
15	2.35	656.1	1.625	4401

[Figure 4.1] Lab Results

We measured our windmill and produced the following 15 data points, with our peak power being 1.823 watts.

Data Points	Load (g)	Deflection (mm)
1	100	0.04
2	200	0.11
3	300	0.18
4	400	0.26
5	500	0.33
6	600	0.41
7	700	0.48
8	800	0.56
9	900	0.63
10	1000	0.69
11	2000	1.43
12	3000	2.09
13	4000	2.69
14	5000	3.17

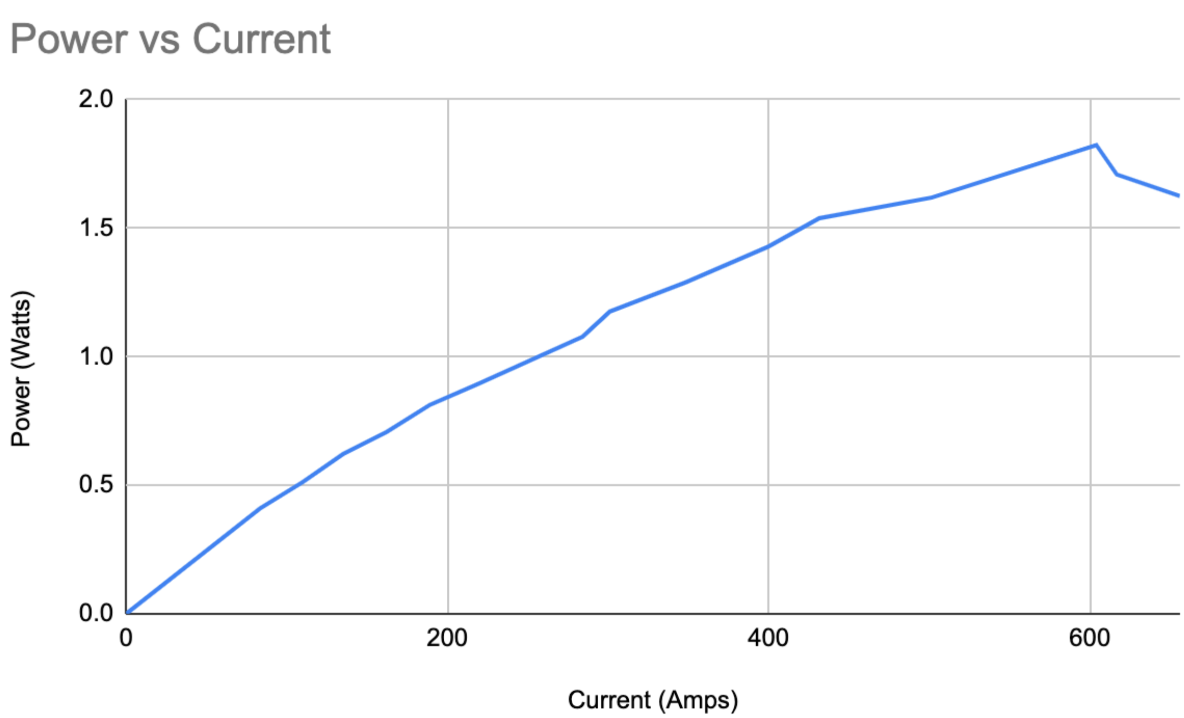
[Figure 4.2] Deflection Measurements

This chart depicts our fourteen data points measuring how the tower reacted to different loads and its corresponding deflection. We were able to gather 14 points of data without the tower breaking. This allows us to calculate the stiffness of our tower:

1kg*9.81m/s^2=9.81 N

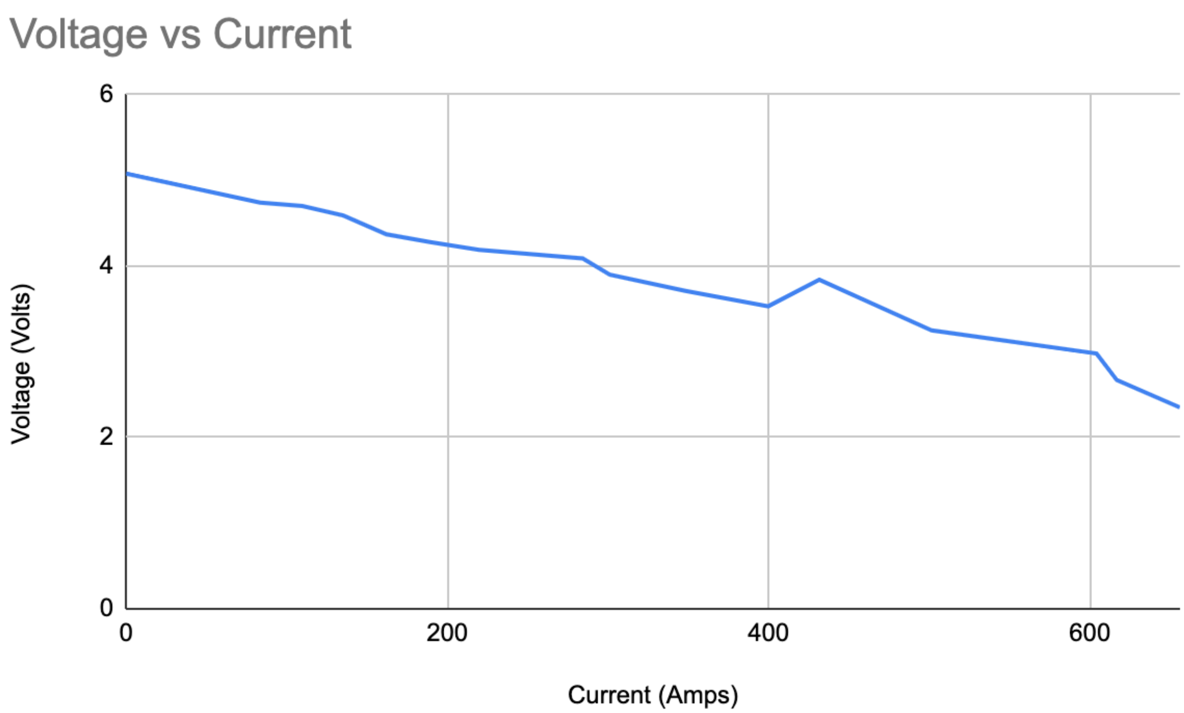
Stiffness (k) = Force/displacement = 9.81N/0.69 mm=14.217 N/mm

Obtaining an actual stiffness of 14.217 N/mm compared to our theoretical stiffness of 21.37N/mm, we can see that there is a 66.5% difference between our theoretical and actual stiffness. This can be a result of having a 70% infill in our printing and/or the ABS material in SolidWorks not having the exact same material properties as what was actually used to print. However, a stiffness of 14.217 N/mm is well above the 8+ N/mm requirement.



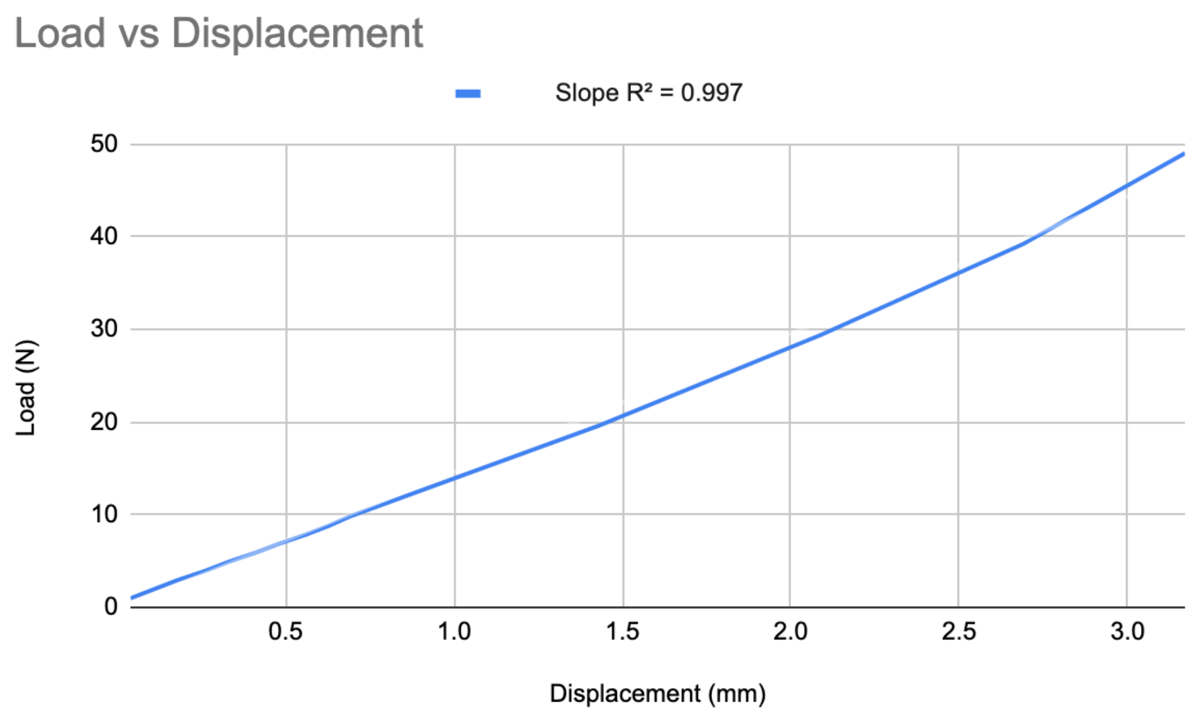
[Figure 4.3] Power vs Current Graph

Based on our lab experiment and data we gathered, power and current appear to have a direct relationship. However, at approximately 600 amps the power generated appears to decrease. This means that the peak power generated by this tower was 1.823 watts.



[Figure 4.4] Voltage vs Current Graph

This graph depicts the relationship between voltage and current in this experiment. We found these two variables to have an indirect relationship, meaning that as voltage decreases, current increases.



[Figure 4.5] Load vs Displacement Graph

This graph shows the relationship between load and displacement in our experiment with windmill design. Our data suggests a direct relationship between load and displacement, so that as load increases, displacement increases. This graph shows that as we increased the weight to one side of the tower, the tower began to deflect. Though this deflection was not initially visible to the naked eye, the Digital Dial Indicator was able to measure the displacement in millimeters.

We then found efficiency, calculated by multiplying theoretical power by experimental power.

P=VI

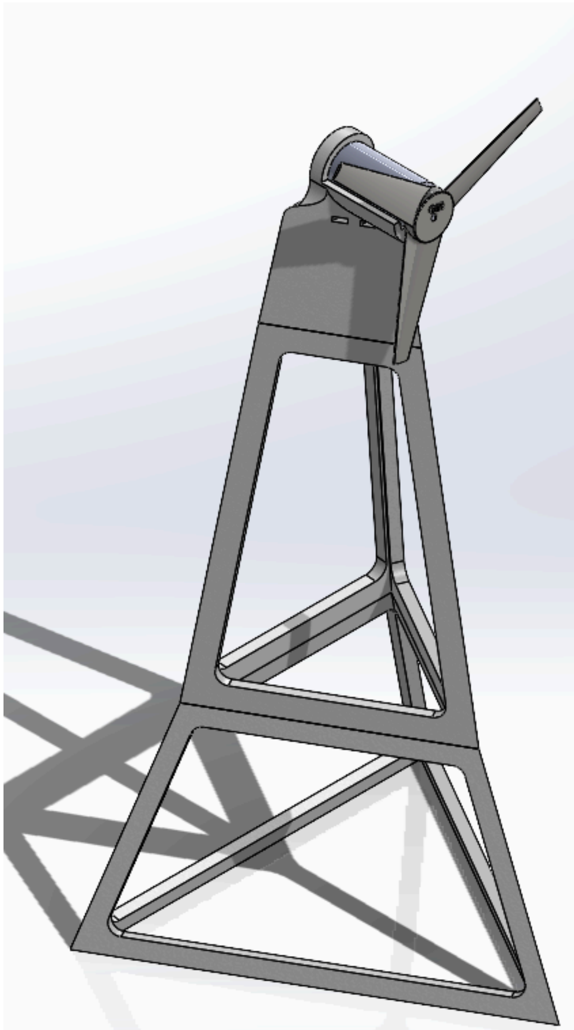
2.98*604.1 = 1800.218 = 1.800218 watts

Our experimental value was 1.823 watts

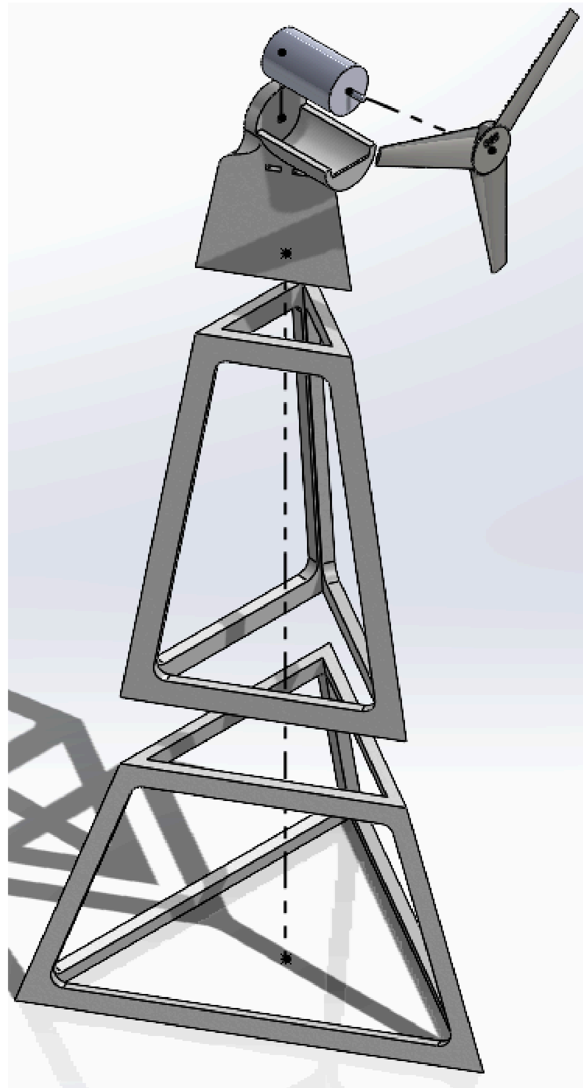
1.800218/1.823 = 0.987503017

Thus, our efficiency was 98.75%

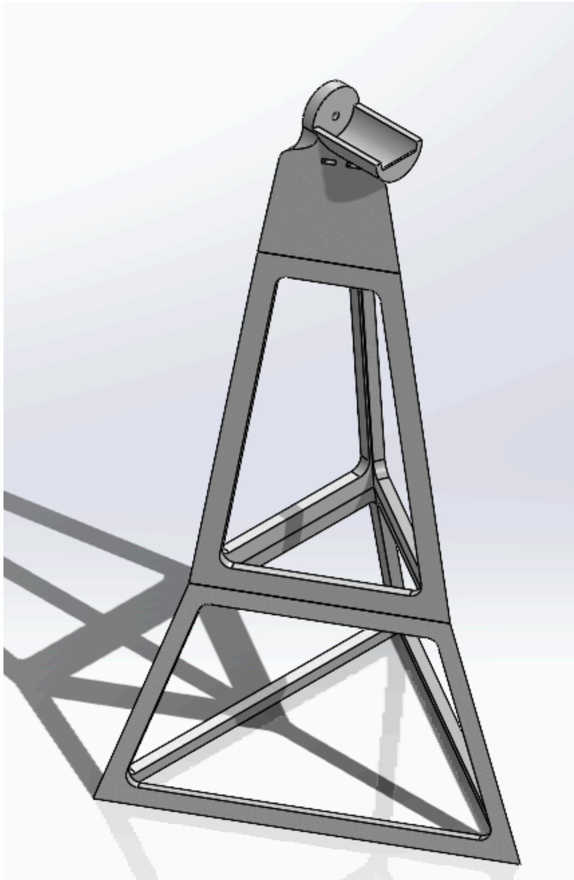
5. CAD Drawings



[Figure 5.1] 3D Assembly of Wind Turbine

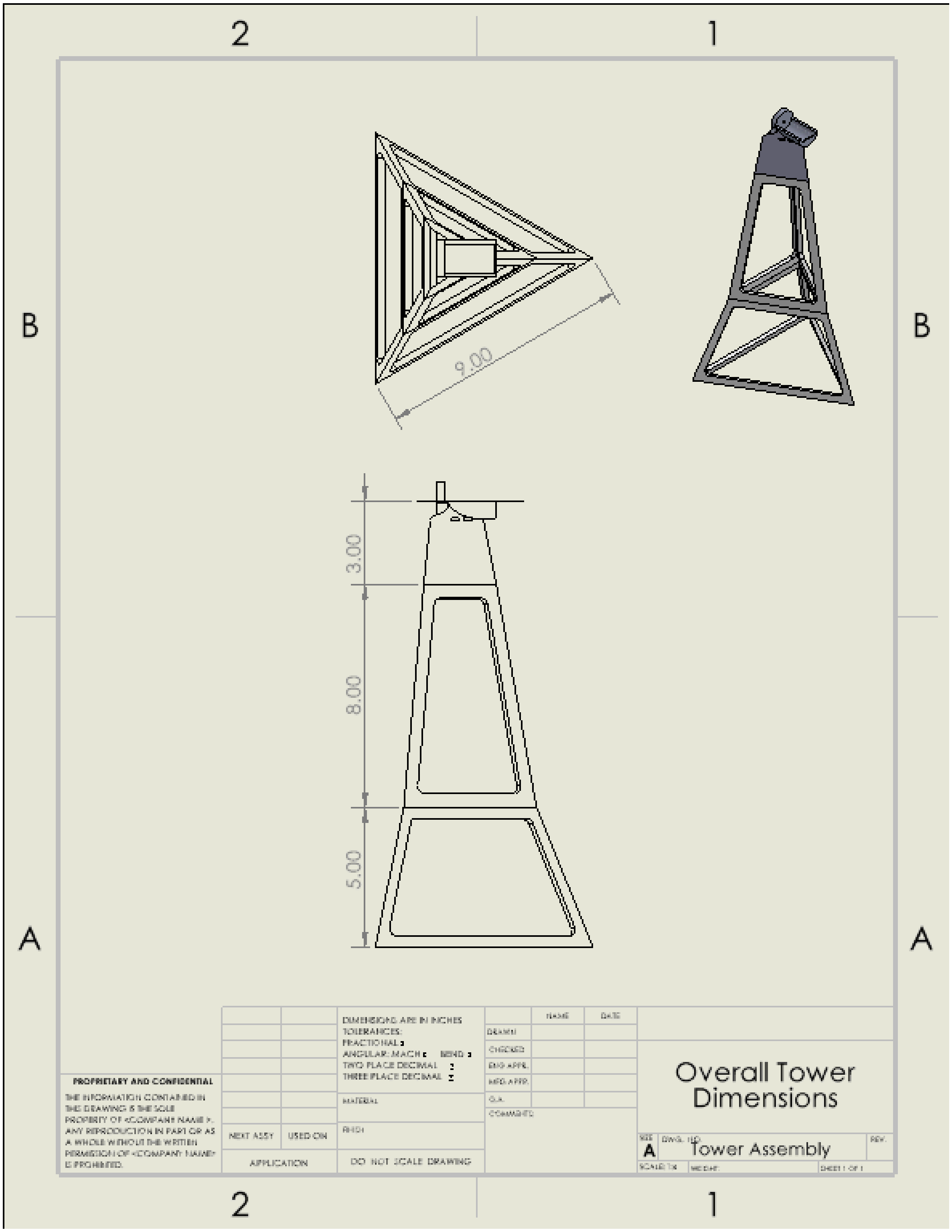


[Figure 5.2] Wind Turbine Exploded View



[Figure 5.3] Isometric View of the Turbine Tower

[Figure 5.4] Isometric View of the Blade



[Figure 5.5] Overall Tower Dimensions *(for individual part drawings, see Figures 2.8, 2.9, and 2.10*

6. Conclusions

We designed our blade profile following a profile of NACA-4418 drawing inspiration from both outside research we conducted and lectures during the project phase. We determined that an angle of attack of 7.5% would produce the most efficient lift-to-drag ratio as we did not want the blade to significantly increase or decrease the lift required for the blade to work. For our angle of twist, we once again consulted outside sources determining a range of 0-20° to be best fit for many industry wind turbines, the NACA-4418 profile we used called for a twist of 11.9% however due to our constraints in blade diameters and predicted variation we concluded on a twist of 15.3%. In the final step of our blade design process, we opted for a three-blade design as it was not only the norm but we also found out that it served as a perfect middle ground between blade stability and energy production. The second part of our design process was the modeling of the tower which was constrained to a 12x12 base plate and expected to carry a load of 1kg. To guarantee that this load would not deflect our tower a significant amount, we utilized a triangular design to equally distribute the load on the three sides, maintaining radial symmetry. To adhere to both height and volume constraints, we utilized both the loft tool to create three separate pieces to later be glued together and the shell tool to make sure that our walls and fillets both had a thickness of 0.25 inches, which we learned would help enhance stress distribution and risk of failure. To make sure our tower would work upon testing we conducted an FEA analysis on the tower constructed out of ABS material to evaluate its stress, deflection, and safety. By subjecting a load of 9.81N (1kg) from our eyebolt we found that our max displacement would be 0.459 mm with a maximum stress of 1.61 10^6 N/m^2, which, being less than the yield strength, ensured that our tower would not fail during the load test. During testing day, we conducted several tests on the wind turbine tower; for our wind speed, we recorded a value of 24.5mph. We also recorded energy output for the wind turbine before plateauing as 1.832 watts which is just slightly under the goal of 2 watts for the project. Finally, we tested the actual displacement of the tower by continuously adding counterweight to one direction of our system and recorded a final deflection of 0.69mm for 1kg and 3.17 mm for 5kg, which resulted in a stiffness of around 14.217 N/mm on par with what was needed for the project. Additionally, we were able to calculate an efficiency of 98.75% using the equation P = VI. Overall, we successfully achieved the objectives, attaining a tower weight of less than 350g, a stiffness exceeding 8N/mm, and a power output of approximately 1.8 watts—demonstrating an impressive level of performance.

7. Recommendations for Future Work

Knowing what we know now, we would have taken several different paths to optimize our blade and tower design fully if we were to redo this project. This includes modeling and printing various blade profiles ourselves with varying parameters (angle of attack, length, number of blades) to determine the best variation of our blade as we based our design on research rather than actual testing. For example, we decided to take the middle value of both the range of attack and twist due to fears that the use of the extreme value would lead to a loss of power because of an increase in lift or issues in stability which may have instead resulted in a better blade profile if we took the time to print them out and test it.

After testing and observing the other groups we would also recommend focusing on a more creative base design rather than its structural integrity as the stress test only needed to withstand a load of 1 kg which could've been achieved with a smaller base area and used our remaining materials on trusses or other features. This would have been changed in our original FEA study where we realized that the 1kg load would only cause a displacement of 0.459 mm and realized we could take some creative liberty on the design without worry of it failing or snapping in half.

Another problem we ran into was the miscalculation of certain parts of our design especially the motor housing where we had to sand down a wall from our original design for the motor to fit in comfortably. Luckily we realized that this extra filament was unneeded as the zip ties gave enough support regardless but the error took up a significant portion of our gluing time. Another miscalculation that we recommend double checking before printing is small details like the placement of your group number as we put it in the opposite direction of the blade, complicating our setup during the day of testing.

Finally, we also recommend designing the wind turbine to be less rigid as due to our large structure the base shook a significant amount before securing it further which if not dealt with may have caused some of our data to be inaccurate or seemingly random.

8. References

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