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Engin 26

LAB WORK #5 - Wind Turbine

General Design: NREL S807 Airfoil

To research blade designs, I turned to a tool I have used in the past, being airfoiltools.com. Using this website, I was able to research the commonly used airfoil designs for wind turbines, where I was able to find the family of NREL (National Renewable Airfoil Lab) of airfoil designs. Using the table from NREL Airfoil Families for HAWTs, I chose the thin airfoil family from the three presented. My reasoning for this was that in our control setting for testing, we would be using a low-wind environment thus creating a weakening air thrust on our blades.

Blade Length (meters)	Generator Size (kW)	Thickness Category	Airfoil Family (root——tip)			
1-5	2-20	thick		S823		S822
5-10	20-150	thin		S804	S801	S803
5-10	20-150	thin	S808	S807	S805A	S806A
5-10	20-150	thick		S821	S819	S820
10-15	150-400	thick	S815	S814	S809	S810
10-15	150-400	thick	S815	S814	S812	S813
15-25	400-1000	thick		S818	S816	S817

Fig 1. Table Showcaring Families of the NREL Airfoils

The next decision involved choosing a **root** or **tip** design so I decided to make a design matrix to come to the best conclusion. According to a forum post on Stack Exchange on airfoil thicknesses (forum post), I was able to understand that root designs are focused on generating higher lift on lower speeds while the tip designs are geared more towards higher stall resistances. This information is also supported by Nasa's Glenn Research Lab (Wing Geometry | Glenn Research Center | NASA) where they review the airfoil families and their differences.

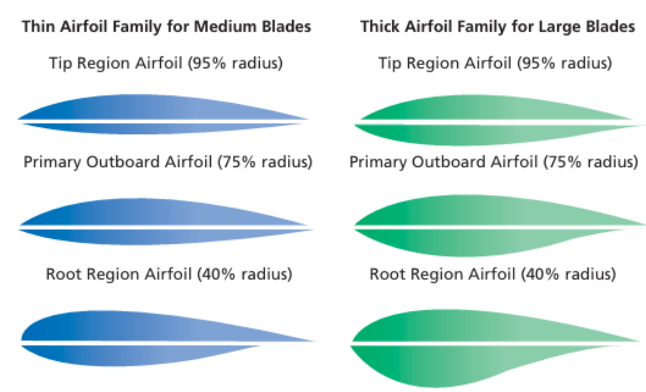

Fig 2. Root vs. Tip Thick and Thin Airfoil Families Diagram

Criteria	Root Airfoil (Thick - NREL Family)	Root Airfoil (Thin – NREL Family)	Tip Airfoil (Thin - NREL Family)	Design Implication
Structural Strength	9	6	3	Thick root airfoils resist bending but are overbuilt for low-load indoor setups.
Aerodynamic Efficiency	5	8	9	Thin airfoils reduce drag and improve lift, ideal for low-speed fan airflow
Manufacturability (3D Print)	8	7	9	Thin profiles print cleanly; NREL designs balance printability with performance.
Fatigue Resistance	9	7	4	Less critical in indoor use, but NREL thin airfoils still offer validated resilience.
Research Validation	5	10	9	NREL thin airfoils have extensive lab and field validation for small-scale turbines.
	46	**55**	**53**	

Fig 3. Decision Matrix for choosing Airfoil Type

Using this decision matrix I made, I concluded by settling on a root airfoil from the thin NREL Family, since it scored higher in the main categories I was concerned with for this project. In my research in this family of airfoils, I settled with the **NREL S807 Airfoil** design.

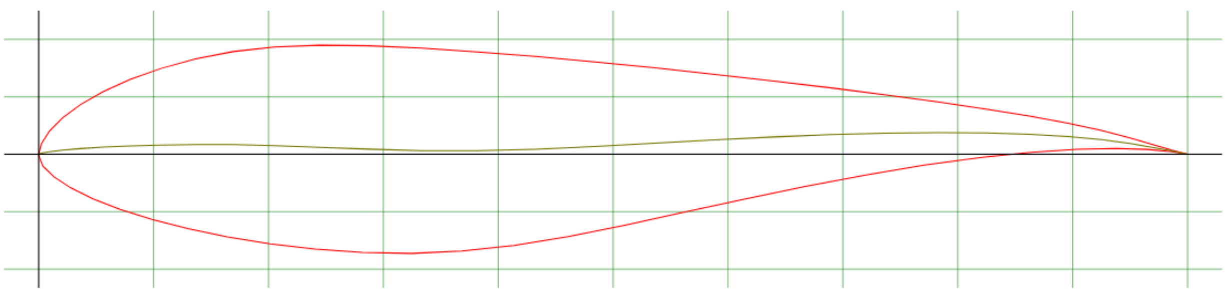

Fig 4. NREL S807 Root Airfoil Design from airfoiltools

According to a research study done by the University of Pacific in Fiji ([SERI - HAWT Airfoil Design Prospects]) explaining how "*The S807 airfoil is commonly used in small- to medium-sized wind turbines. Its design aims to optimize energy capture while minimizing aerodynamic losses."* This makes for justification of the airfoil design being effective if its use cases are solely lower stress environments.

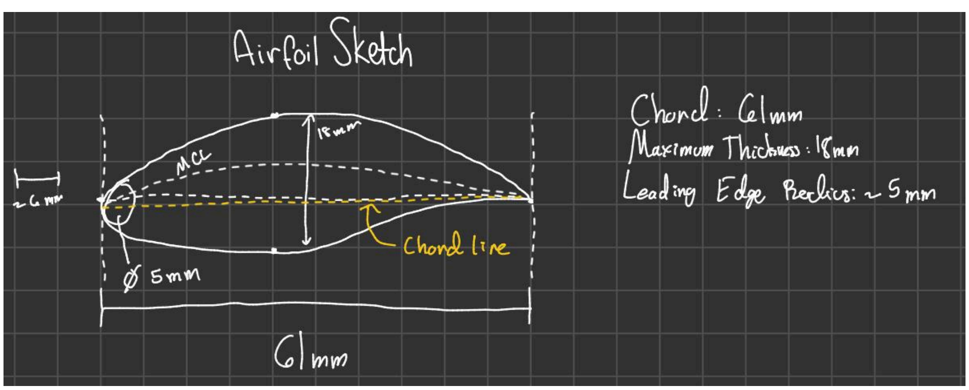

Fig 5. Hand sketch with projected dimensions

Since we would be eventually designing this model, I made a quick sketch in Solidworks to determine some mock dimensions for each blade in the turbine, settling on:

- **Chord Length: 61mm**
- **Maximum Thickness: 18mm**
- **Leading Edge Radius: ~5 mm**

While this is a very arbitrary data set, it will be useful in determining the settings for the creation of the data plot used for Airfoil plotter (s813-nr) to export the .dat file.

Angle of attack: 7.5 Degrees
For determining the angle of attack for the NREL S807 Airfoil Design, I looked towards the lecture with Professor Youseffi, where he told us about how having a higher angle of attack gives a greater lift coefficient, however puts a greater risk on simply stalling. Using this idea, I referenced a graph showcasing the angle of attack (or pitch) to decide on using the mean stall point for both of these graphs, being between 7.5-10 degrees, eventually picking the middle ground at **7.5 degrees**

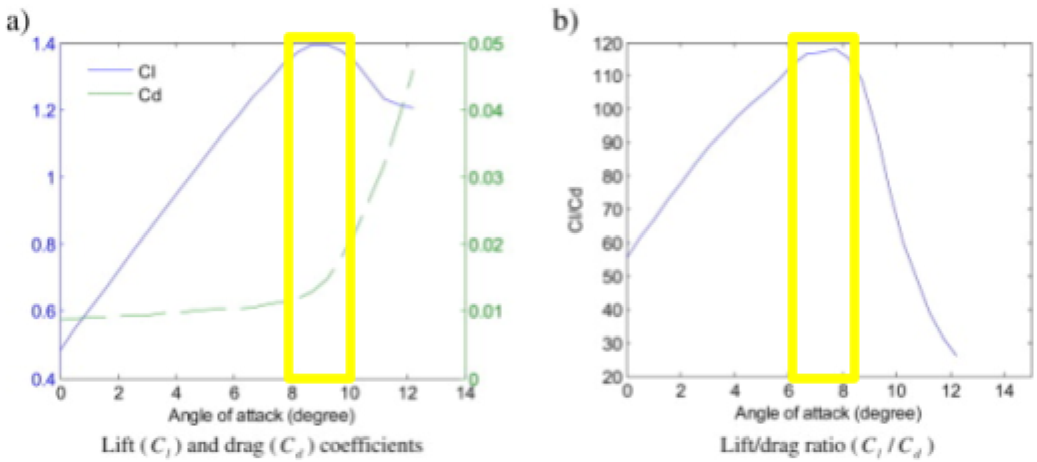

Fig 6. Graph of Lift Coefficient vs, Angle of Attack with Stall point Highlighted

According a study done on the NREL S807 Airfoil (**ANALYSIS OF NREL S807 BLADES AEROFOIL SHAPE UNDER VARYING WIND SPEED**), *"For the curved bladed as the angle of attack is increased lift coefficient of the curved bladed increases and became less influenced by the wind velocity."* Using this data, a greater angle of attack for the S807 will be necessary to ensure a more consistent rotation rather than a higher velocity rotation thus securing a more consistent generation of power compared to inconsistent spikes (evidenced by inconsistent spikes in speed in the study).

Blade profile Twist Angle: 17.5 Degrees
Regarding the angle of twist, it has a proportional relationship to the drag that blades produces. In the article An Iterative Method to Optimize the Twist Angle of a Wind Turbine Rotor Blade on JSTOR, it explains how "The torsional deflection changes the angle of attack of the airfoils and will reduce the aerodynamic performance of the turbine if this deflection is not taken into account in the blade shape design." This essentially means that in order to optimize the angle of attack, the twist angle must remain consistent with the airfoil shape, and according to theory and testing performed in the graph below from Blade airfoil thickness and twist angle along the blade

span for the S807, we can see that the two sections converge at a common angle of **17.5 degrees**, thus making it the best possible option.

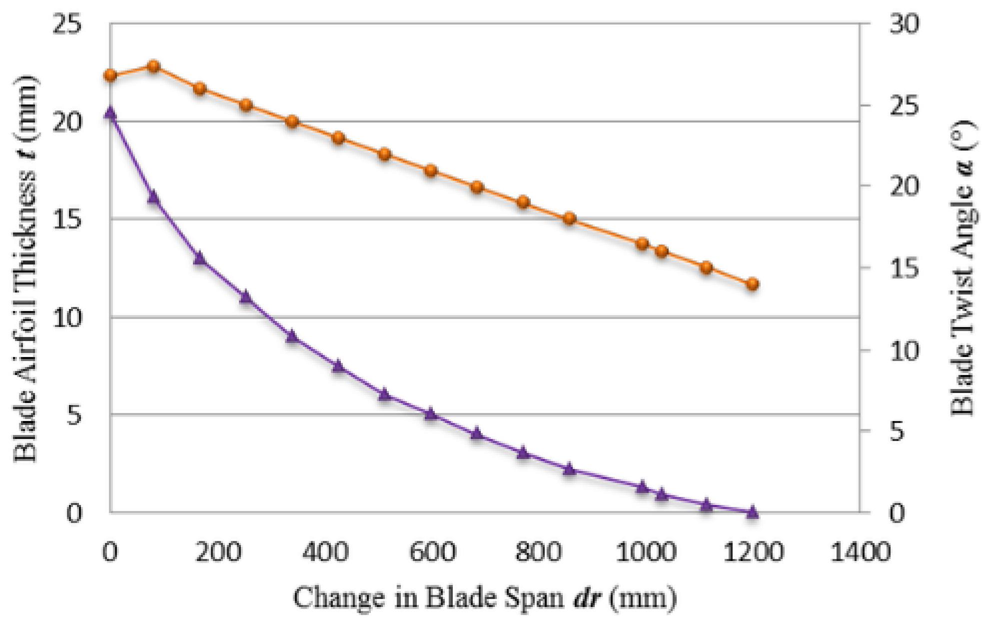

Fig 7. Graph of Blade Airfoil Thickness vs, Blade Twist Angle

# of blades: 3 Blades
In lecture, Professor Youseffi explained how having an even number of blades on the turbine design would be incredibly unstable; Additionally, he also explained how only having one airfoil would prove to be just as inefficient. Because of this, I began searching for justification in using a number of blades like 3, 5, and increasing. When researching I was able to find justification in the same earlier study, (**ANALYSIS OF NREL S807 BLADES AEROFOIL SHAPE UNDER VARYING WIND SPEED**), where it explained in their testing how, "*They have also shown that three bladed HAWT produced higher rotation and speed as compared to the HAWT have two blades."* Thus, not only is having an odd number of blades more stable, it has proven to produce a higher rotation and speed. Overall, I determined that the optimal number of blades to use for our wind turbine design is 3.

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