CWC '19

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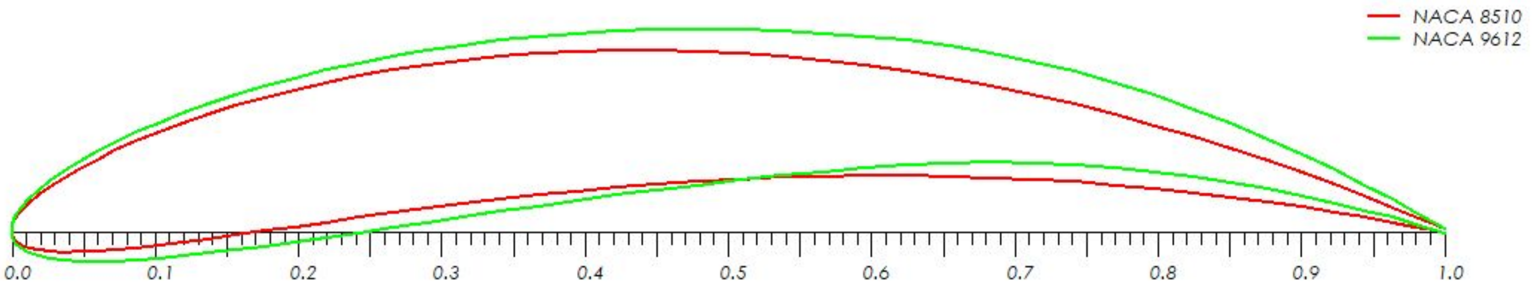
Project Description

- U.S. Department of Energy is the sponsor
- Collegiate Wind Competition
  - Competition held in Boulder, Co. May 13th-14th
  - Fifth team representing NAU at the Competition
  - Collaboration with Electrical Engineers

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

Blade Design Background

- Use wind to produce lift
  - Leads to torque around shaft, spinning the generator
- Low Reynold’s Number operating environment
  - Must use a high camber airfoil to optimize lift
- Multiple airfoils implemented throughout the blade



Blade Design Calculations

- Design to specified variables
  - Tip-Speed Ratio = 5
  - Blade Number = 3
- Ignore losses caused by blade and flow relationship
  - No tip loss
  - No Drag at operating attack angle
- Used MATLAB to calculate blade shape characteristics
  - Relative Wind Angle
  - Chord length
  - Twist angle

Blade Design Results

- Operating Reynold’s numbers:
  - Start-up: 3,443
  - Operating: 63,396
- Q-Blade
  - Output of 30W predicted at rated wind speed
  - 25W expected
  - Start-up speed unpredictable in Q-Blade

Blade CAD

- NACA 8510 on in-board
- NACA 9612 on out-board

- Future work will investigate the performance of Selig Series airfoils for future iterations

Shaft Design Background

- Design consideration

  - Weight and size

  - Type of material

  - Safety and protection

Shaft design Calculations

- Material Used for testing

Carbon steel, alloy steel, Stainless steel

$$d = \left(\frac{32 \times n_s}{\pi \times S_y} \times \sqrt{M^2 + \frac{3}{4} T^2} \right)^{1/3}$$

- Design torque = 3.8877N.m
- Bending moment = 0.4905N.m
- Three lengths were used

$$d = \left(\frac{32 \times n_s}{\pi \times S_y} \times \sqrt{M^2 + T^2} \right)^{1/3}$$

L=10 cm , L=15 cm and L=20 cm

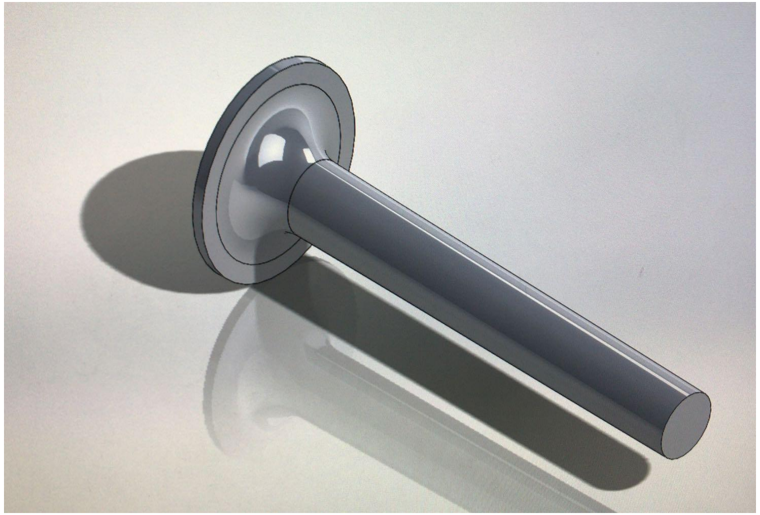
Shaft design Results

•Every material is analyzed using three different lengths and corresponding diameter are calculated using distortion energy theorem and maximum shear stress theory.

Length of shaft(cm)	Diameter of shaft(mm)
10	12.45352
15	12.49376
20	12.54903

Shaft CAD

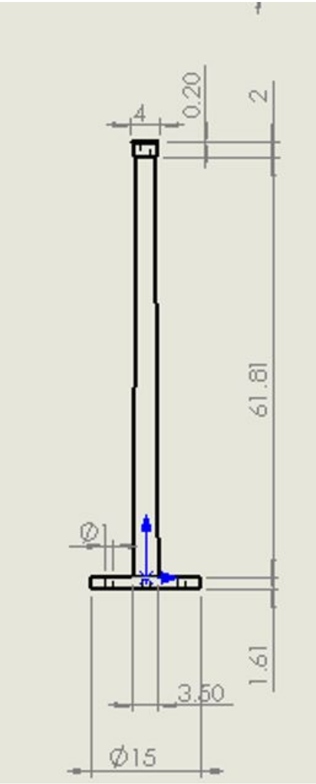
- Make Cad model using SolidWorks.



Tower Design Assumption

- The wind velocity is constant through the tower
- Selected material that isotopic and incompressible
- Material should be linear, homogenous and elastic

Tower background and analysis



- Von mises stress for the plane

$$\sigma' = \sqrt{\left(\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2\right)}$$

- Normal strain

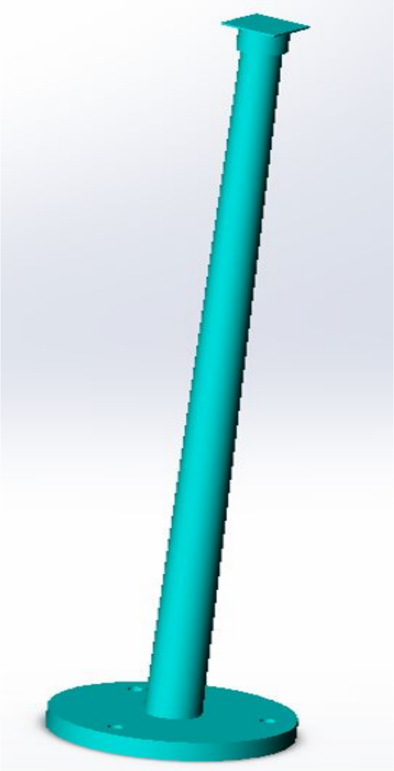
$$\epsilon = \frac{l - l_o}{l_o}$$

Tower background and procedure

- Create base plate with 15 cm
- Bolt M10 *1.5 size
- Thickness of the plate 1.61 cm
- The length of the pipe defined as 61.91 cm include base plate and top plate
- Stainless steel defined in SolidWorks
  - AISI-316

Tower Cad Model

- Mesh Generation design
- Boundary conditions
- Von Mises stress result 5.314e+005 N/m^2
- Deplacement analysis result 2.794e-003 mm
- Strain analysis result 2.331e-006
- FOS analysis
    - 3.2e+002 and maximum was achieved by 1.00e+016.



Yaw Design Background

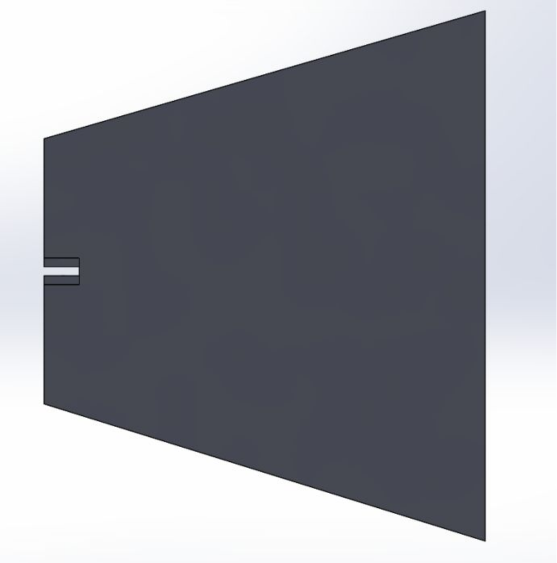
- Yaw system is a crucial aspect in a wind turbine

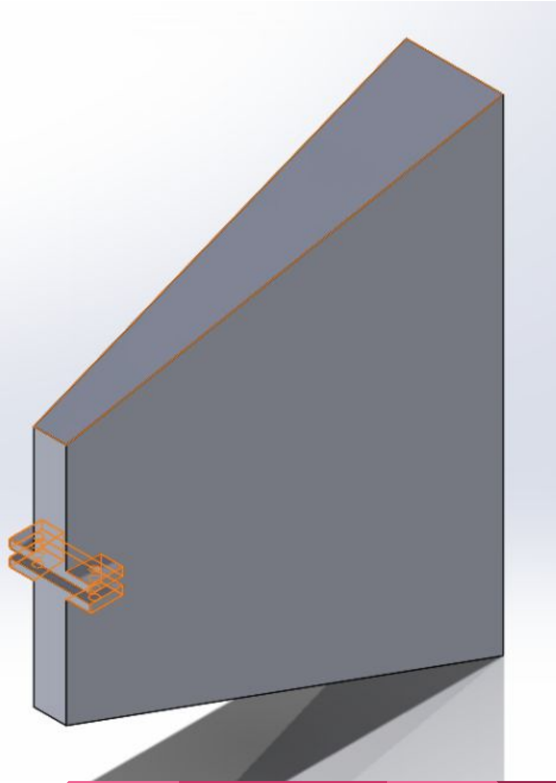
- The rotor is yawed it is less efficient compared to the non-yawed rotor

- The overall efficiency of the wind turbines is mainly influenced by a variety of factors such as wind shear, wind turbulence and yaw

Yaw Governing Equations

- r=X+2c/3 = 3.3 mm
- $M = k_N J \Omega \omega$





Brake Design Background / Calculations

- Provide sufficient force to rotor to stop the shaft from rotating
- Calculations done for Linear Actuator and Stepper Motor
- Clamping Force
  - **D** - diameter, **P** - operating pressure/force

$$CF = \frac{\pi D^2 P}{4}$$

- Brake Torque
  - r_e - equivalent radius, μ_d - friction coefficient

$$BT = \frac{r_e}{2} \times (2\mu_d CF)$$

Brake Design Calculations / Results

Assumptions:

- Brake rotor material is steel
- Brake pad material is rigid molded asbestos

Friction Coef.	Rotor Diameter (mm)	Linear Actuator Force (N)	Stepper Motor Force (N)
0.36	70	18	5.5

Results:

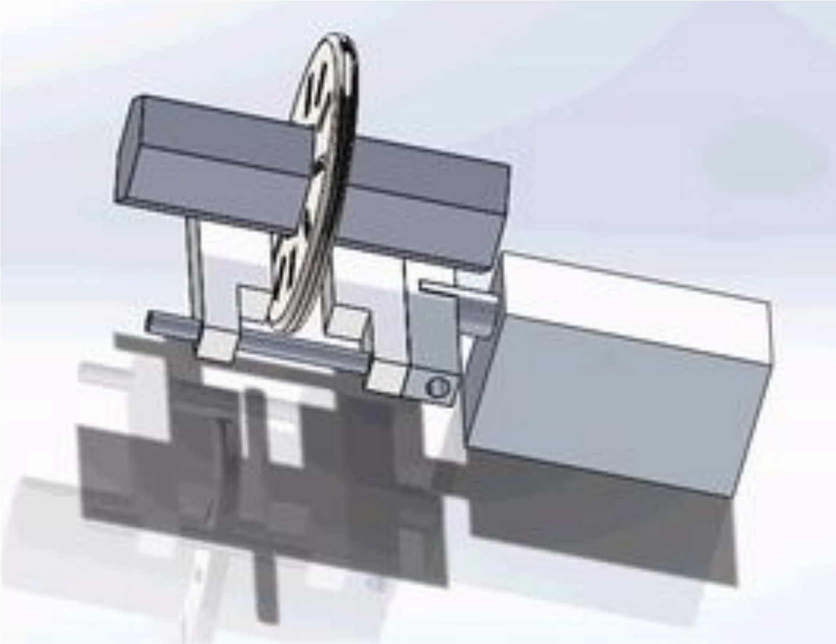
	Clamping Force (N)	Braking Torque (Nm)
Linear Actuator	153.94	3.33
Stepper Motor	47.04	1.02

Brake Design CAD

- Linear actuator can apply more force

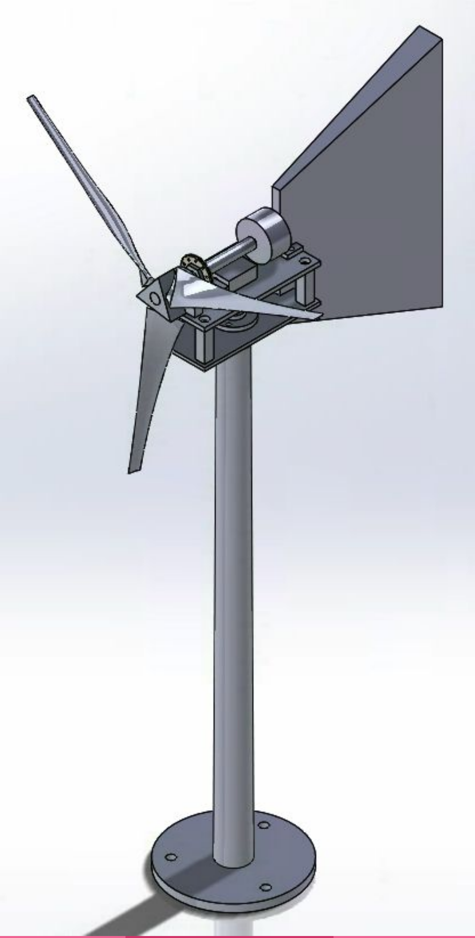
Future:

- Testing will be done to compare linear actuator and stepper motors



Design / Customer Requirements

- Blades
  - Cut-in speed must be between 2.5 and 5 m/s
- Shaft
  - Withstand constant spinning from rotors
- Tower
  - Less than 15 cm in diameter
- Yaw
  - Must be able to yaw 180º/sec
- Brakes
  - Must be able to stop at cut-out speed and for random tests



Budget

- Available budget anticipated:
  - $500.00
- Actual Expenses To Date:
  - $ 127.88

- Current budget does not include electronics cost

Table_ : Project budget sheet

	Budget		
	Part	Cost	
Bought:	Blade 2B4:C630s Blade Swashplate	$	10.88
	4x8x3mm Rubber Shielded Ball Bearings	$	10.88
	EL-Kit-003 UNO Project Super Starter Kit	$	38.12
	Carbonx Fiber Reinforced Nylon	$	68.00
Future Costs:	2' of 1" OD 4130 Chromoly Steel	$	18.29
	2' of 1" Aluminum Square Tubing	$	4.67
	8" x 8" (0.5" thick) 6061-T6 Aluminum Plate	$	24.93
	.125" 4130 Steel Sheet (12"x12")	$	31.67
	(12"x24") 6061-T6 Aluminum Sheet	$	26.40
	SunnySky X4108S-17 KV380 Motor	$	33.98
	Z9504B 3/4" Bearing	$	7.77
	PLA Filament	$	42.00
	Linear Actuator	$	65.00
	1/4" 6061-T6 aluminum round	$	3.64
	Pillow Block Bearing	$	16.50
	Anemometer	$	44.95
	Assortment of nuts and bolts	$	35.00
	Travel and Competition costs	N/A	
Travel and Costs:	Total:	$	482.68

Schedule

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE	PERIO 1 2
Website Setup	11	3	24	3	100%	
Website Update(s)	15	70	24		100%	
House of Quality	15	4	16	2	100%	
Benchmarking	10	5	15	2	100%	
Research Design(s)	10	10	16	10	100%	
Concept Generation	20	6	25	10	100%	
Ind. Analytical Report	42	30	42		100%	
Designing	26	20			15%	
Blade Design	24	12			10%	
Brake Design	28	10			10%	
Yaw Design	35	8			10%	
Nacelle	28	8			5%	
Tower/Baseplate	30	5			10%	
EE systems collaboration	40	5			0%	
EE systems incorporation	45	5			0%	
Solidworks Modeling	46	12			100%	
Blade Modeling	32	40			100%	
Yaw Modeling	40	5			100%	
Nacelle Modeling	35	10			100%	
Tower/Baseplate Modeling	37	5			100%	
3D printing for prototype	50	10			10%	
Preliminary Report	5	40	8		100%	
Final Report	45	5			0%	

- We are on time!

Future Work

- EE team collaboration
- Begin building over Winter Break
- Begin testing in mid-February
- Upcoming assignments
  - Final Proposal Rewrite and Individual Post Mortem due 1/14
  - Website Check 1 due 1/28
  - HR1 summary and Peer Eval 1 due 2/18

Questions?