2024 Northern Arizona University Collegiate Wind Competition Turbine Design

Midyear Report

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The NAU CWC24 design team is designing a three-blade turbine with both pitching and braking systems and has successfully created numerous functional prototypes of integral HAWT components. All prototypes have utilized some form of collaboration among group members where strong communication and organization have defined the foundation for current successes. Thus far, prototyping efforts have been split among team members by interest and iterative technique: blade development, pitching systems, brakes, and nacelle configuration.

Several basic stress analyses on the tower and anchor subsystems have been completed and the team are looking to start testing a suction caisson anchor, but it has yet to be prototyped. All current CAD models for the tower and anchor demonstrate dimensions with strict adherence to the CWC Rules and Guidelines, where a profound factor of safety is also achieved.

Analytical prototyping of the blades has shown that a realistic blade can be configured within software such as QBlade, conceptually checked with numerical methods within MATLAB, then transferred to CAD software for solid part creation. After 4 analytical airfoil and physical blade iterations, present design parameters are decided at a tip speed ratio of $\lambda = 5$, an airfoil designed for low Reynold's numbers, ~4000, and proper dimensioning specifications per the rules and guidelines.

The team has found the most prototyping success in the pitching system. Current design goals reflect a configuration with 110-degree rotation. Three iterations have resulted in a pitching angle of 90-degrees. Further analysis with MotionGen 2D informs future adjustments. Alternate shaft geometries, like a triple D shaft profile, are also being considered within the pitching system to minimize oscillation as the swash plate translates along the shaft. Ideally, stabilization steps such as this will dampen output noise caused by mechanical fluctuations and decrease mechanical complexity moving forward.

The mainframe has gone through two iterations, the biggest changes being the overall size was reduced, the mounting position of the brake system's linear actuator was changed from the roof to the floor of the mainframe, and the latest iteration is more modular and can be assembled with screws, whereas the first iteration was all one solid piece.

The team has chosen a rotor-disc brake for this application. The first version of the braking system utilized a pulling motion to compress the disc between two brake pads. Its prototype demonstrated to the team the geometric complexity of such a design and potential points of failure due to shear stresses. After several iterations, it was determined that a basic push-brake controlled with a 50 N linear actuator is the most space conscious and stable method. The current model also includes a brake pad with a 0.47 coefficient of friction, and a 7.5 cm aluminum disc. Factor of safety sits at about 4 overcoming a max rotor torque of 1 N*m.

For the electrical system, a MATLAB/Simulink simulation of the AC-to-DC rectifier, the DC-to-DC converter, and resistive load has been made. The DC-to-DC converter will boost the voltage by a 1.7 ratio. A generator with a 200KV rating has been selected and code has been written for the pitch/brakes.

Static brake testing informs the team exactly what static forces might be found between the braking system components. Validating key calculations such as torque is hugely important in the early stages of design, with most of its consideration to a safe design as the brake must completely halt the rotor when actuated. Other results from static testing will inform linear actuator selection and mounting methods. Some dynamic brake testing using a dynamometer and a Prony brake has been completed to ascertain necessary motor characteristics like the power and torque that the motor is generating on a shaft when a braking force is applied to it.