Oscillating Wing Unit (OWU) for Power Generation – *Analysis & System Development*

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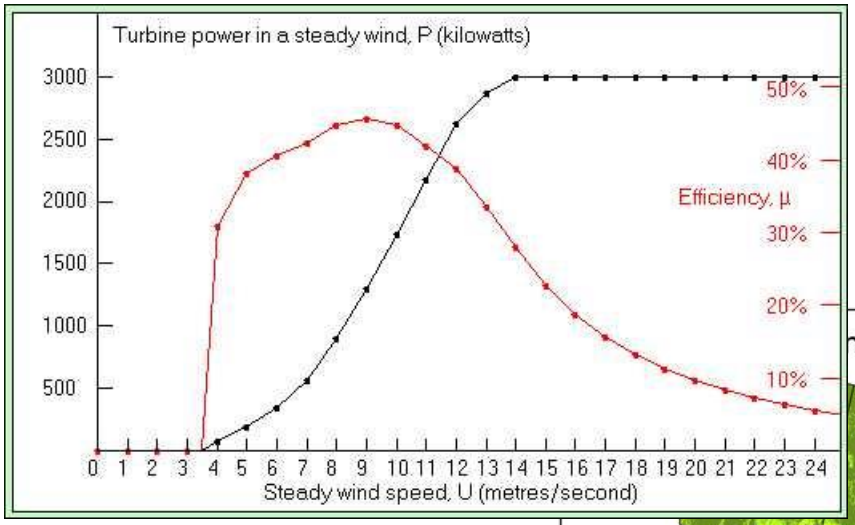
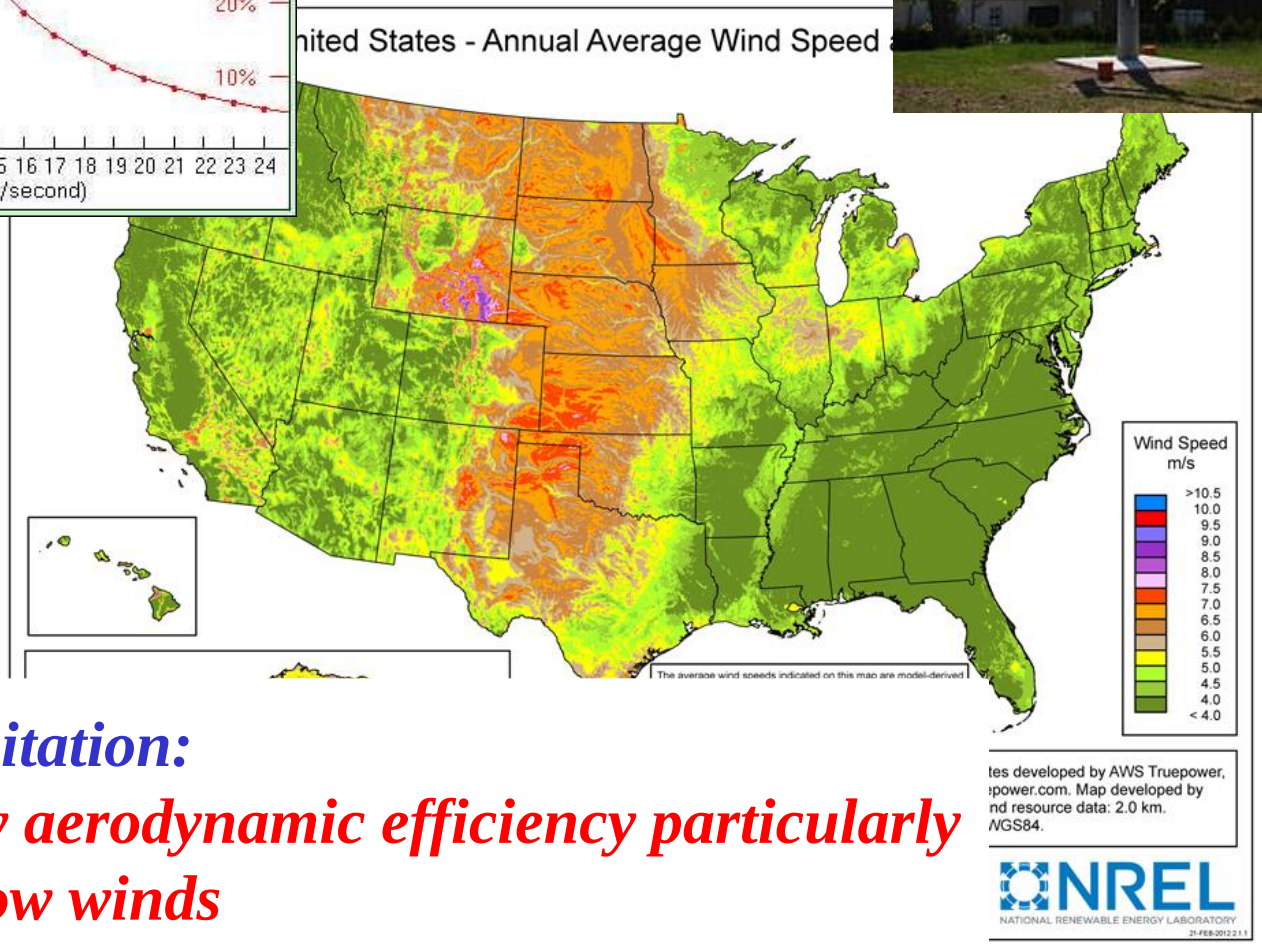
Current Wind Turbines





Limitation:

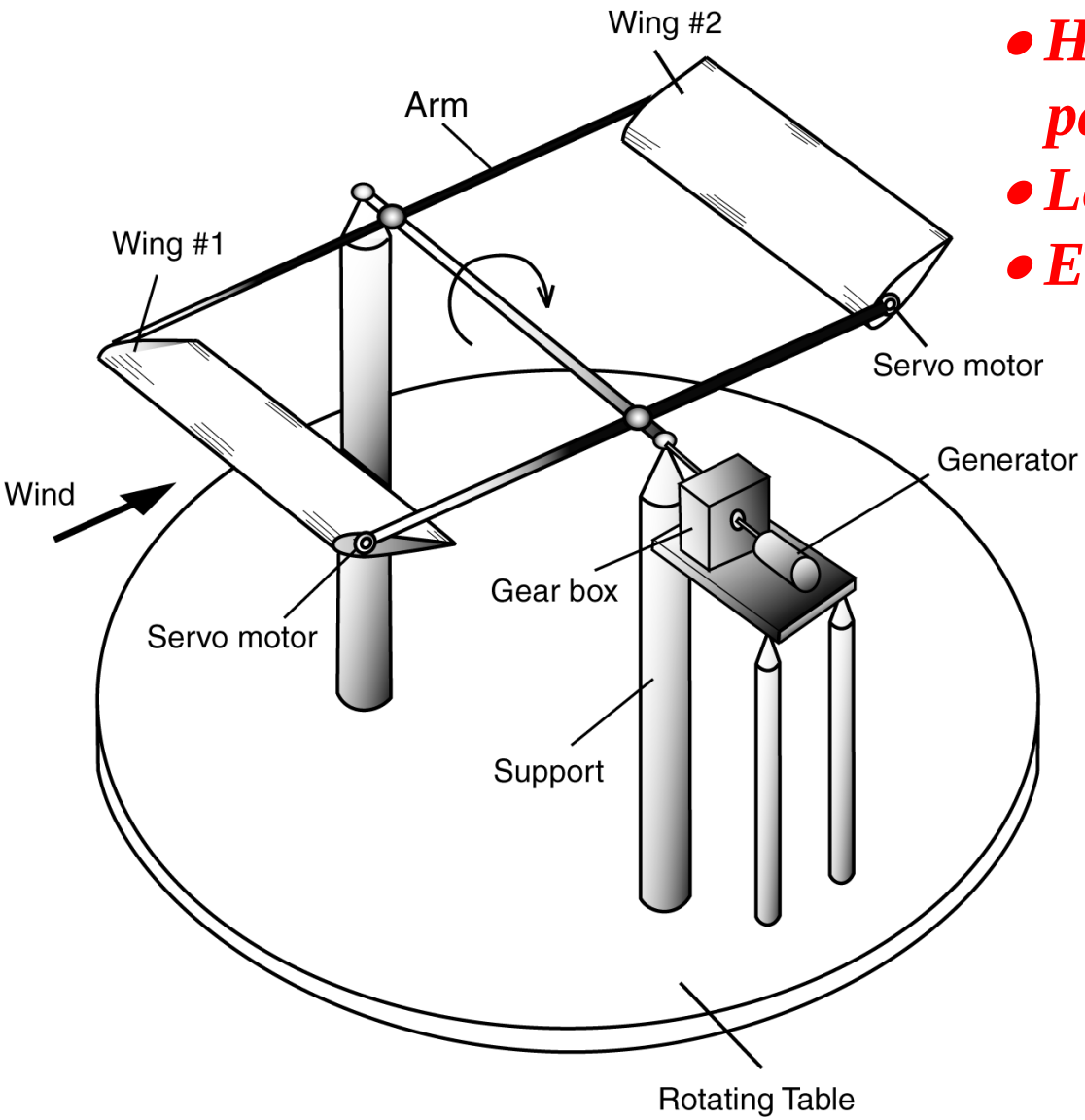
Low aerodynamic efficiency particularly at low winds

Objective

To develop a new wind power converter

- ***High aerodynamic efficiency particularly at low winds (< 5 m/s);***
- ***Simple structures for easy manufacturing;***
- ***Low setting-up and maintenance cost.***

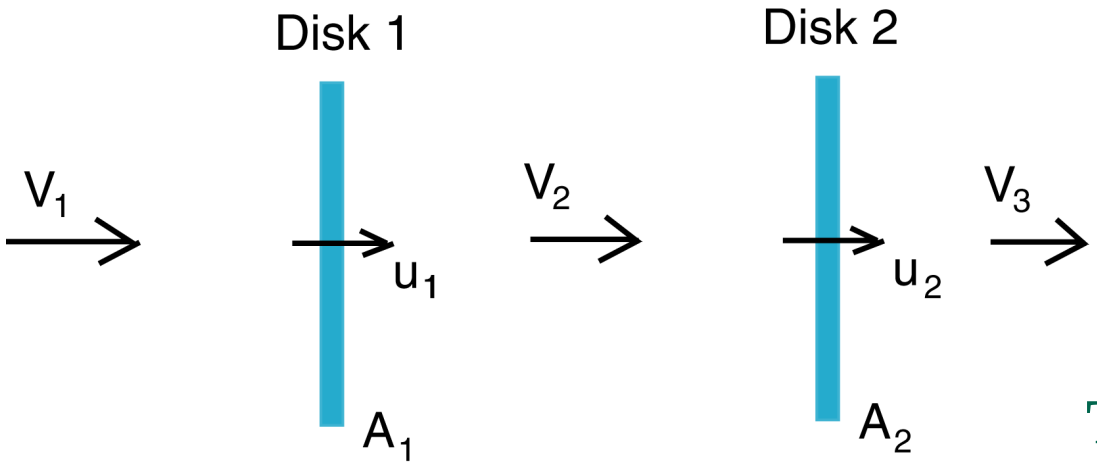
Conceptual Design of Oscillating Wing Unit



Advantages

- *High aerodynamic efficiency particularly at low winds*
- *Less-constrained structures*
- *Easy maintenance*

Actuator Disk Model for the OWU



Total Disk Area:

$$A_{act} = A_1 + A_2$$

The power coefficient:

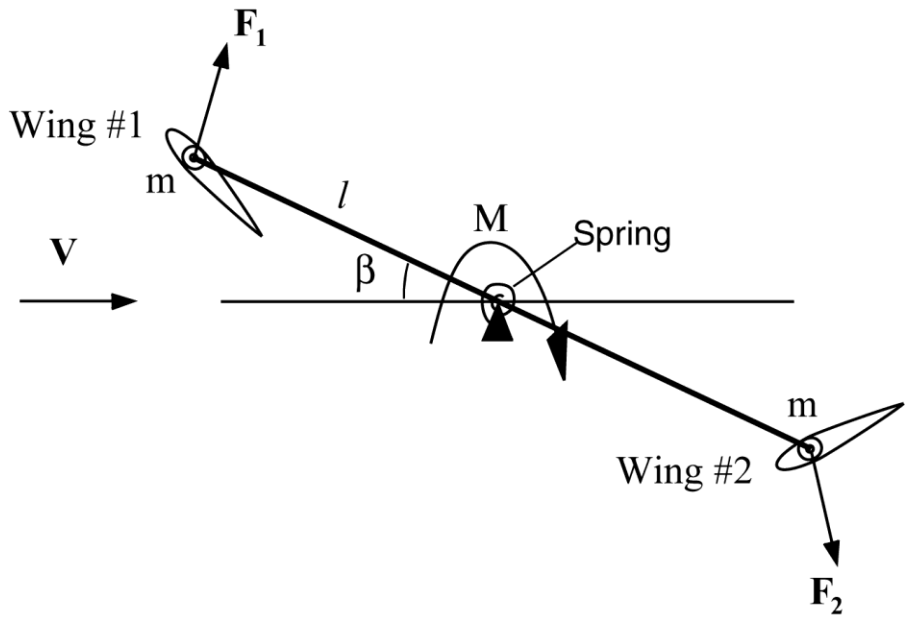
$$C_p = \frac{P}{(1/2)\rho V_\infty^3 A_{act}}$$

$$= 4a_1(1-a_1)^2(A_1/A_{act}) + 4(1-2a_1)^3 a_2(1-a_2)^2(A_2/A_{act})$$

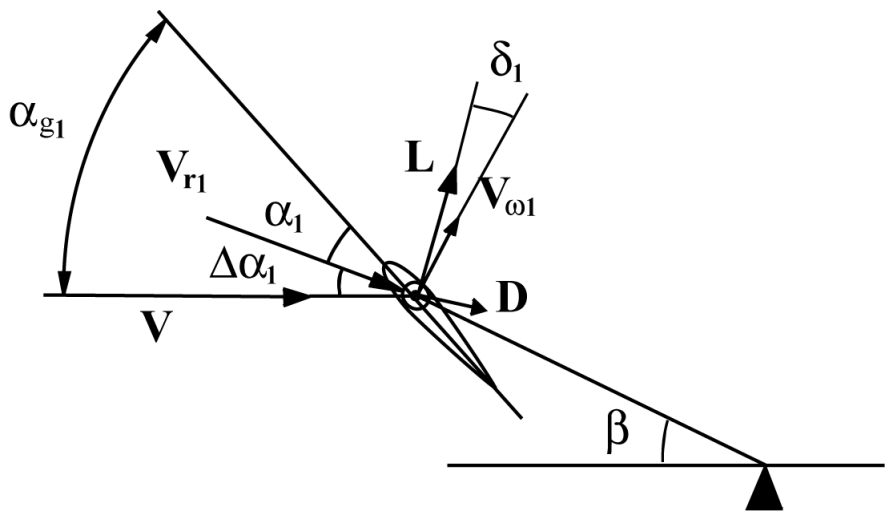
a_1 a_2 **: the axial interference parameters of Disks 1 & 2**

Dynamical Model

The aerodynamic forces in a simplified mechanical model



Velocity and aerodynamic force vectors on the wing #1



Motion Equation

$$\frac{d^2\beta}{dt^2} = \frac{1}{2\tau_1^2}\left(C_{L1}\,\gamma_1 \cos\delta_1 - C_{L2}\,\gamma_2 \cos\delta_2\right)$$
$$+\frac{1}{2\tau_1^2}\left(C_{D1}\,\gamma_1 \sin\delta_1 - C_{D2}\,\gamma_2 \sin\delta_2\right) - \frac{1}{2\tau_2^2}\beta - T_{load}^*$$

The lift and drag coefficients are calculated based on The lifting-line model by considering the local effective wind velocity of the moving wings.

The power:

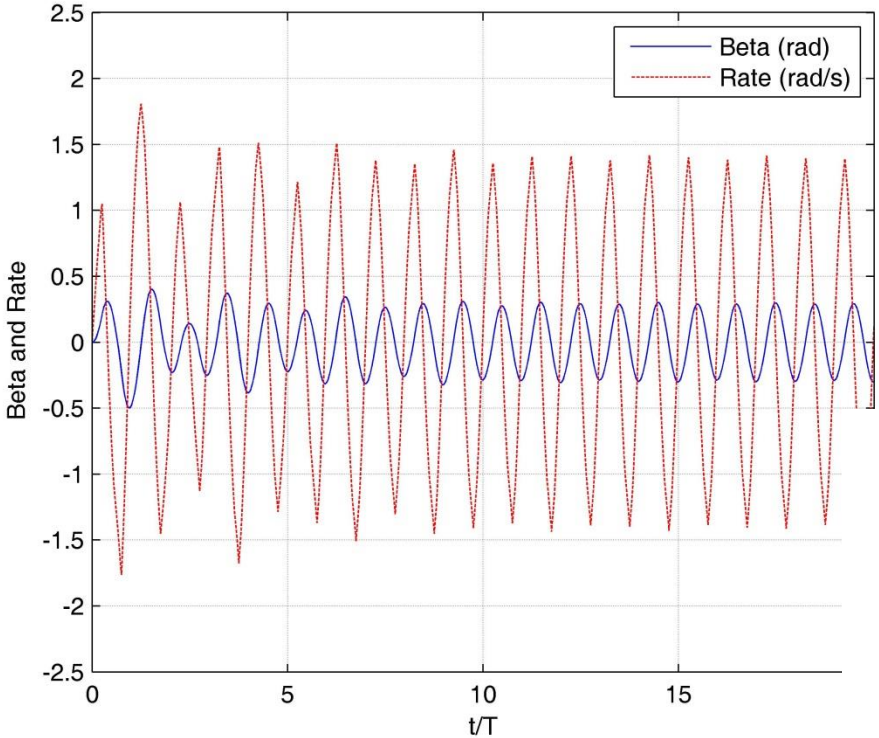
$$P(t) = 4\pi f\, l q S_w \eta_{mech} \gamma_1 \left| C_{L1} \cos\delta_1 + C_{D1} \sin\delta_1 \right|$$

Conceptual Design of Medium-Size Oscillator

Table 1. Design Parameters for a Wind Oscillator

Components	Design Values
Single wing mass (kg)	100
Arm length (m)	8
Single wing area (m^2)	40
Wing aspect ratio	12
τ	0.2
Oswald efficiency	0.8
Zero-lift AoA (degrees)	0
Stall AoA (degrees)	12
Zero-lift drag coefficient for the wing #1	0.05
Zero-lift drag coefficient for the wing #2	0.05
Air density (kg/m^3)	1.21
Spring constant 1 (N-s)	30000
Spring Constant 2 (N-s)	200000
l_s (m)	0.5
CL at stall AoA	1.5
CD at stall AoA	0.2
Amplitude of AoA control (degrees)	12
η_{trans}	0.8

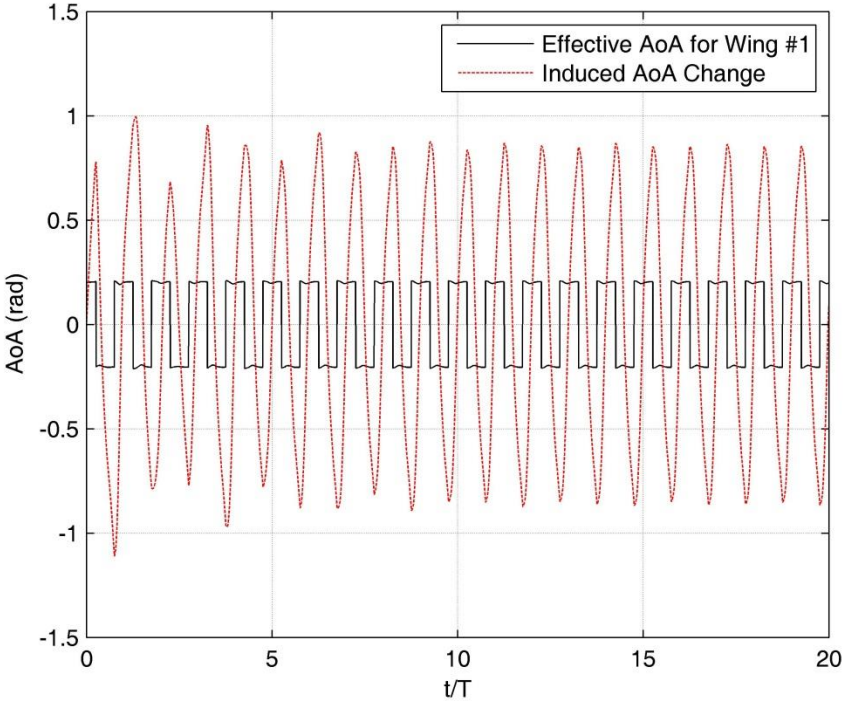
Kinematical Parameters



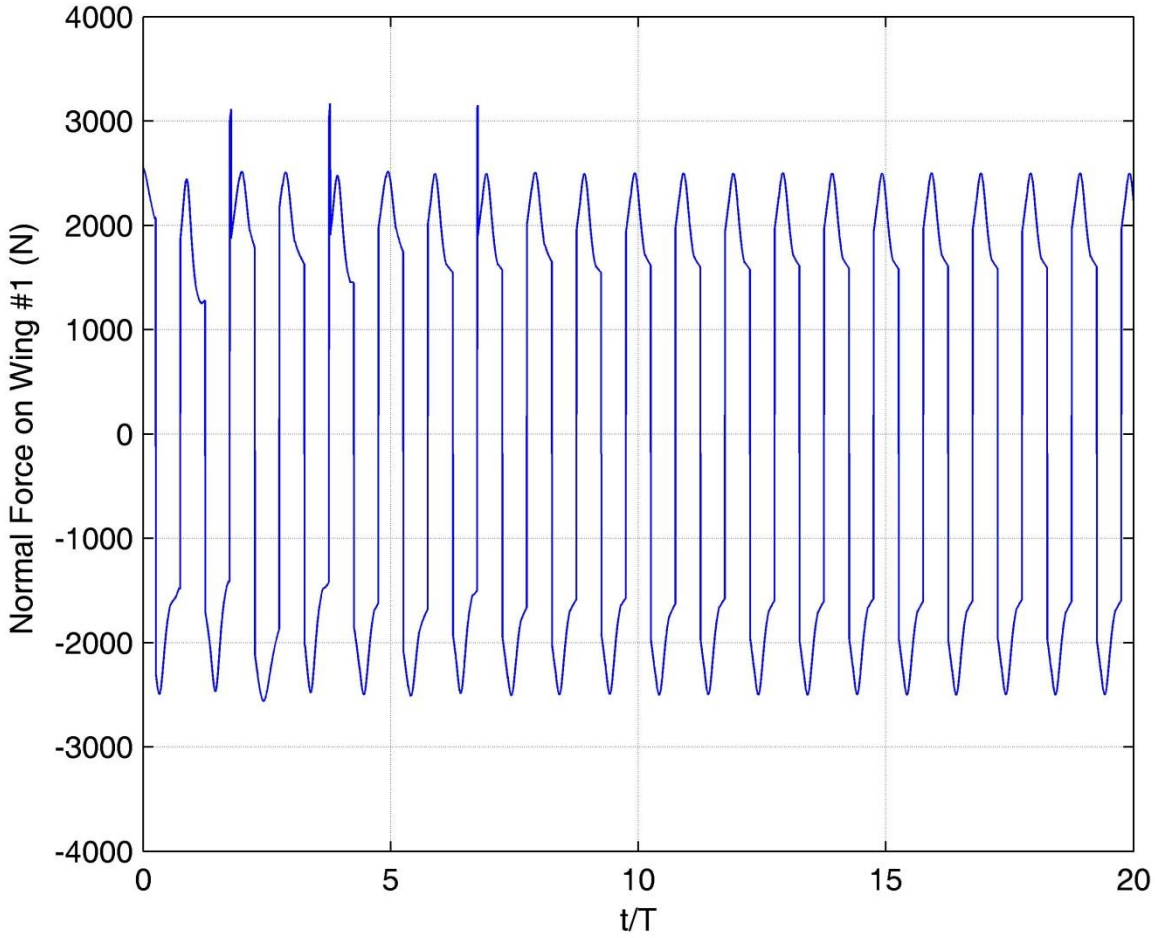
$\beta(t)$

$d\beta / dt$

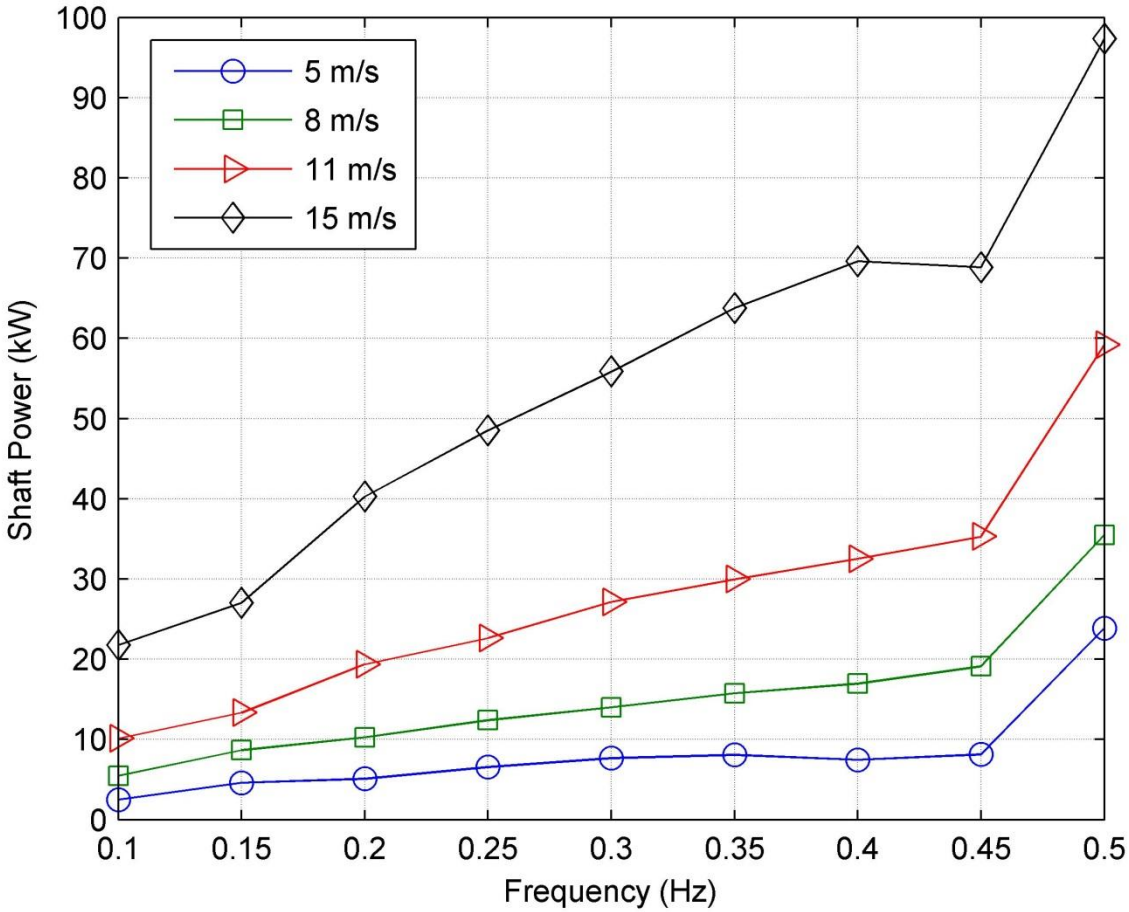
AoA



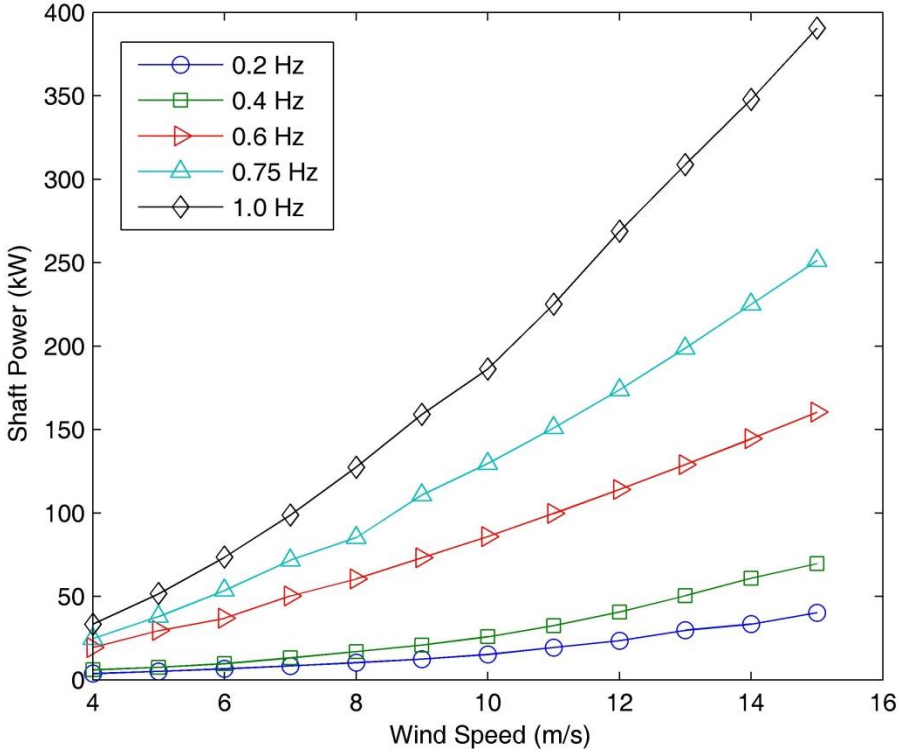
Normal Force on the Wing #1

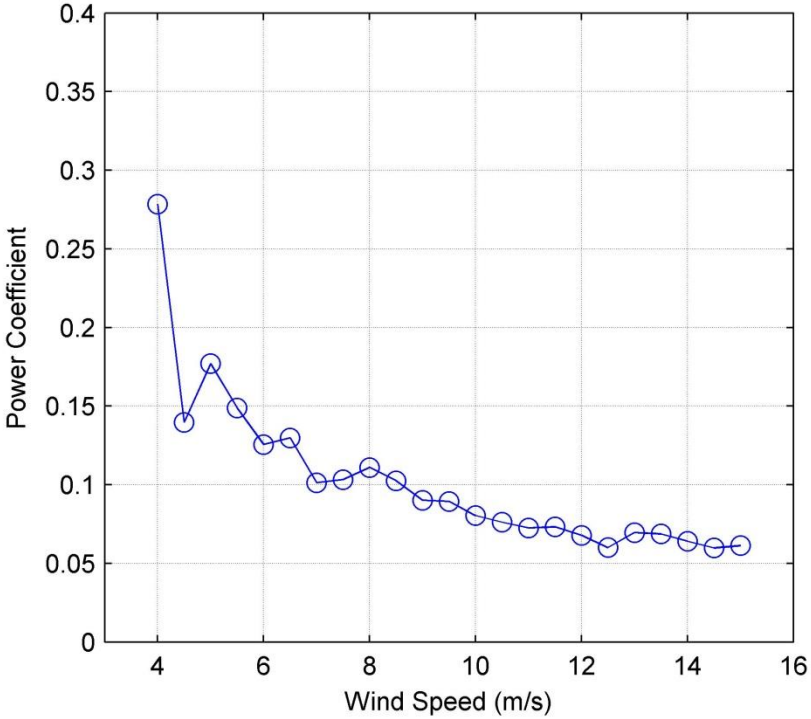


The Mean Shaft Power as a Function of Oscillation Frequency

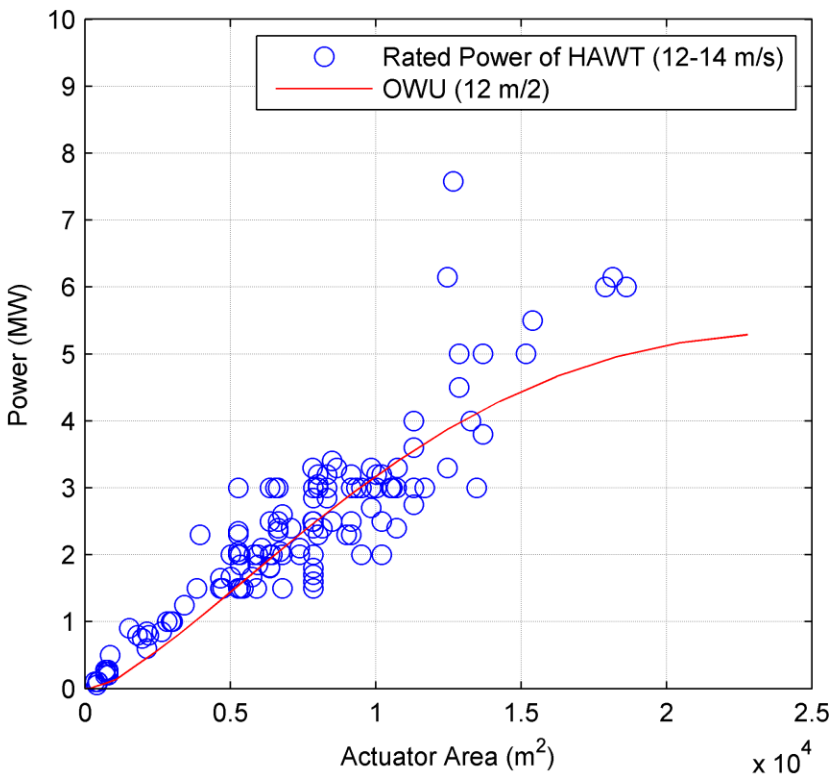


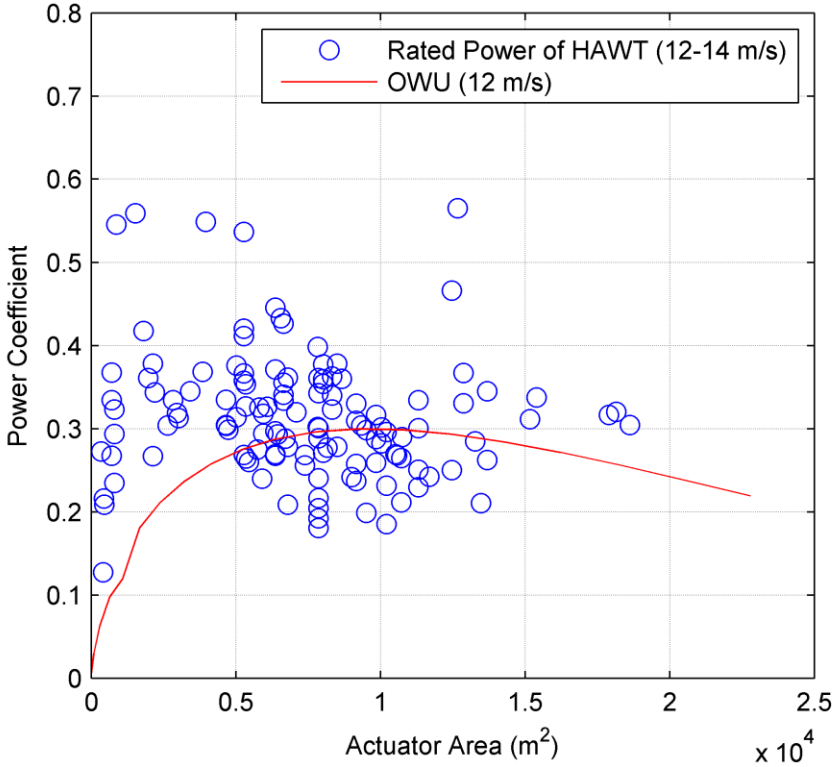
Estimated Power Output and Efficiency of Medium-Size Oscillator



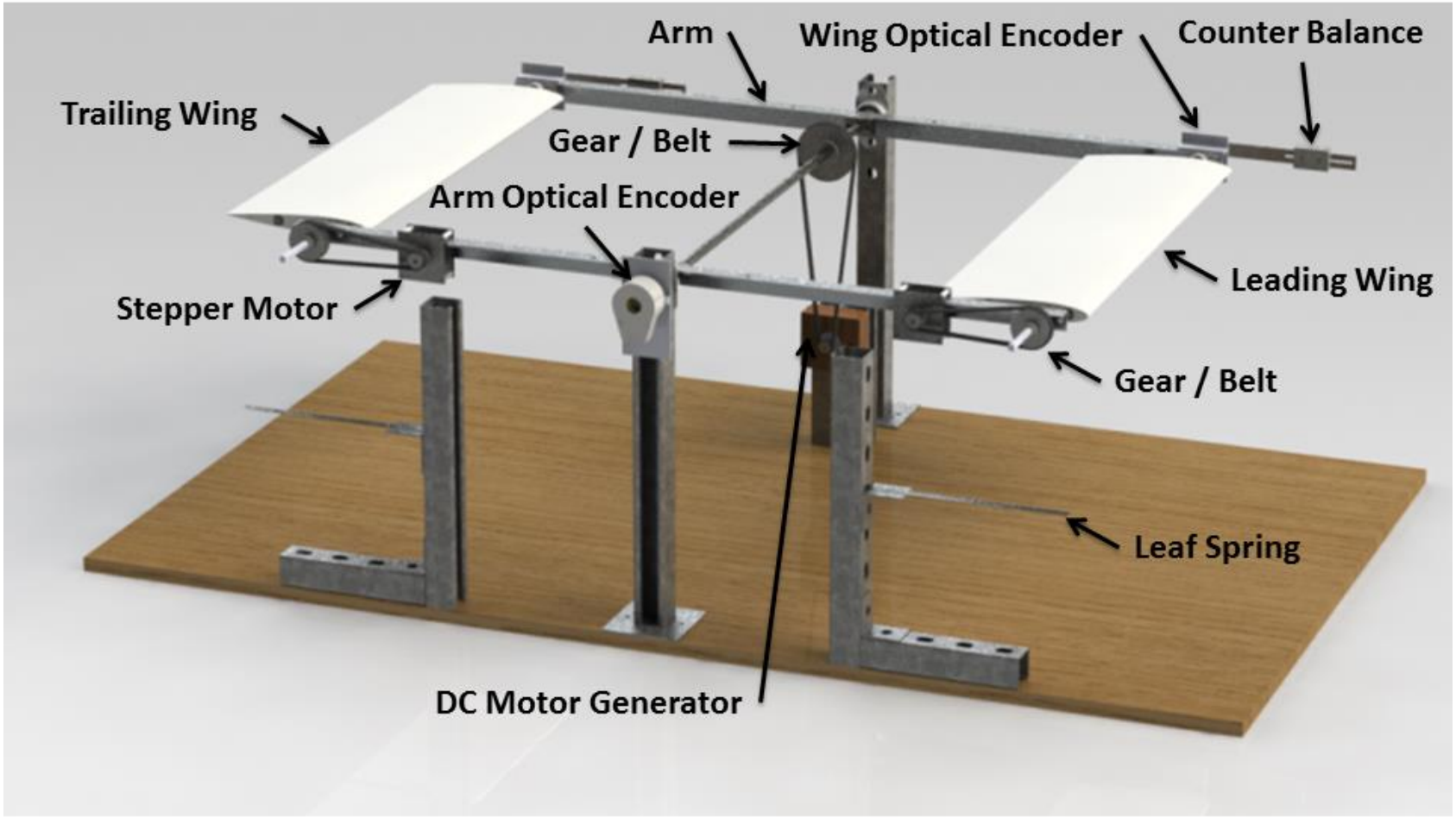


Power Scaling

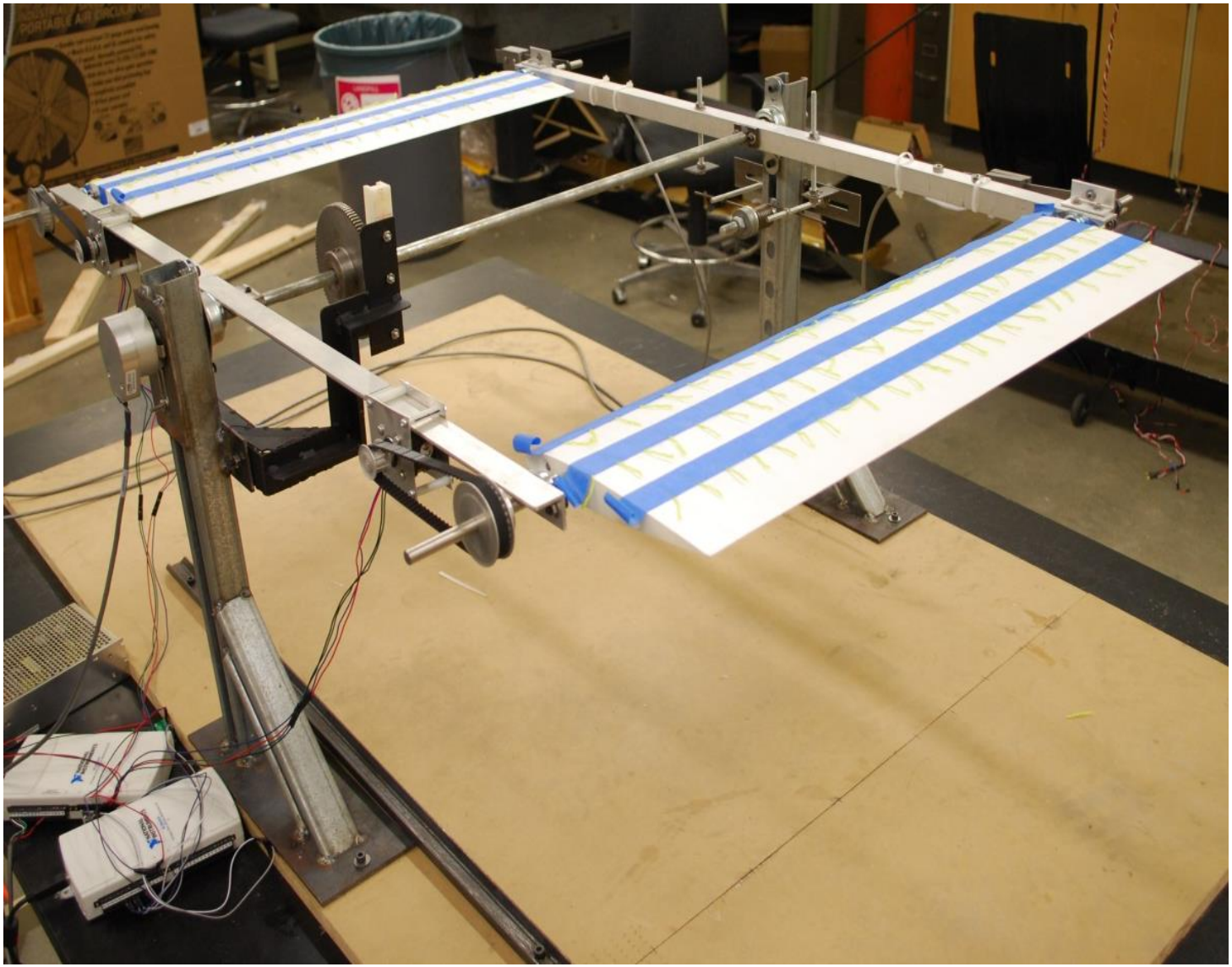




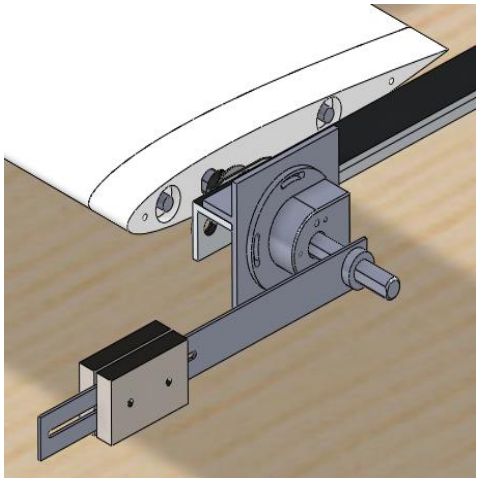
Design of Model OWU for Wind Tunnel Testing

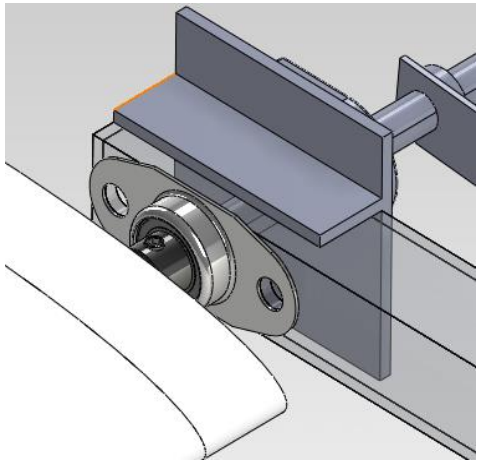


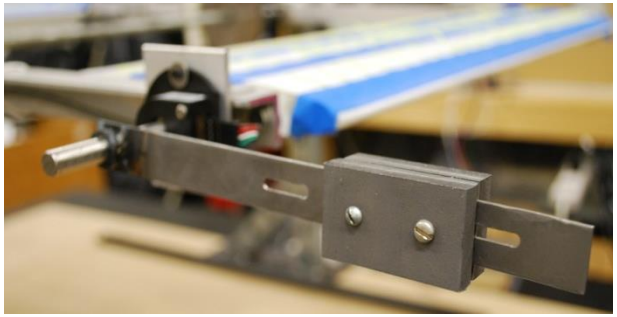
Main Parts of Real Model OWU for Wind Tunnel Testing

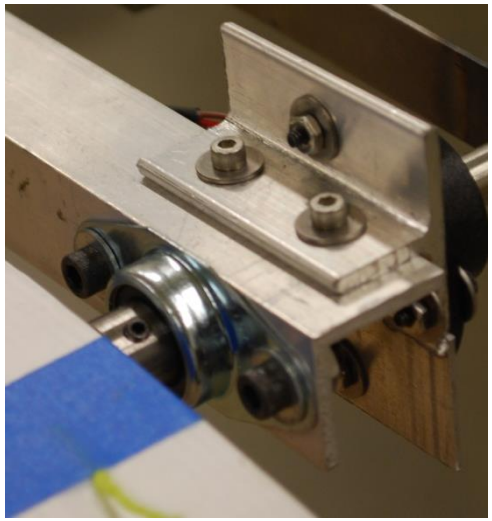


Design Details: Counter Weight









Design Details: Servo Motors

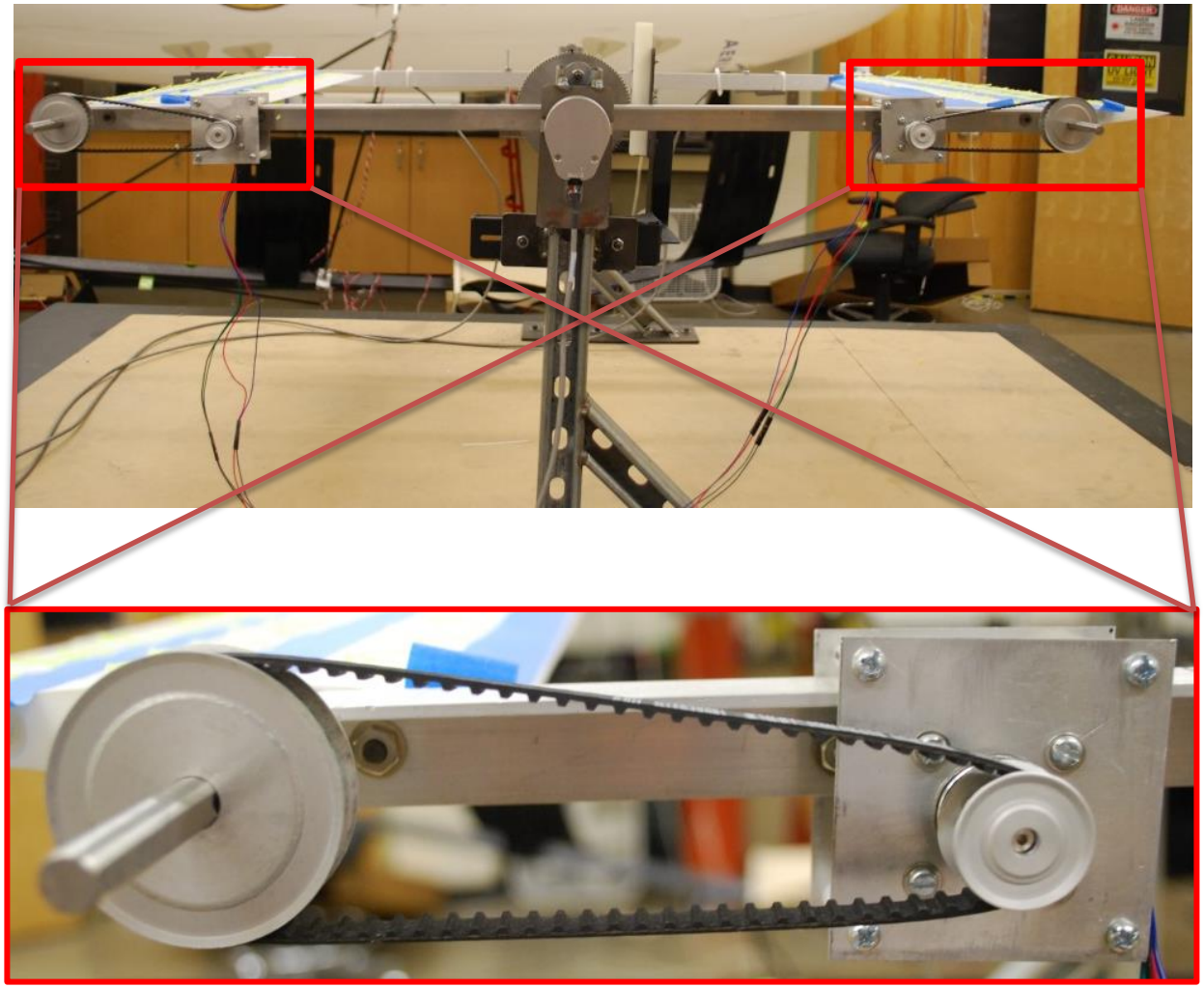
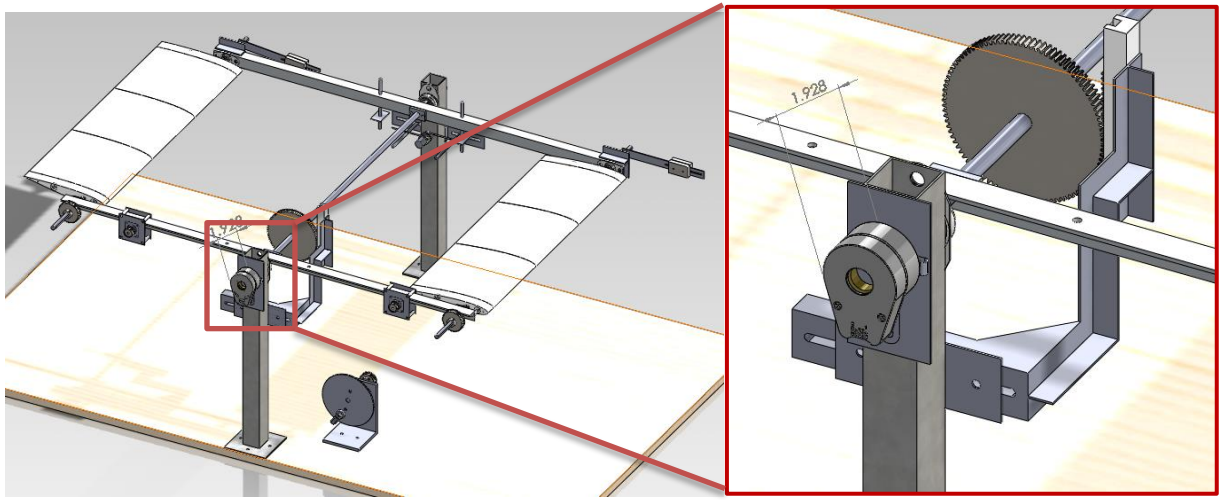


Image above shows the location of the stepper motors and how they are driving the wing

Design Details: Optical Encoder



Drawing above shows the optical encoder located at the end of the middle rod

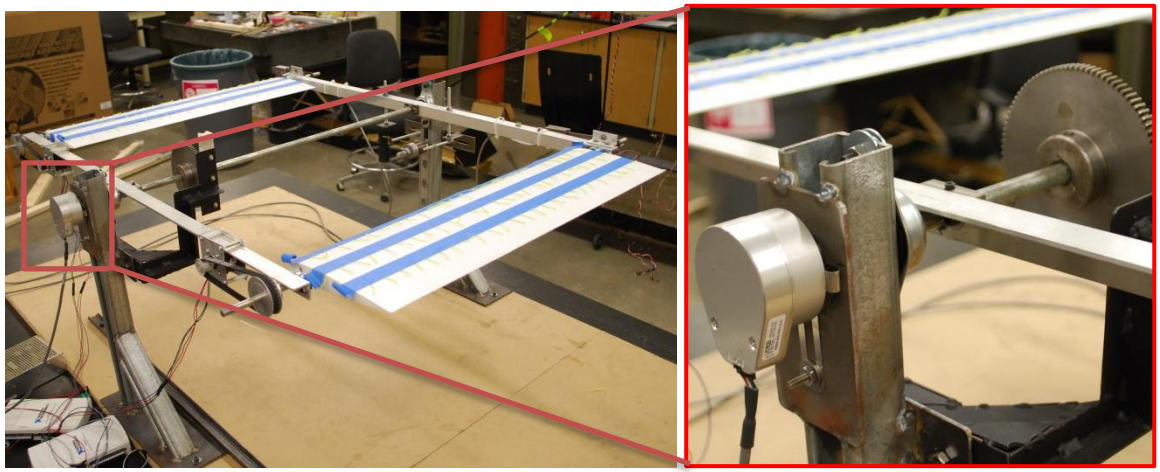
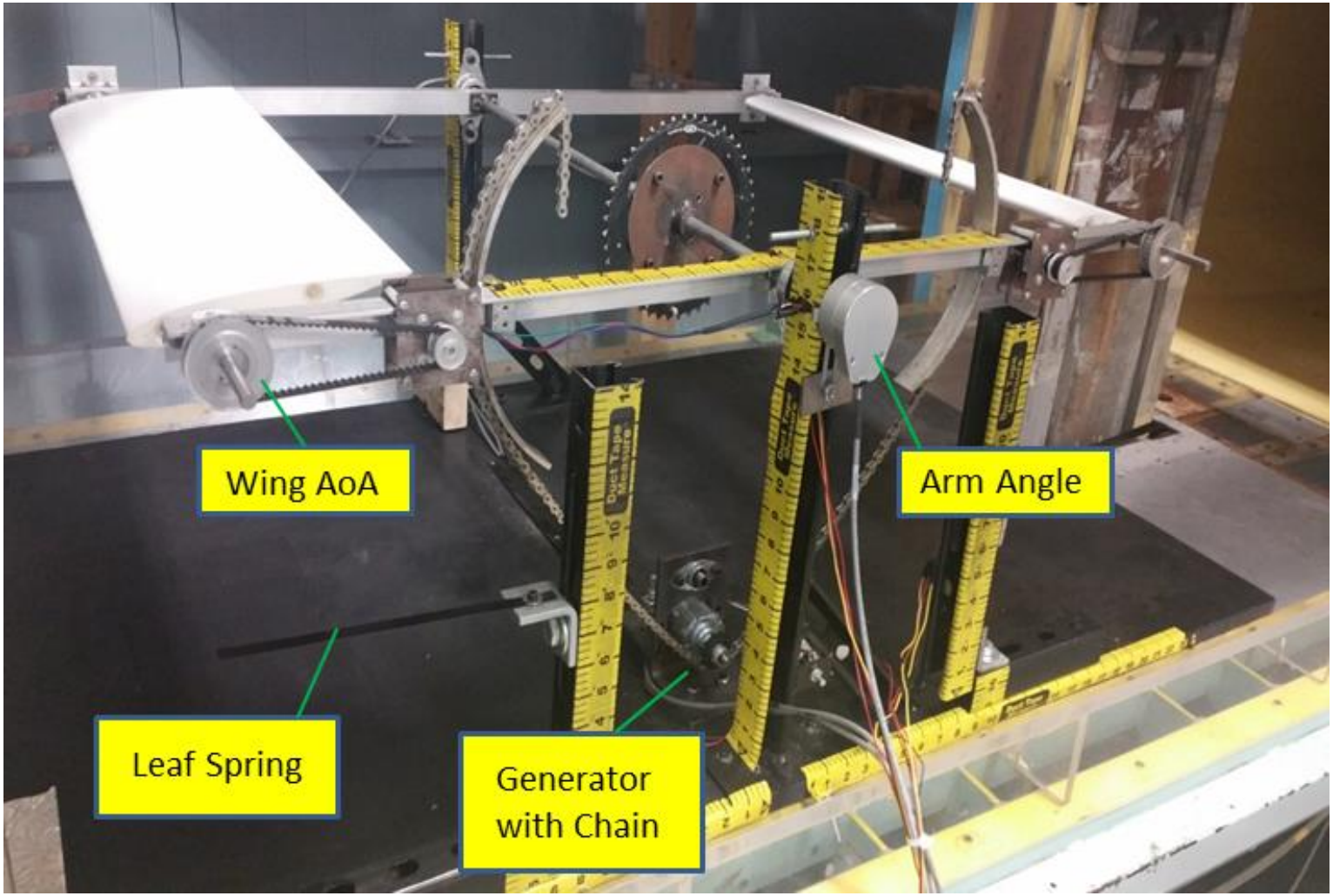
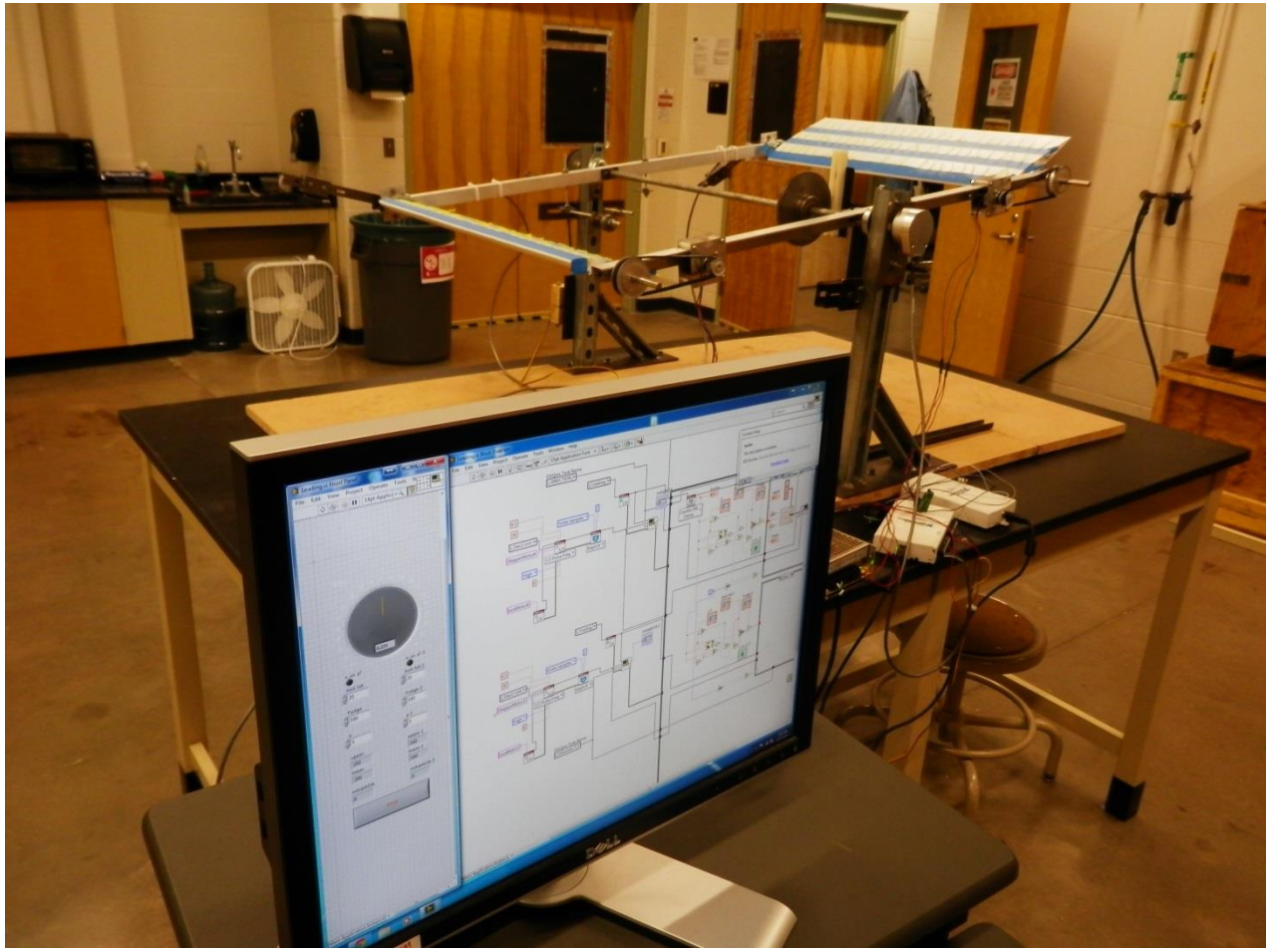


Image above shows the location of the optical encoder which is located at the end of the middle rod

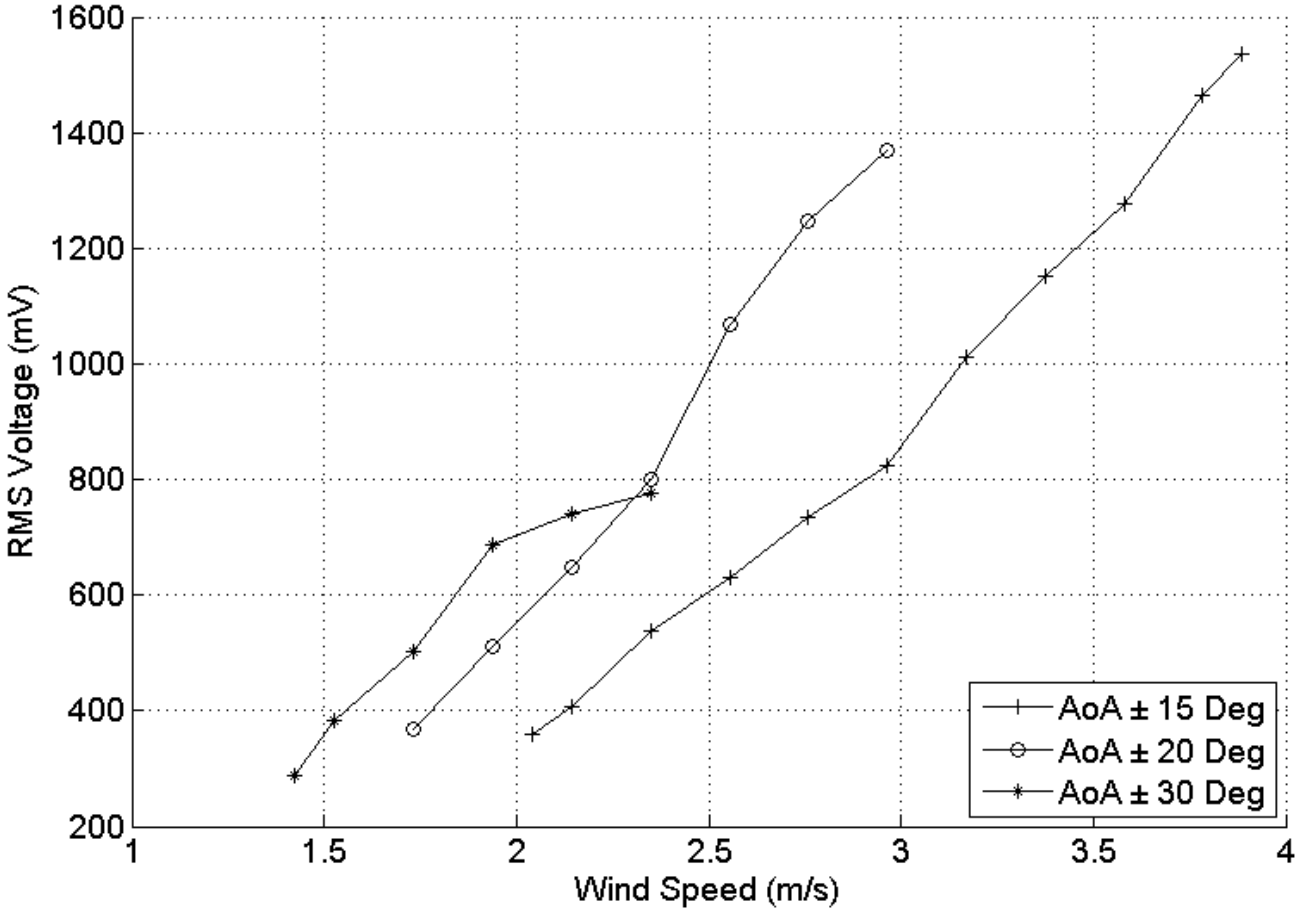
Model OWU in Wind Tunnel Test Section



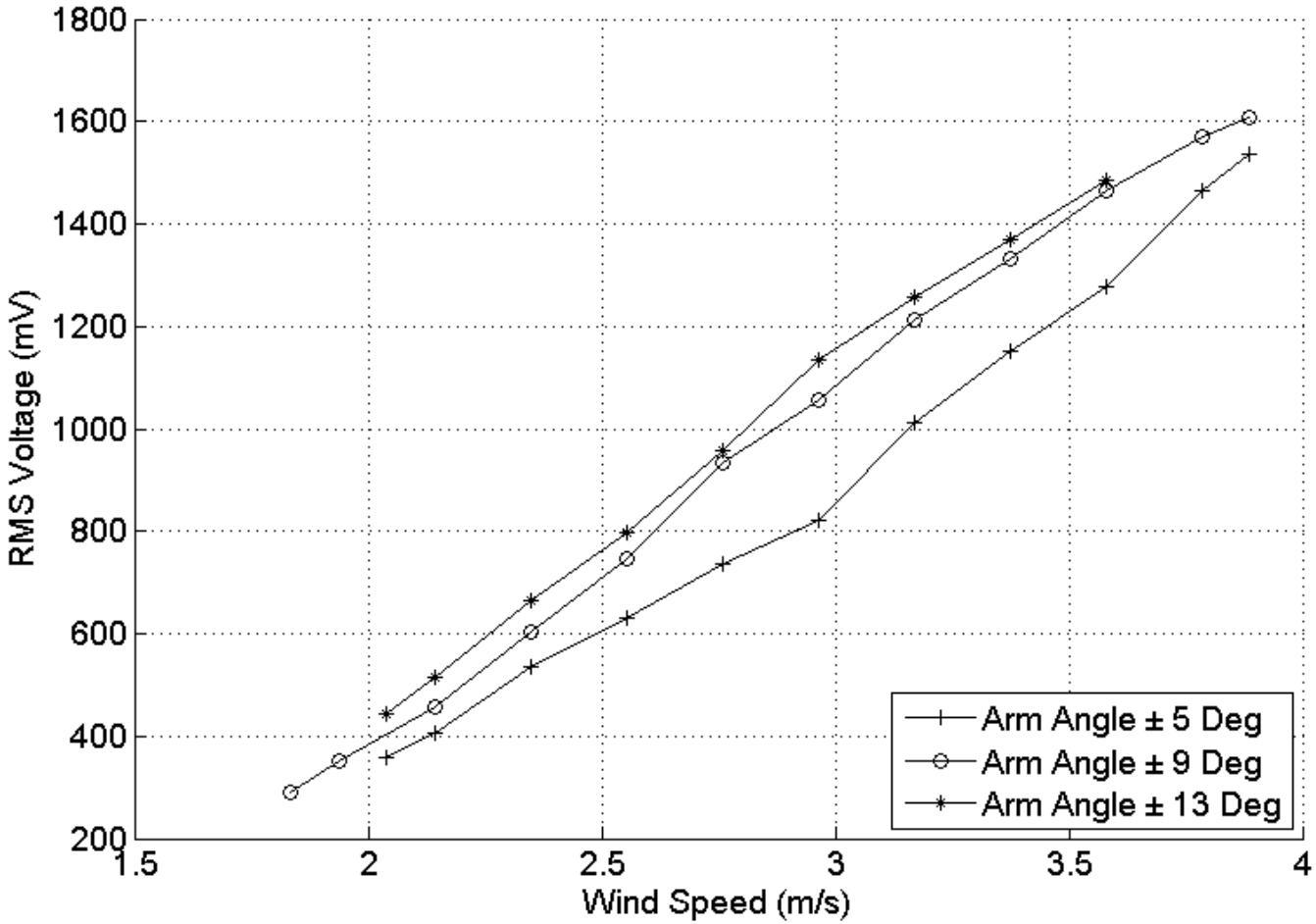
Design Details: Computer Control



Typical RMS Voltage as a Function of Wind Speed at Different AoAs



Typical RMS Voltage as a Function of Wind Speed at Different Arm Angles



Conclusions

- *An aerodynamics analysis has been made to evaluate the performance of the wind oscillator.*

- *A model wind oscillator has been designed and built for wind tunnel testing.*

- *The model wind oscillator is operational and ready for systematical wind tunnel testing.*