An Experimental Study on the Near Wake of Fixed Base Darreius Vertical Axis Wind Turbines

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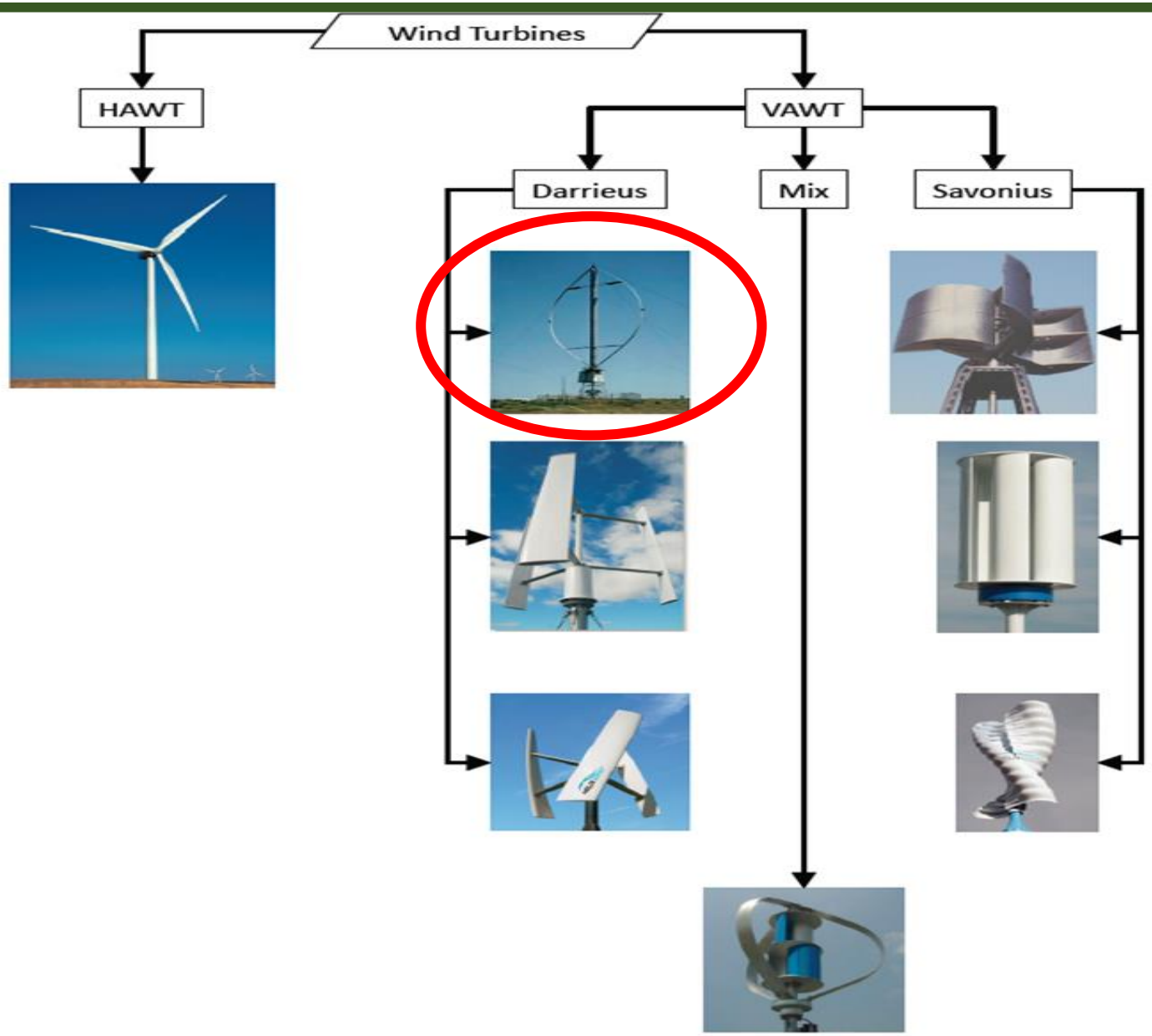
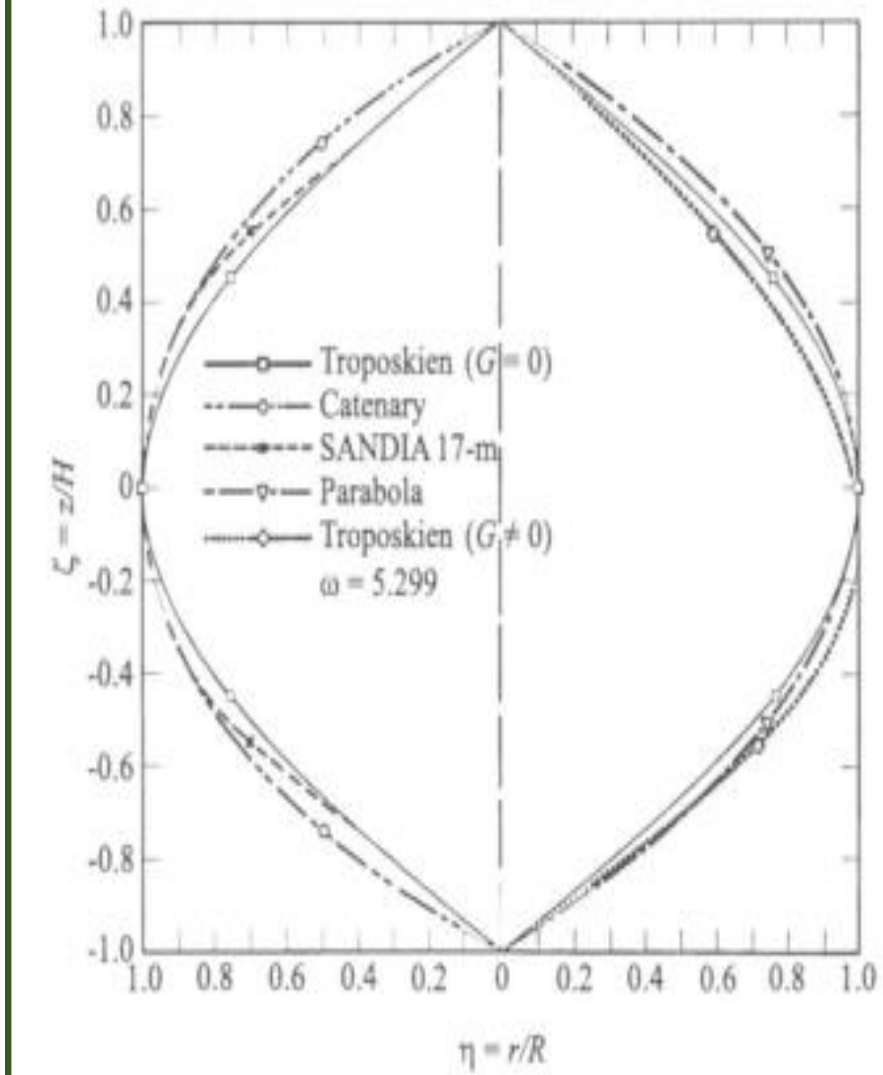
Why study near wake

- ***The near wake is the region where the vortices are generated.***
- ***Vortices are sources of suction, resulting in higher drag on the turbine. Higher drag will increase the loading and decrease the performance of the turbine.***
- ***Vortices are also responsible for low pitch noise coming from wind turbines.***
- ***As vortices break down, the T.K.E. increases, entraining the high energy flow into the wake.***
- ***The near wake also reflects the rotor characteristics, interaction between blades, hub and the nacelle.***

Different Types of Wind Turbines

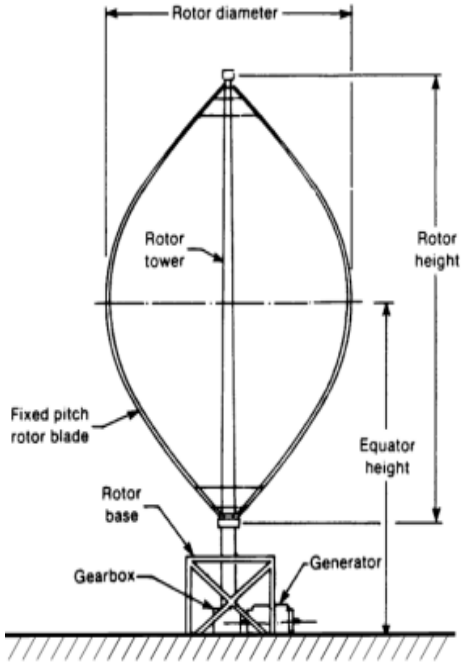




Design Process

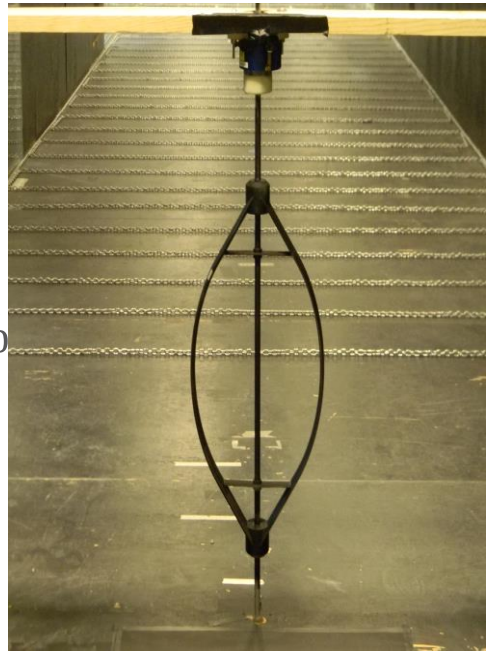
Sandia's design

- Rotor
  - Diameter = 34 m
  - Height = 50 m
  - Speed = 28 to 38 RPM
  - # of blades = 2
  - H/D = 1.47
  - Airfoils = SNL0018/50 & NACA 0021
  - Swept Area = 955 m^2
  - Solidity = 0.13
  - Rotor Shape = Sandia's
- Performance
  - Rated power = 500kWe
  - Rated Speed = 12.5 m/s
  - Rated RPM = 37.5
  - Cut-out = 20

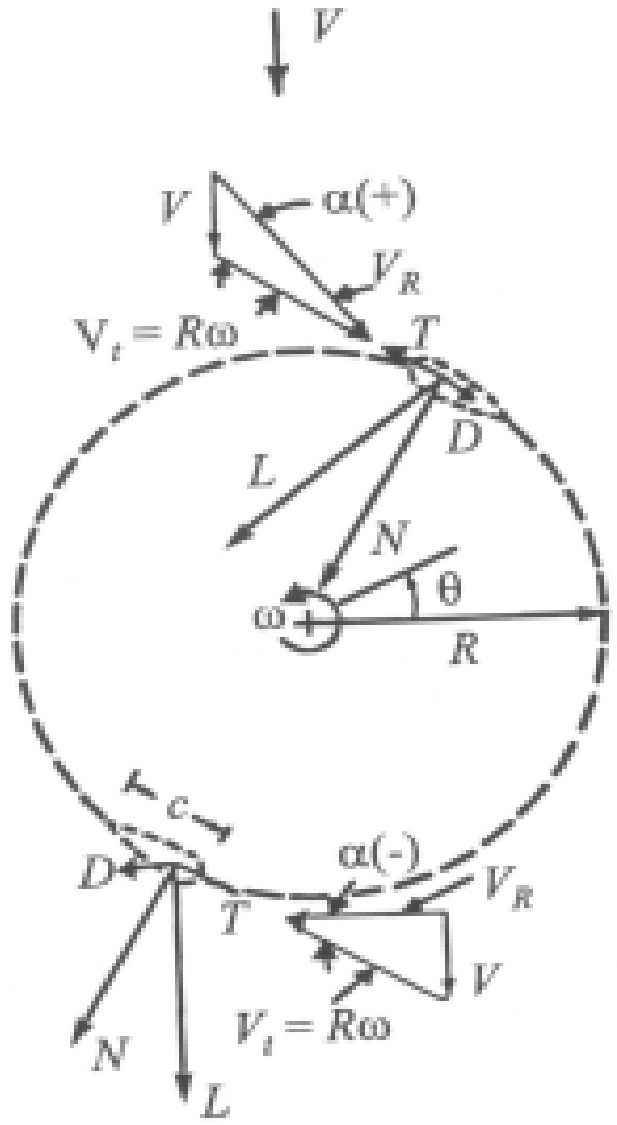


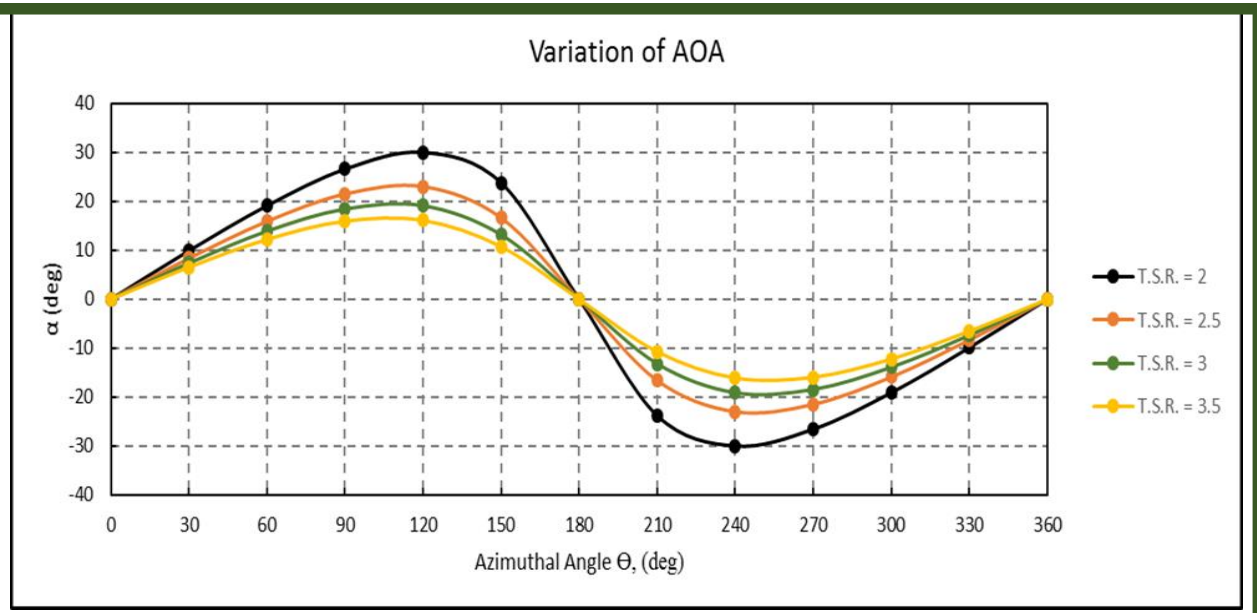
Scaled Model

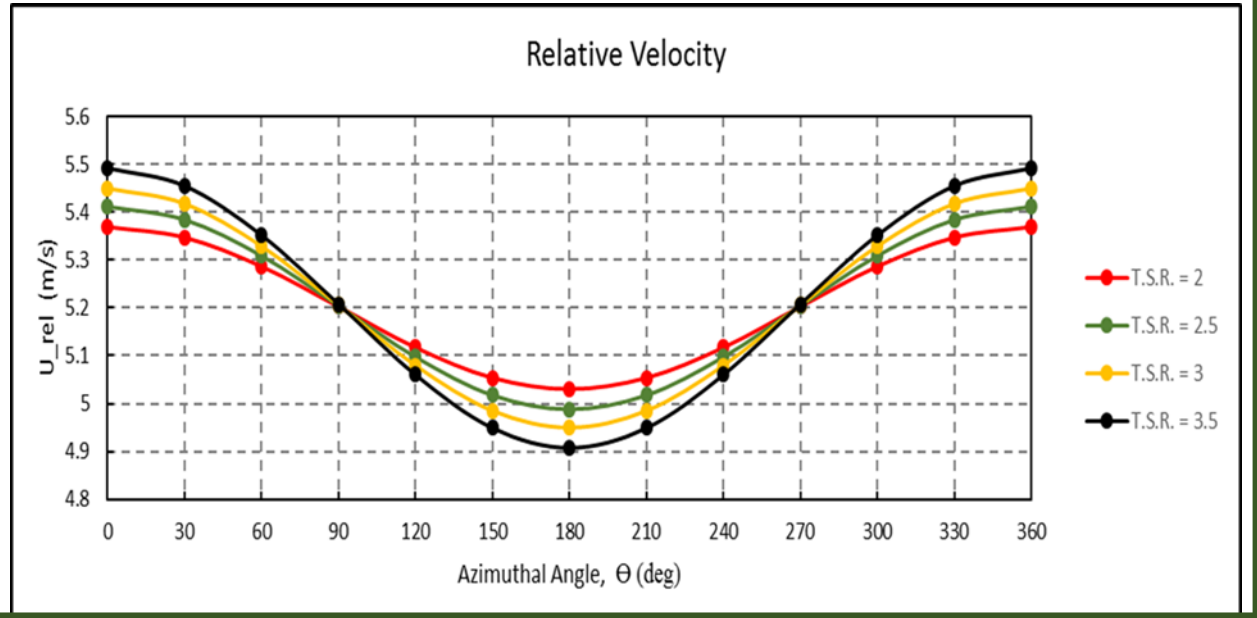
- *NACA 0018*
- $H = 0.4\ m$
- $\frac{H}{D} = 1.5 \rightarrow D = 0.27\ m$
- $\lambda_L = \frac{L_m}{L_p} = \frac{1}{125}$
- $A_s = D^2 = 0.0715\ m^2$
- $\frac{A_{model}}{A_{tunnel}} = 0.013$
- $Chord = 0.05\ m$
- $\sigma = \frac{NcH}{A_s} = \frac{2*0.05*0.4}{0.0715} = 56\%$



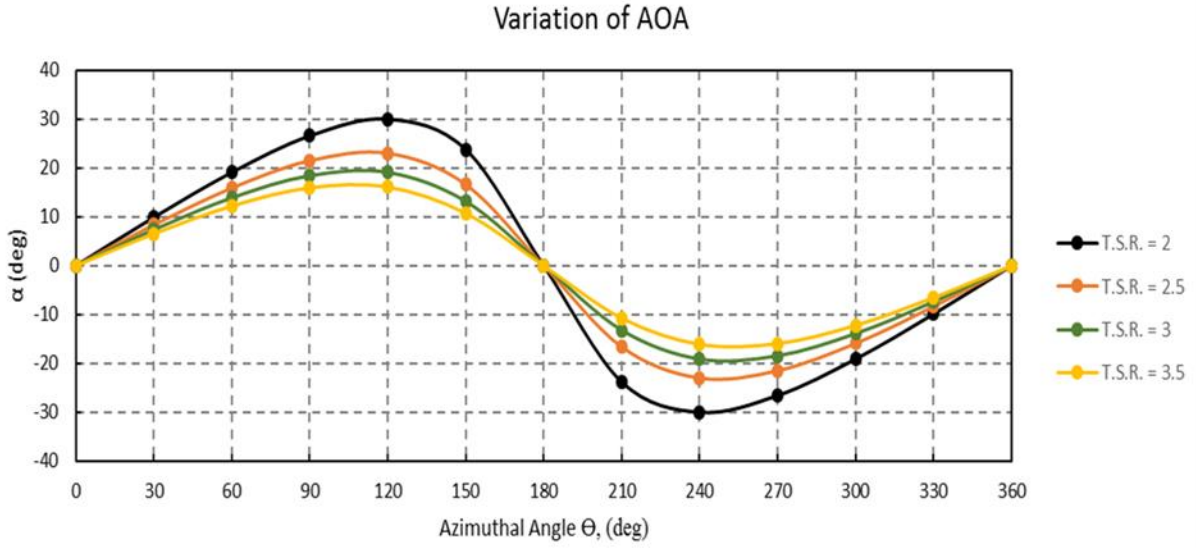
Dynamics of VAWTs

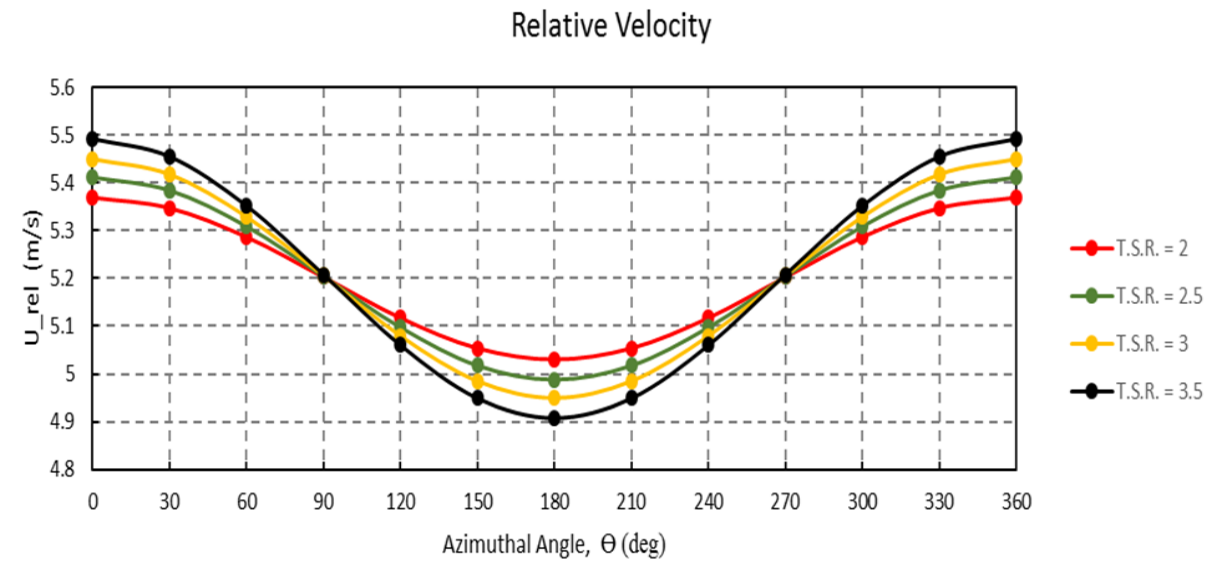


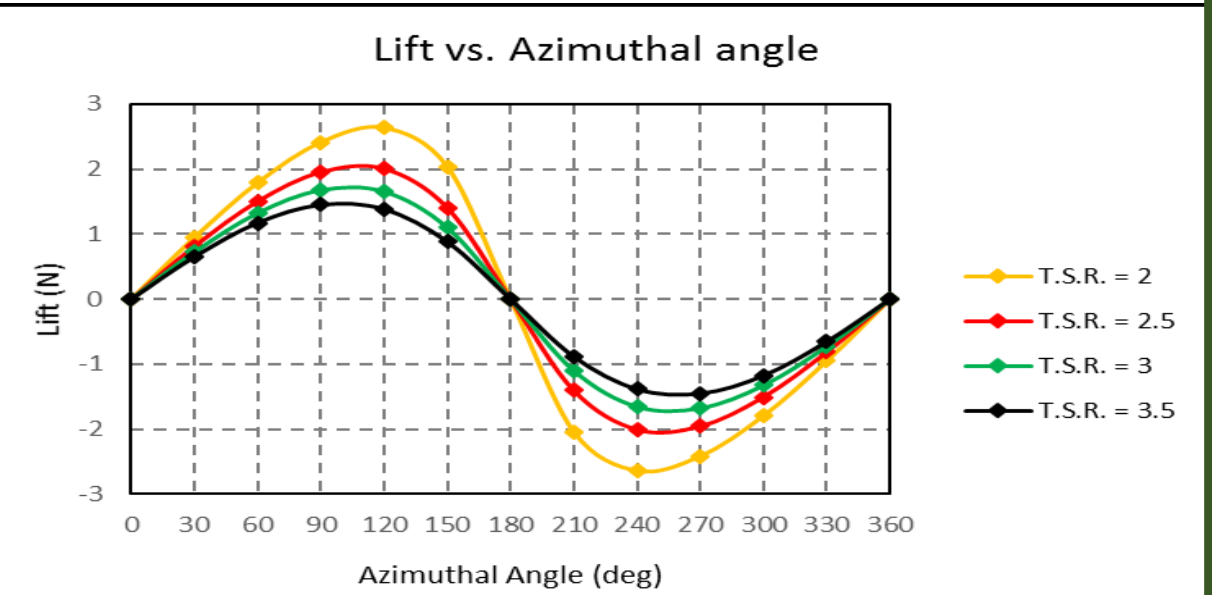


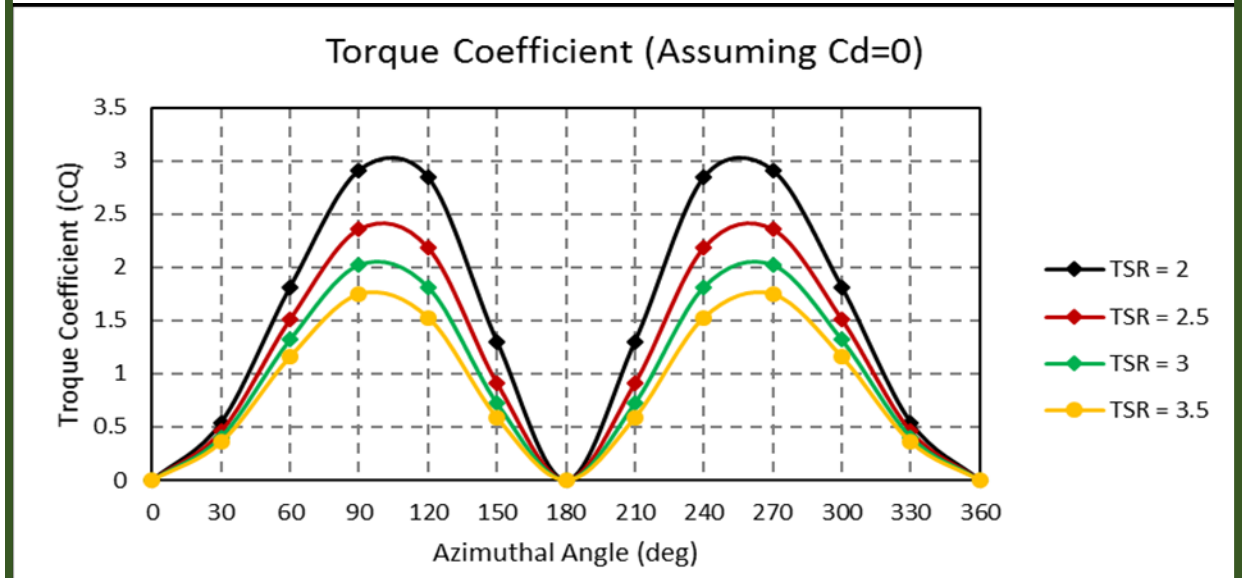


Dynamics of VAWTs





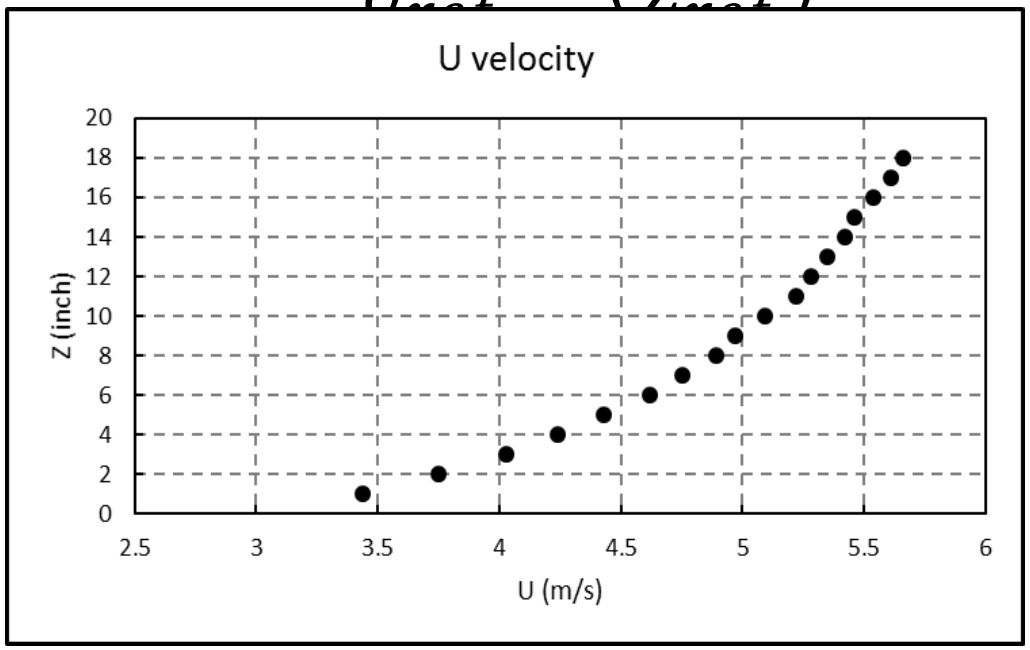


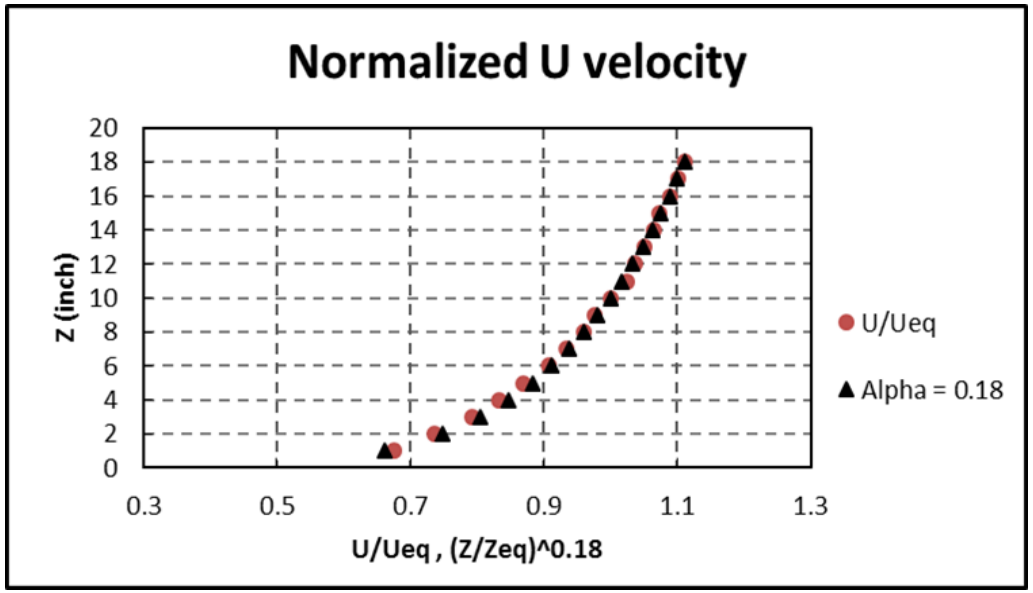


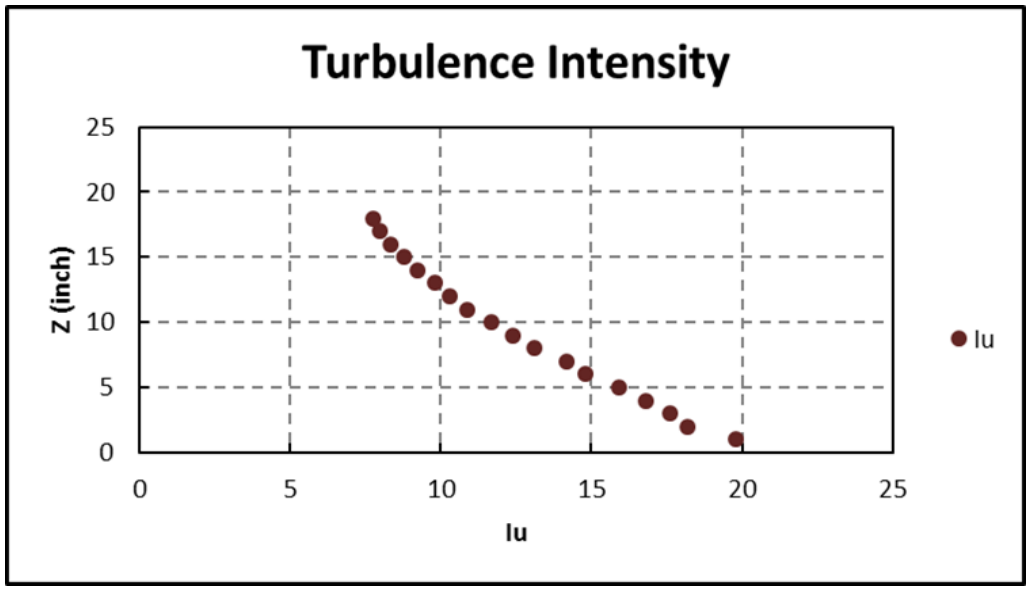
Flow Characteristics

- Equatorial wind speed= 5.2 m/s
- Power law exponent was found to be 0.18

$$\frac{U}{U_{ref}} = \left(\frac{Z}{Z_{ref}}\right)^{\alpha}$$

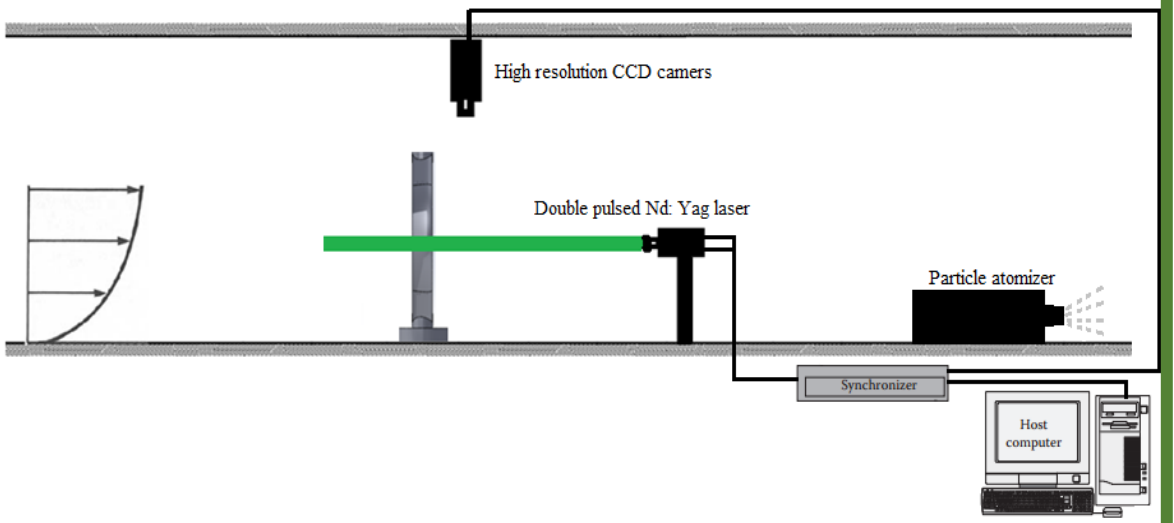


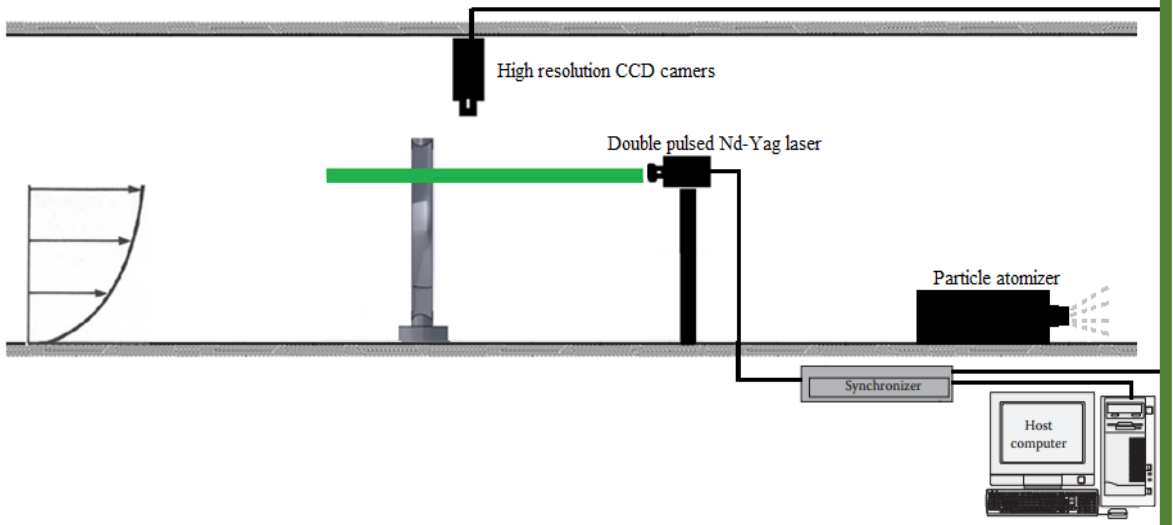




PIV Experiments

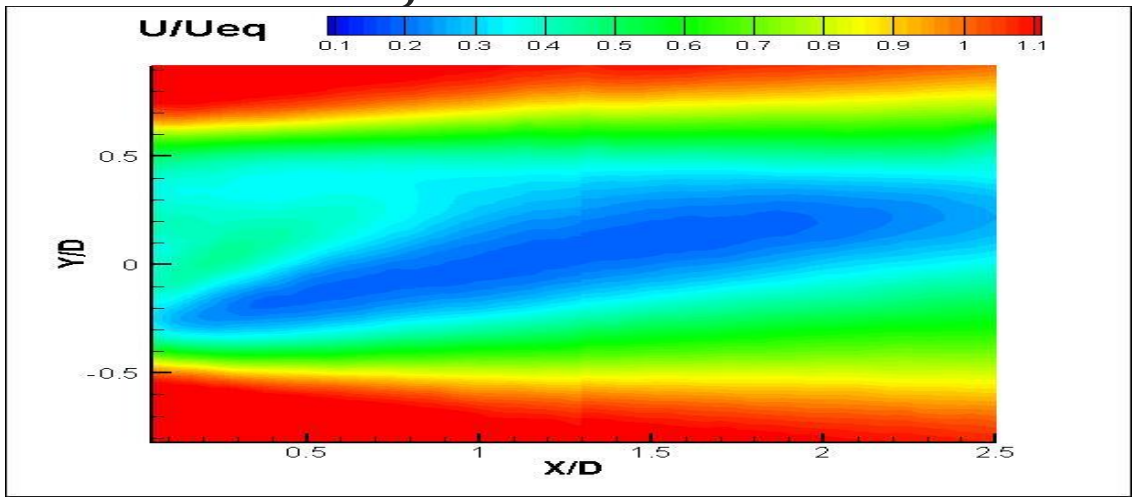
- 3 sets of PIV measurements were taken at:
  - **Top view**
    - $Z = \frac{H}{2}$
    - $Z = \frac{3H}{4}$
  - **Side view**
- Free run vs. phase locked



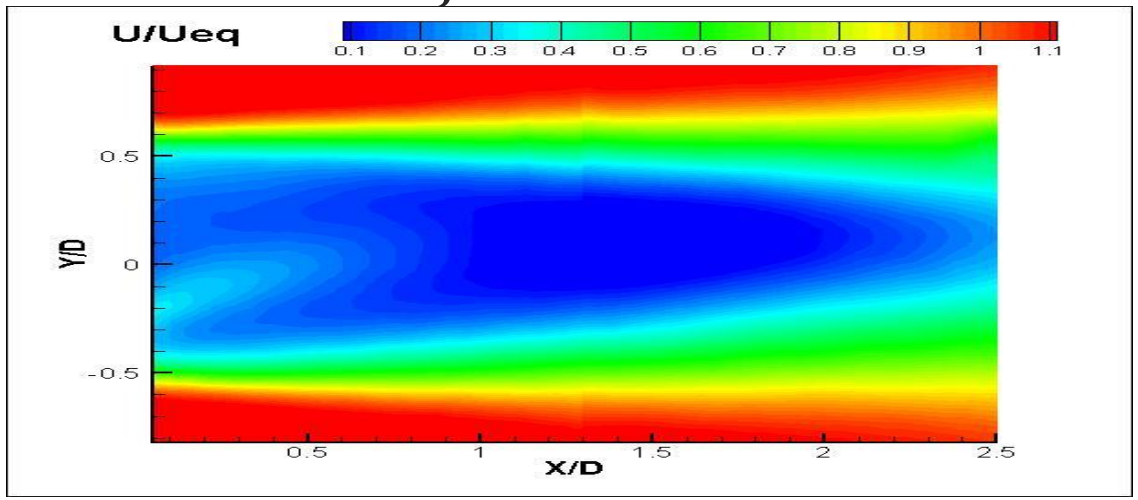


Free-Run Plots for Normalized Stream-Wise Velocity for $Z = \frac{1}{2} H$ (Top View)

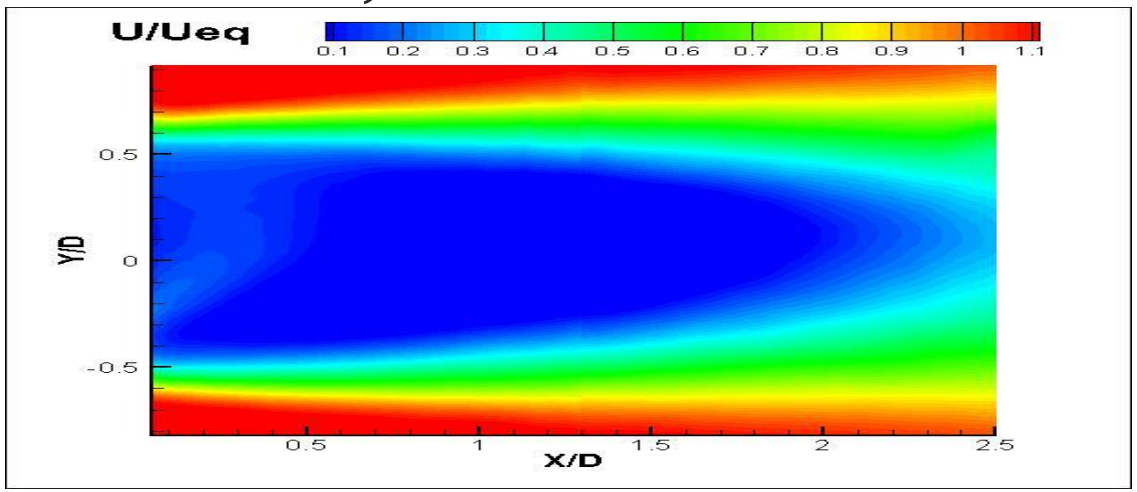
λ=2, Ω=12 RPS



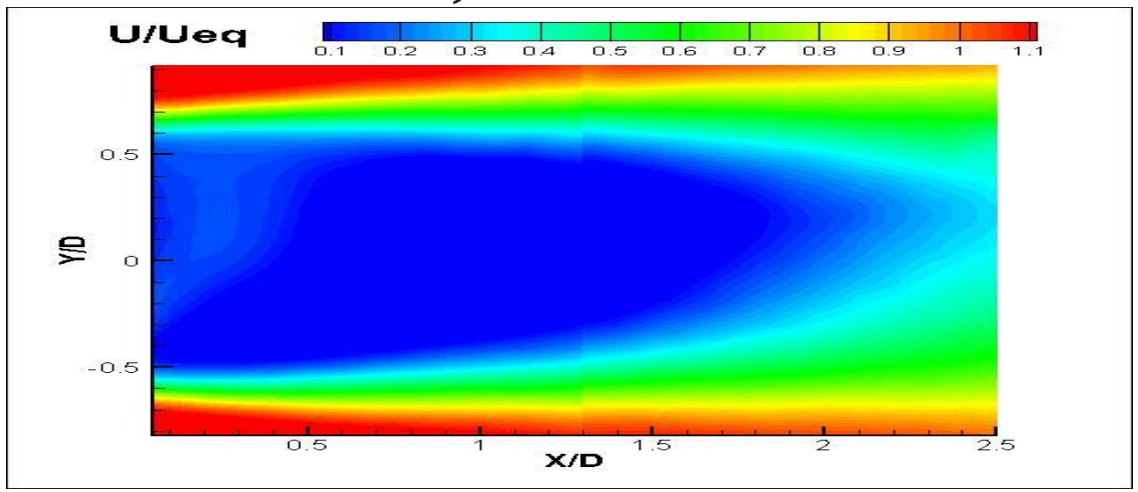
λ=2.5, Ω=15 RPS



λ=3, Ω=17.7 RPS

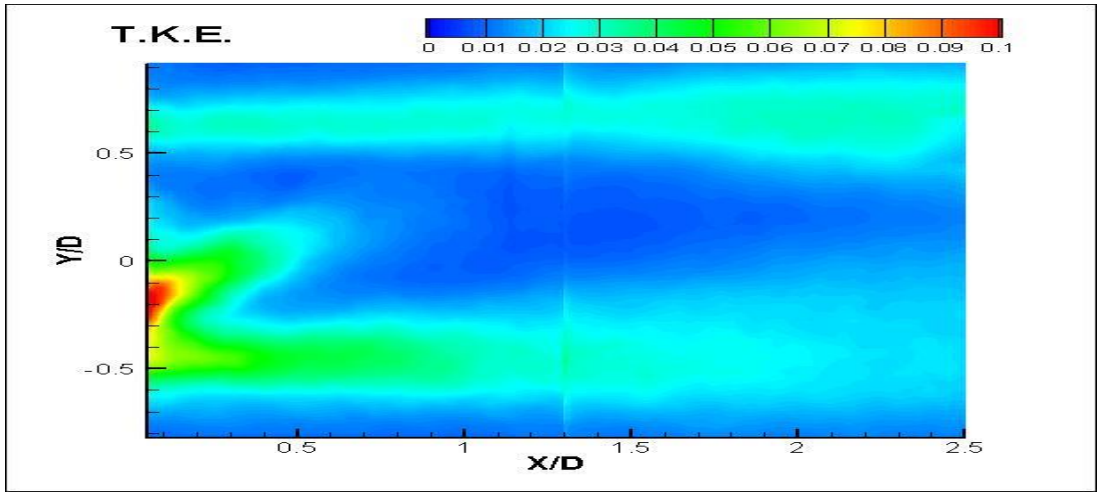


λ=3.5, Ω=20.7 RPS

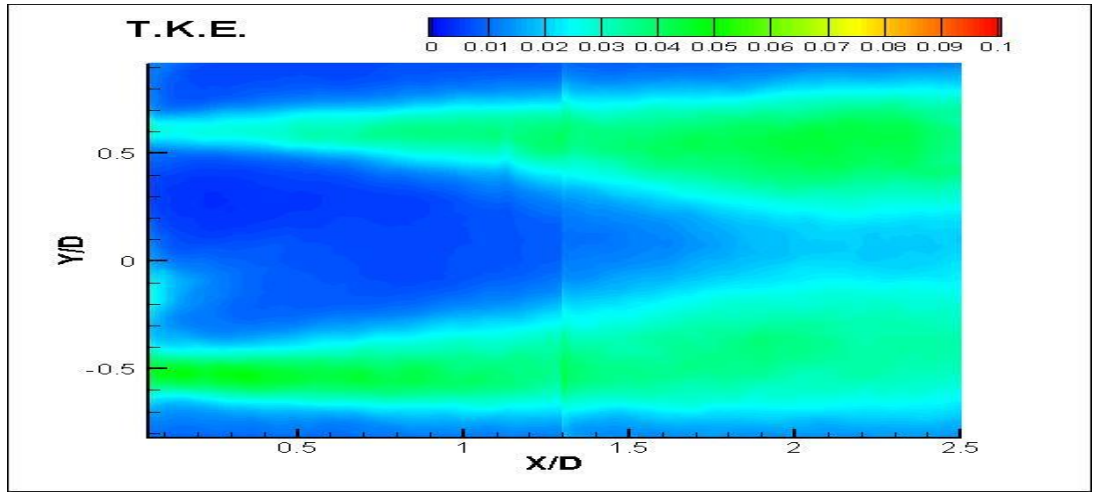


Free-Run plots for T.K.E. for $Z = \frac{1}{2}$ H (Top view)

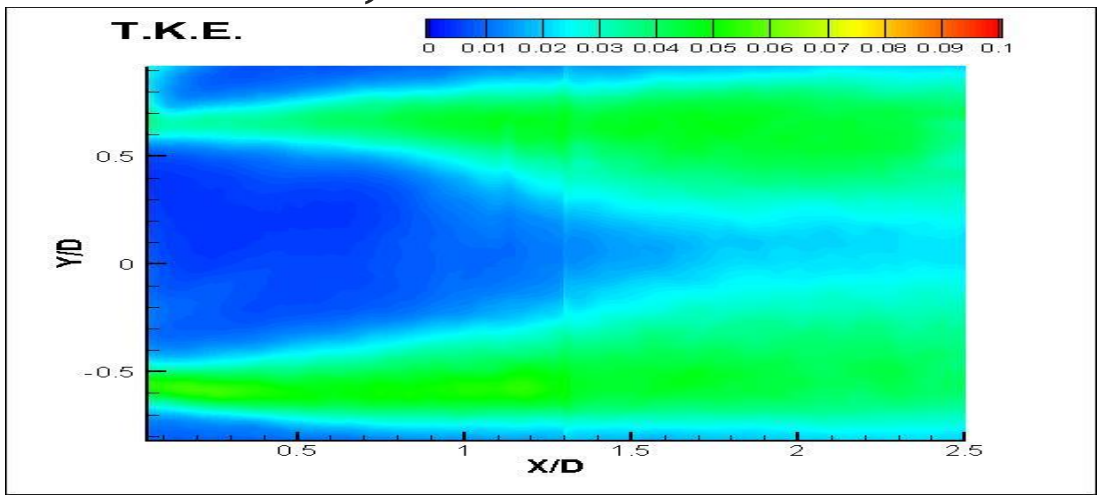
λ=2, Ω=12 RPS



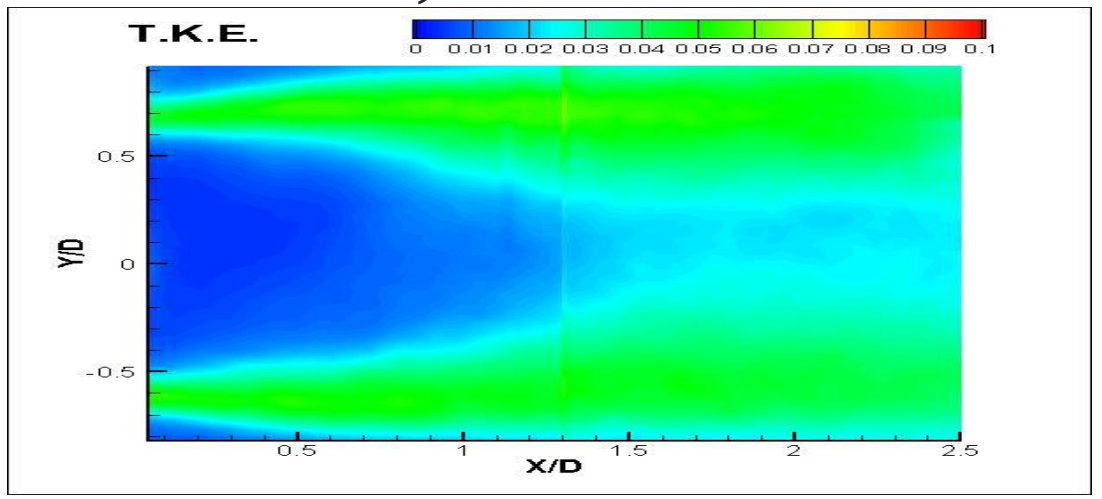
λ=2.5, Ω=15 RPS



λ=3, Ω=17.7 RPM

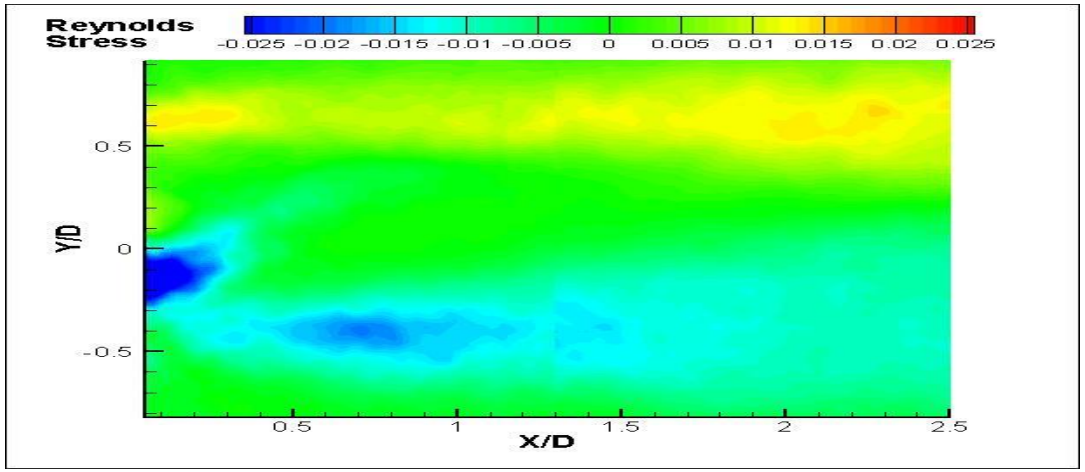


λ=3.5, Ω=20.7 RPM

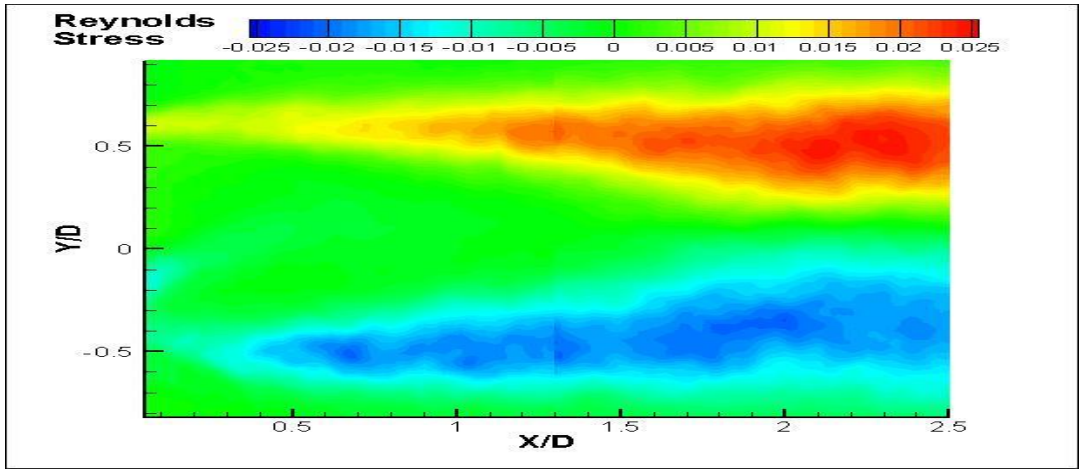


Free-Run plots of Reynolds Shear Stress for $Z = \frac{1}{2} H$ (Top View)

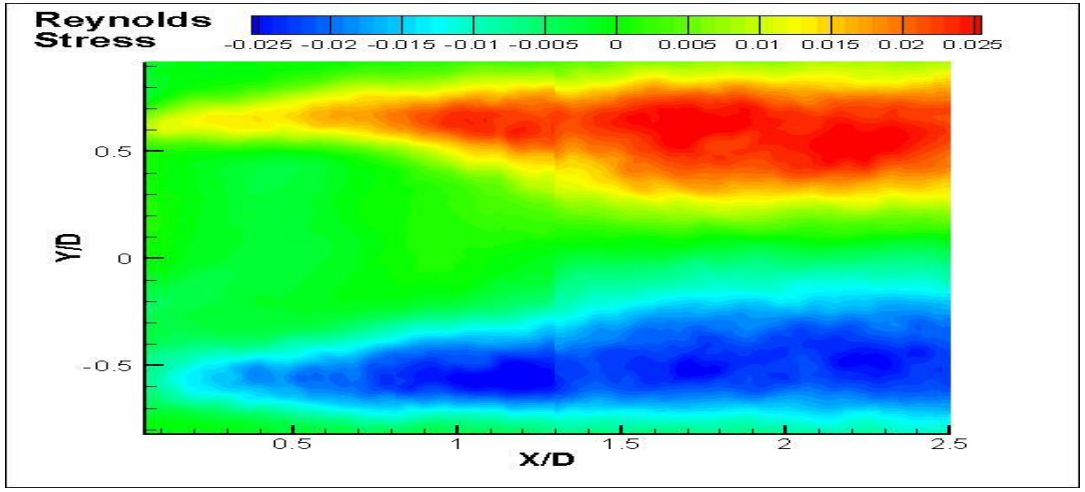
λ=2, Ω=12 RPS



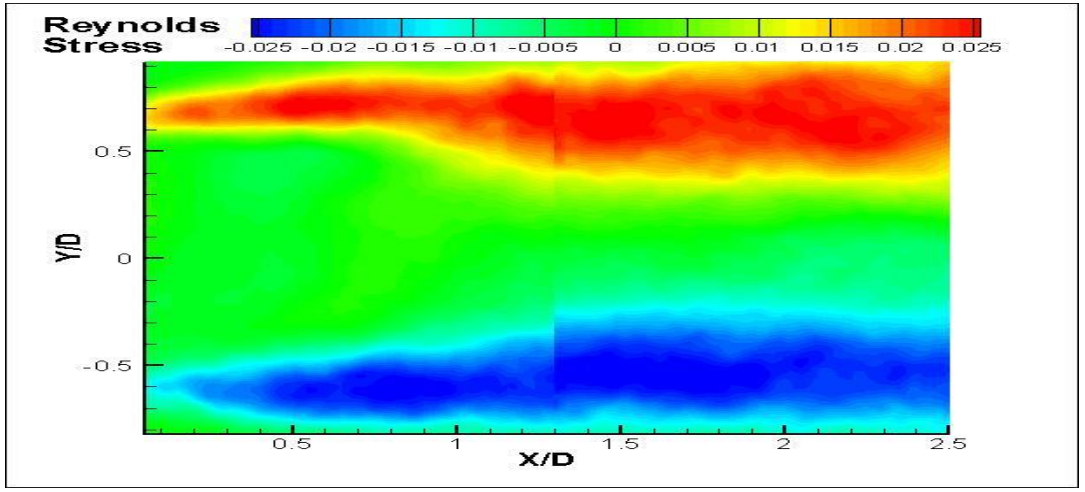
λ=2.5, Ω=15 RPS



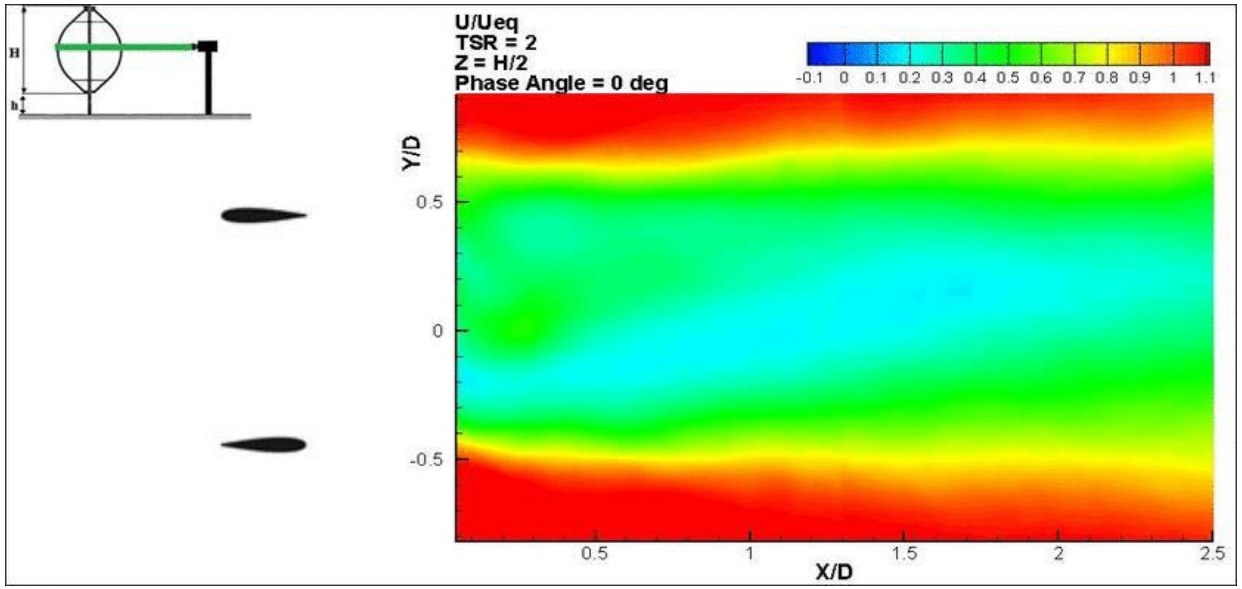
λ=3, Ω=17.7 RPS

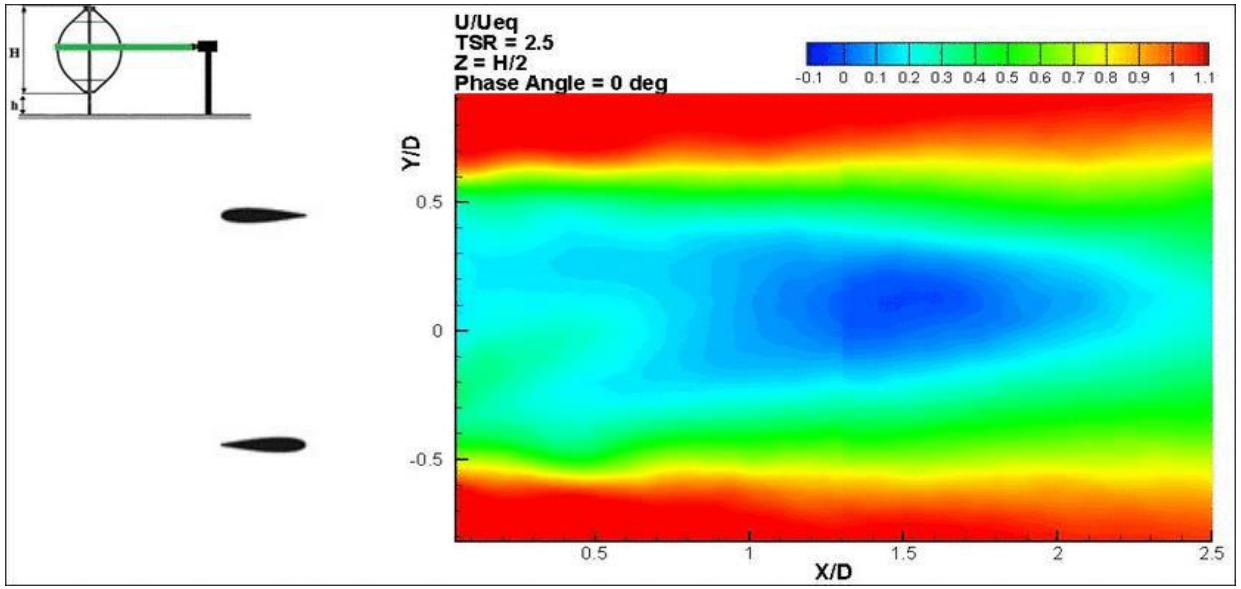


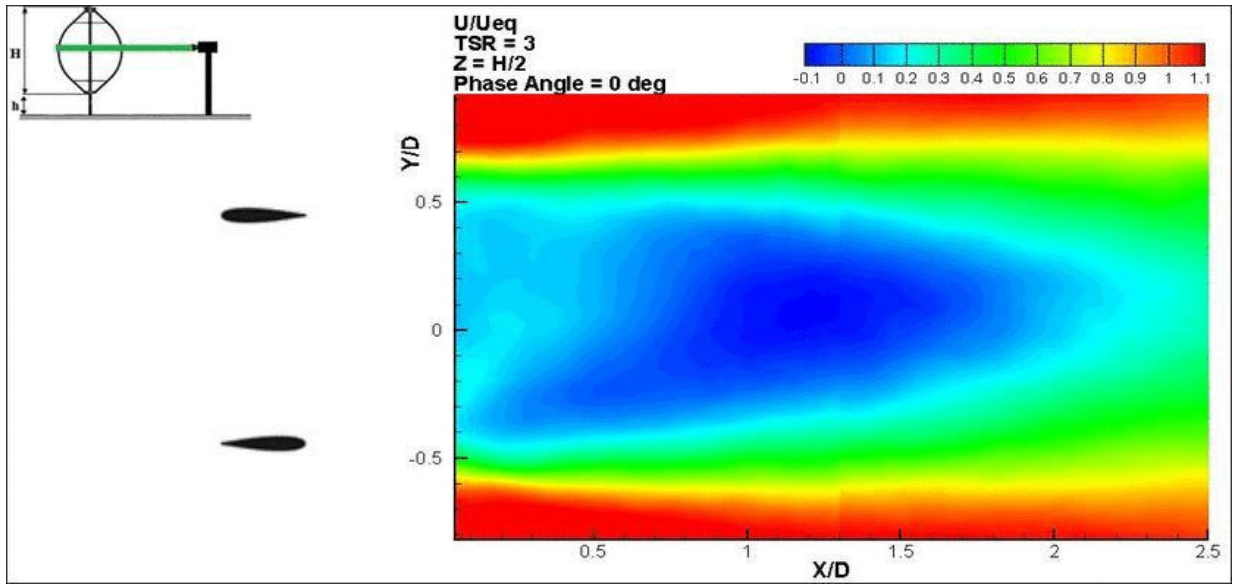
λ=3.5, Ω=20.7 RPS

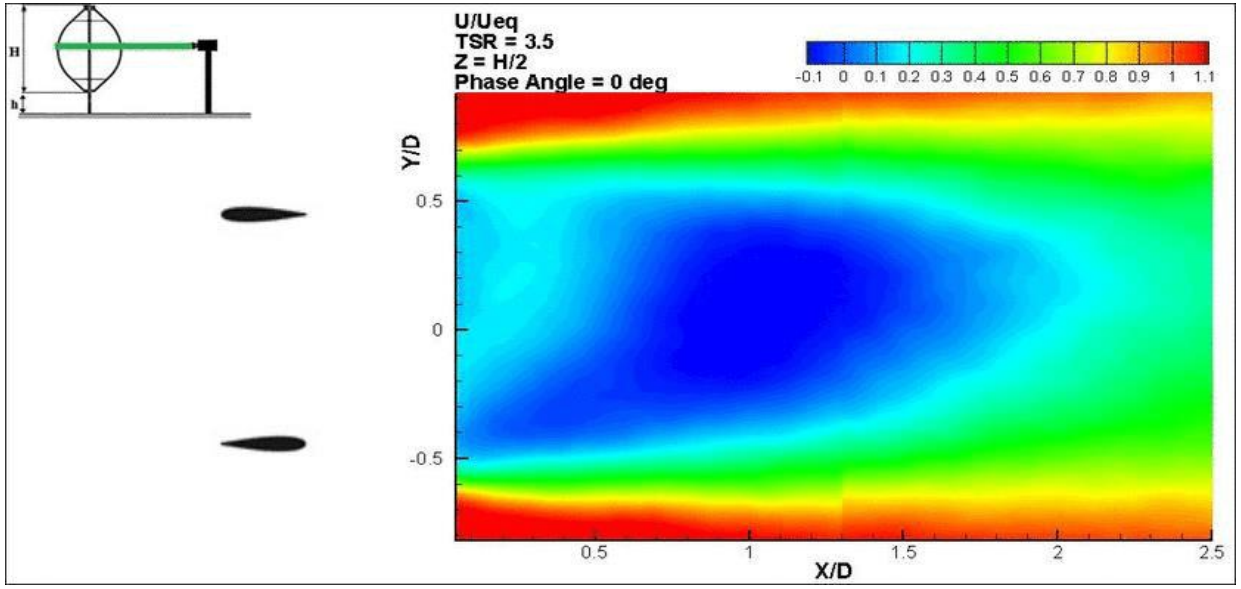


Phase Locked Plots of Stream-Wise Velocity for $Z = \frac{1}{2}$ H (Top View)









Phase Locked Plots of Vortices for $Z = \frac{1}{2}$ H (Top view)