Effects of Tip Injection and Mie Vanes on the Performance of a Model Wind Turbine Rotor

A. Abdulrahim, E. Anık, O. Uzol

Department of Aerospace Engineering
METU Center for Wind Energy (METUWIND)
Ankara, Turkey

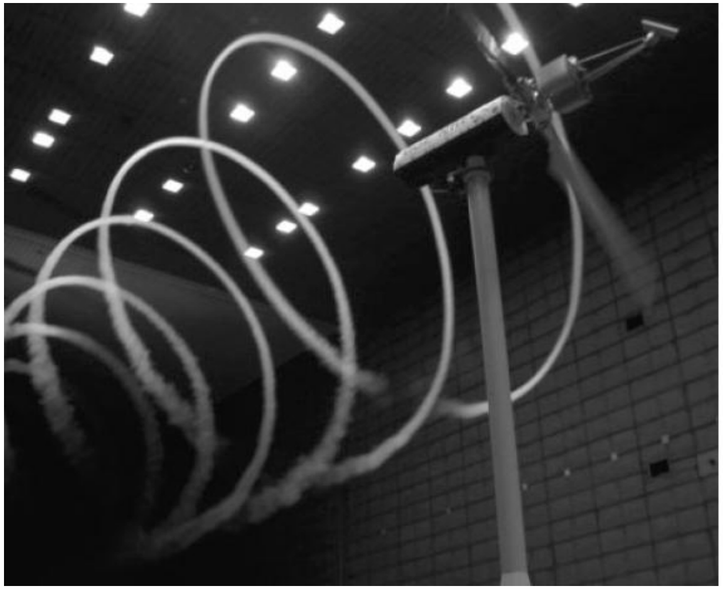
OUTLINE

- ❑ **Introduction**
  - ➢ The Tip Vortex
  - ➢ Previous Studies
- ❑ **Objective**
- ❑ **Experimental Setup**
- ❑ **Results**
  - ➢ Load measurements
  - ➢ Wake measurements
- ❑ **Conclusions**
- ❑ **Acknowledgments**

Introduction

The Tip Vortex

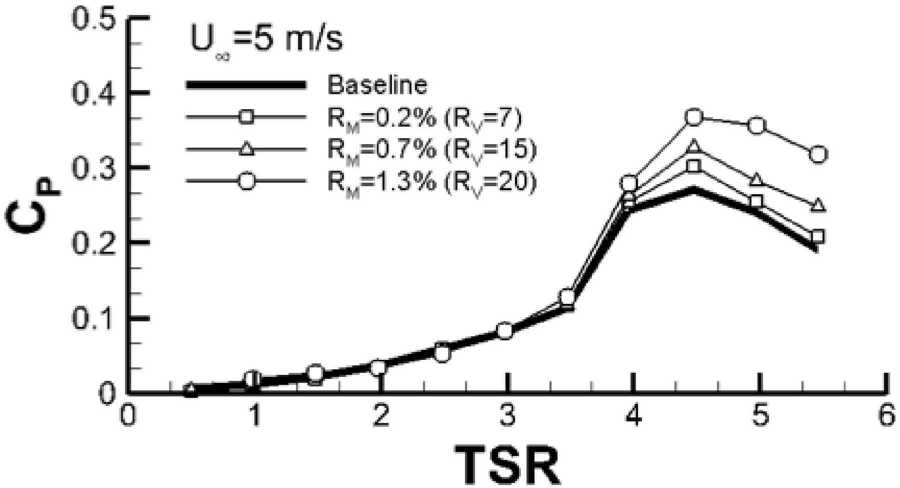
- Due to the lift generated by a wing/blade
- Aerodynamic performance losses
- Dominates the wakes, interacts with downstream rotors
- Noise
- Wind turbines, fixed-wing aircraft, rotorcraft, turbomachinery

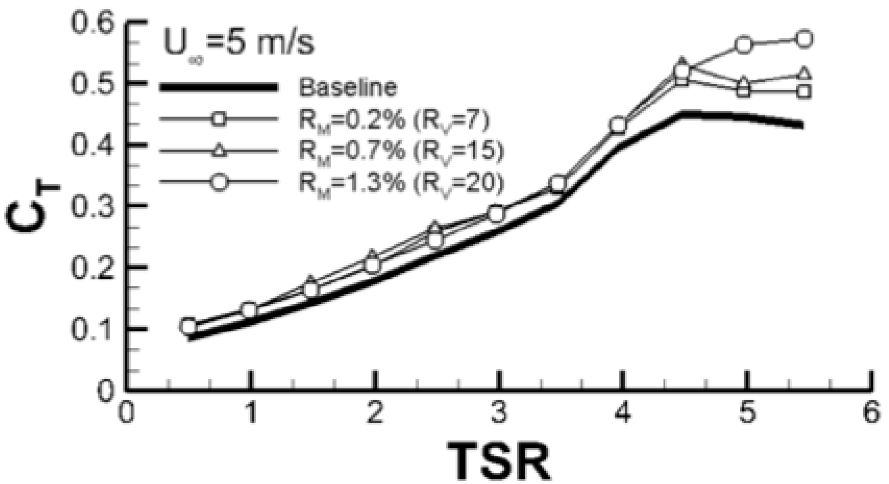


Introduction

Previous Studies on Tip Flow Control in Wind Turbines

- **Tip Flow Control Techniques:**
  - Special type V-shaped winglets (Mie Vanes) (Shimizu et al. [2003])
  - Winglets (Johansen and Sorensen [2006])
  - Vortex diffusers (Bai et al. [2011])
  - Tip injection (Anik et al. [2014]), (Abdulrahim et al. [2015])





Anik, E., Abdulrahim, A., Ostovan, Y., Mercan, B., Uzol, O., 2014. Active Control of the Tip Vortex: An Experimental Investigation on the Performance Characteristics of a Model Turbine. The Science of Making Torque from Wind (TORQUE2014), Journal of Physics: Conference Series 524 (2014)-012098.

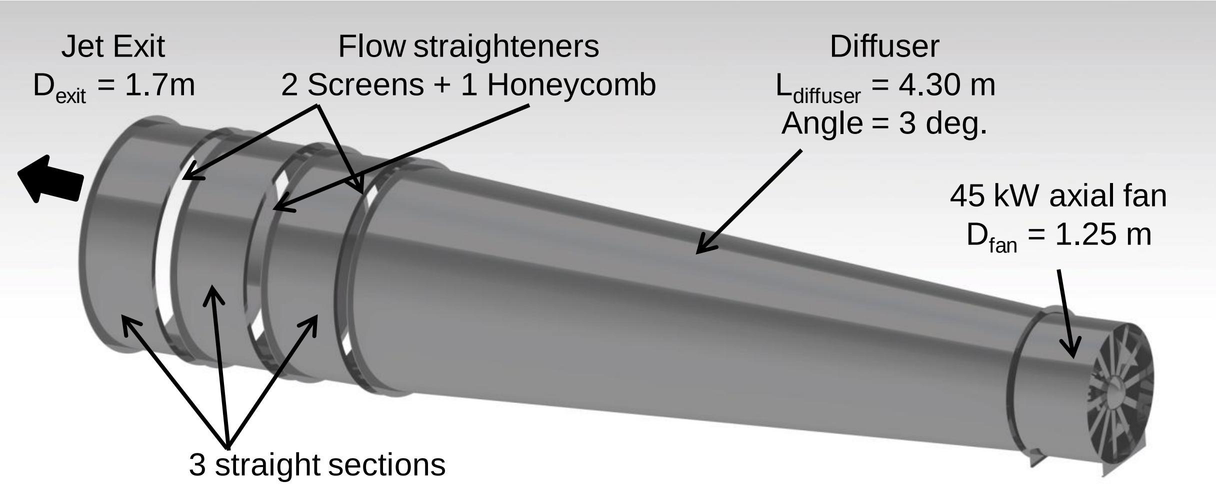
Tip Injection Research in Wind Turbines

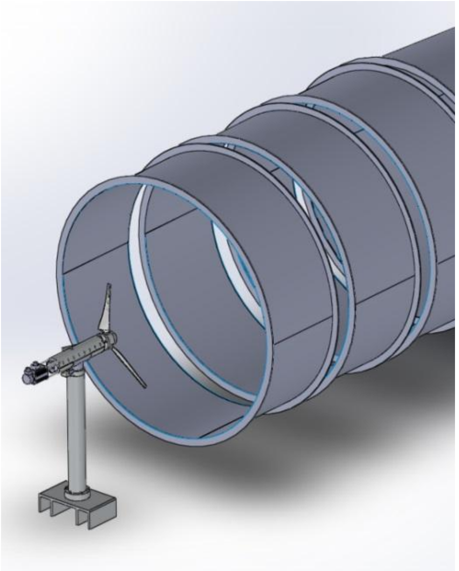
Objective

To investigate the effects of tip injection and Mie Vanes on load and wake flow field characteristics

Experimental Setup

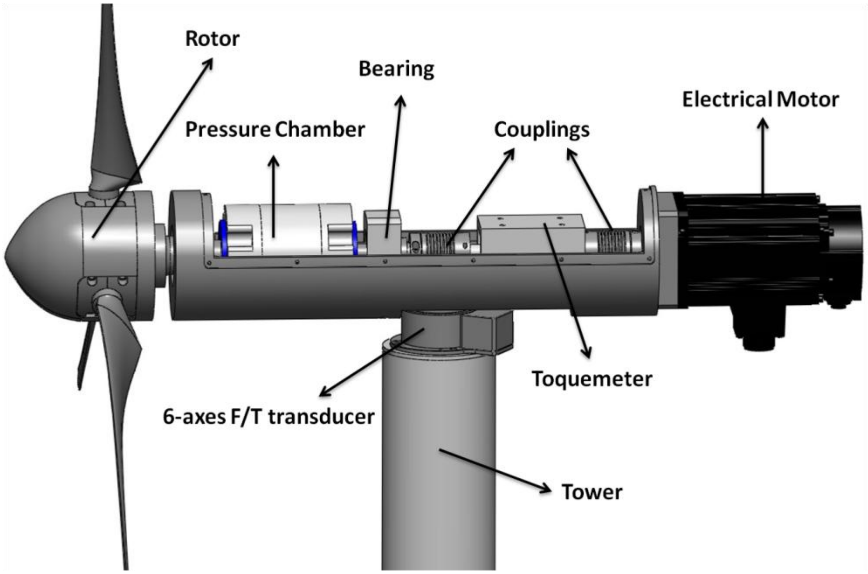
- Open-jet wind tunnel
- 45 kW electric motor and 1.2 m diameter fan
- 4.30 m long circular diffuser with a 3 deg diffusion angle
- Two screens and a honeycomb
- 1.7 m jet exit diameter
- Maximum jet exit velocity 10 m/s.
- Turbulence intensity around 2.5%

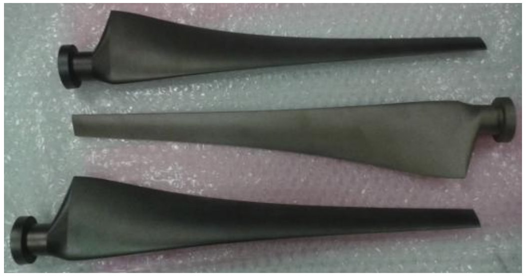




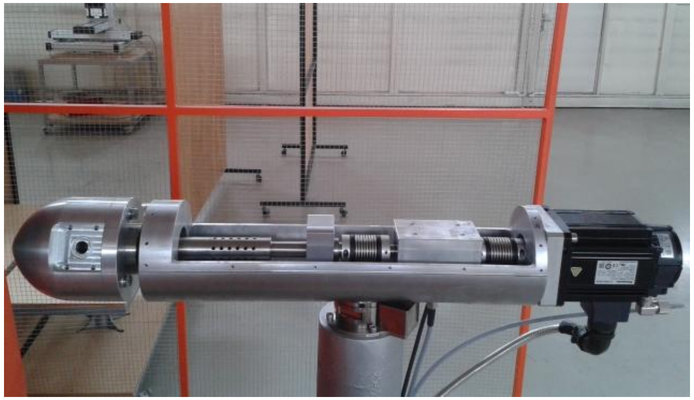
Experimental Setup

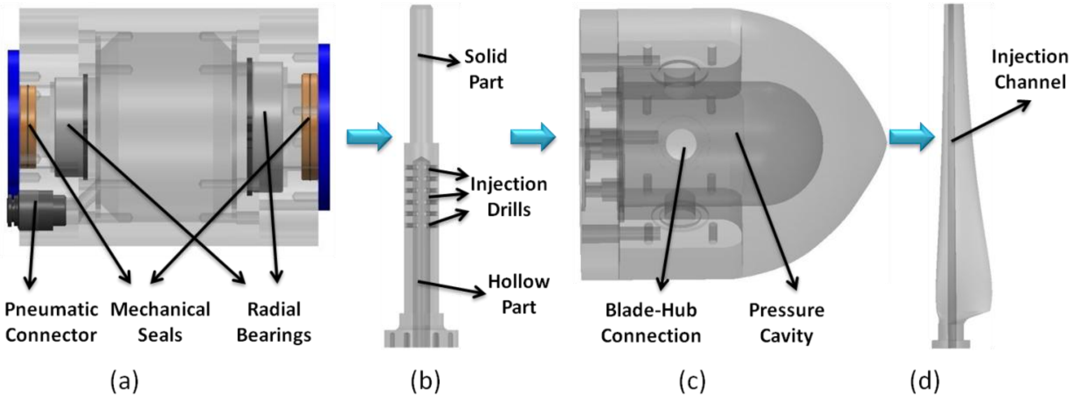
- Blades with NREL S826 profile (Replica of the NTNU rotor used in the Blind Test Experiments, *Adaramola and Krogstad [2011]*)
- Rotor diameter 0.95 m.
- Non-linear twist and chord distributions
- 3D printed titanium blades
- 1.5 kW speed controlled AC servo motor
- T20WN/5Nm torque transducer
- 6- axes F/T transducer
- Pressure chamber, hollow shaft and pressurized hub for air transfer for tip injection from the rotor blades.

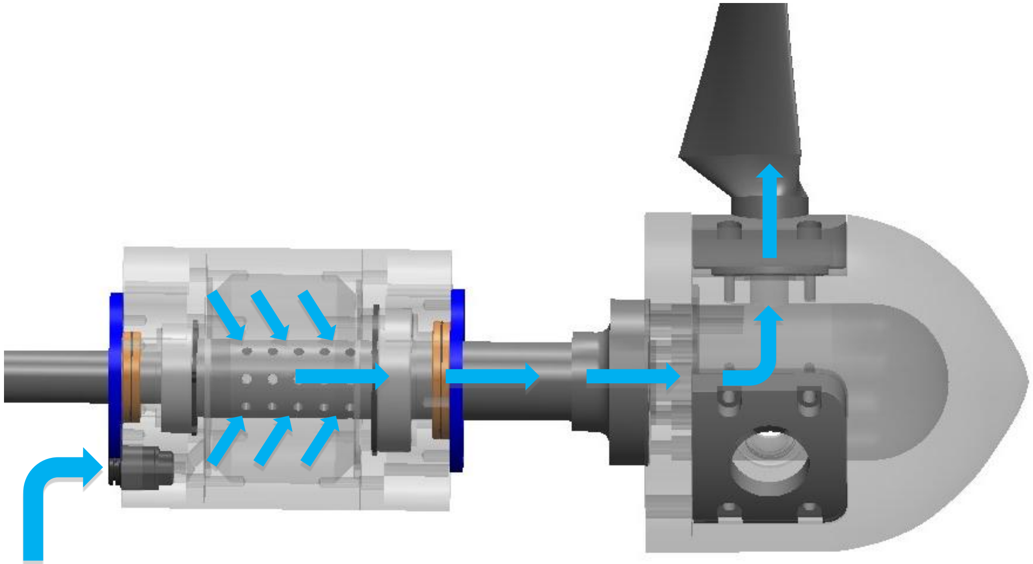


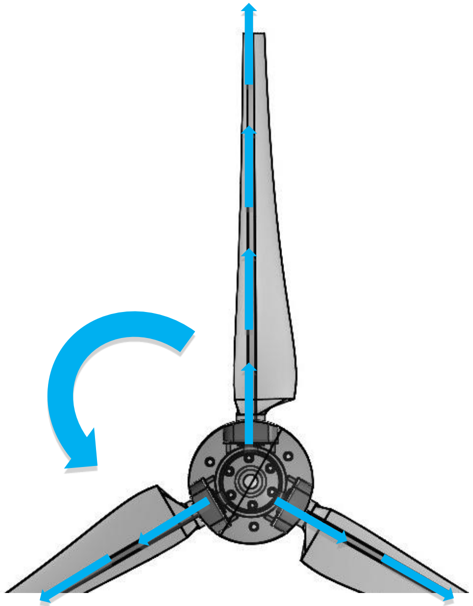


Experimental Setup

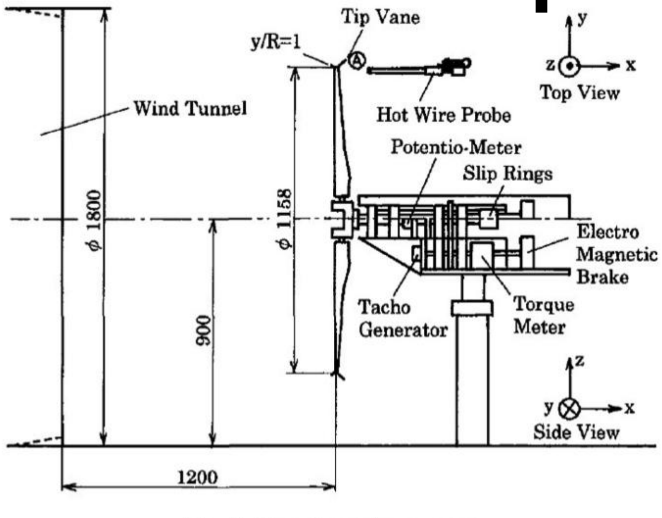


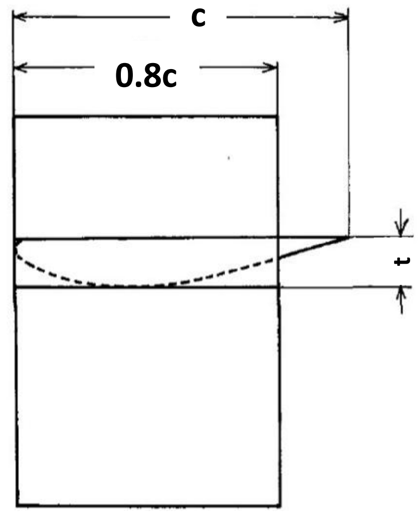


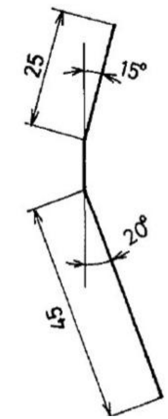




Experimental Setup



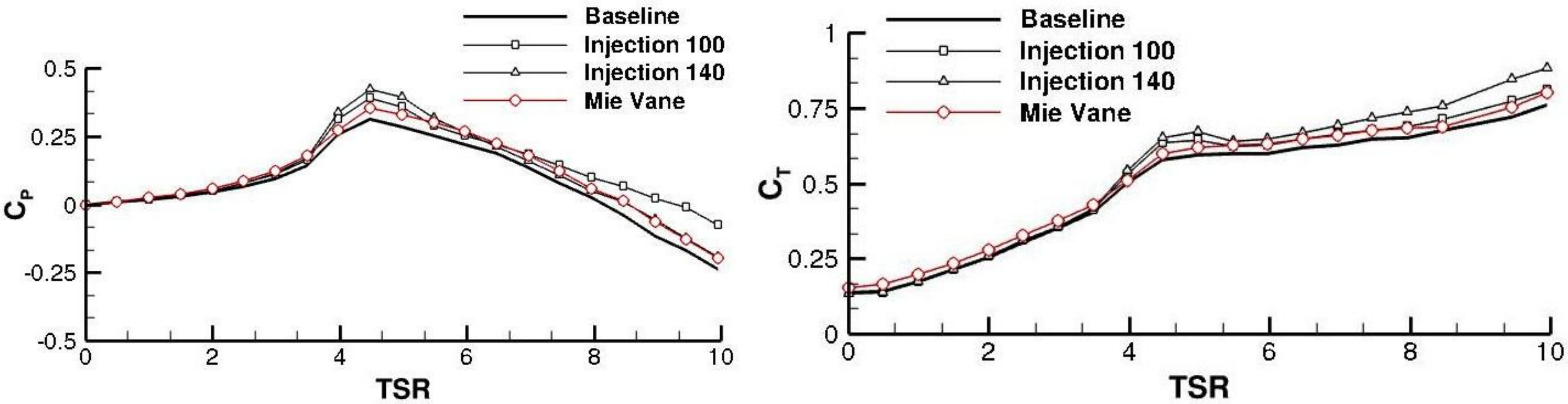




•Shimizu, Y., Imamura, H., Matsumura, S., Maeda, T., 1995, ''Power Augmentation of a Horizontal Axis Wind Turbine Using a Mie-Type Tip Vane: Velocity Distribution Around the Tip of a HAWT Blade With and Without a Mie-Type Tip Vane,'' ASME Journal Solar Energy Engineering, Vol.117, pp. 297–303.

Results

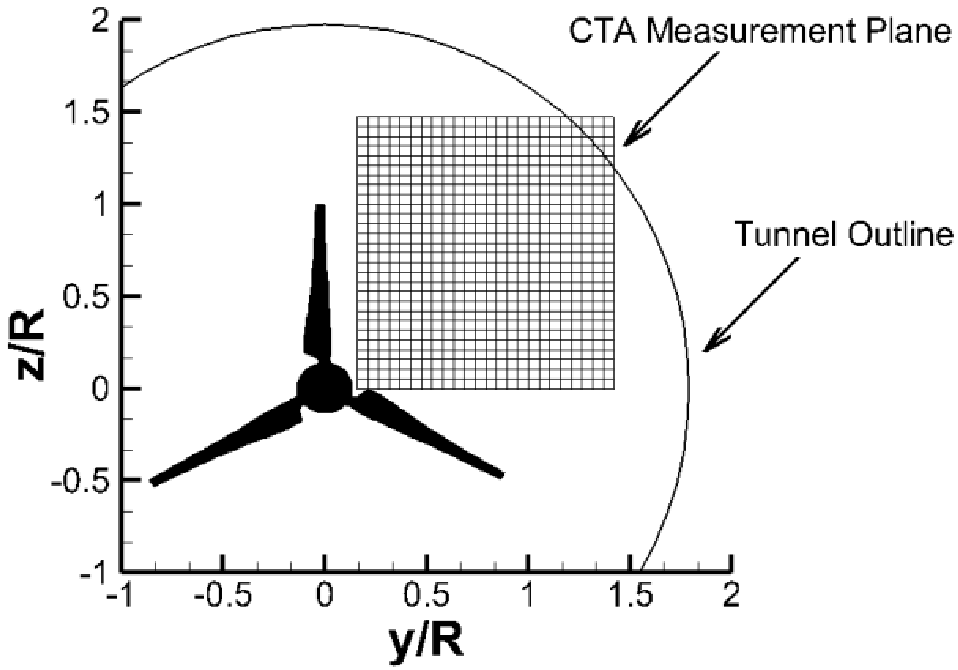
Load Measurements



Measured power and thrust coefficient variations with TSR at U_∞=5 m/s wind speed, for baseline, Mie-vane, injection momentum ratio of R_M=0.2% (injection 100 l/min) and injection momentum ratio of R_M=0.7% (injection 140 l/min) cases

Results

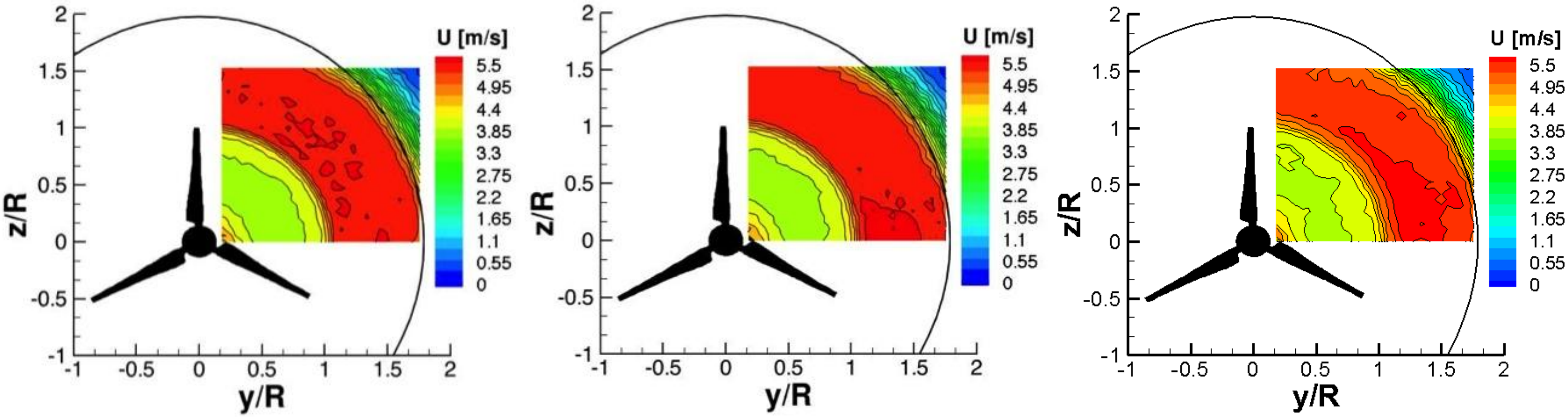
Wake Flow Field Measurements



- Single sensor CTA
- Axial location of 0.5D downstream
- Step size of Δy=Δz=2.5 cm
- Traverse area of 65 cm x 65 cm
- NI DAQ system through a LabView program.
- Sampling rate of 5 kHz for 5 seconds

Results

Wake Flow Field Measurements-0.5D Velocity

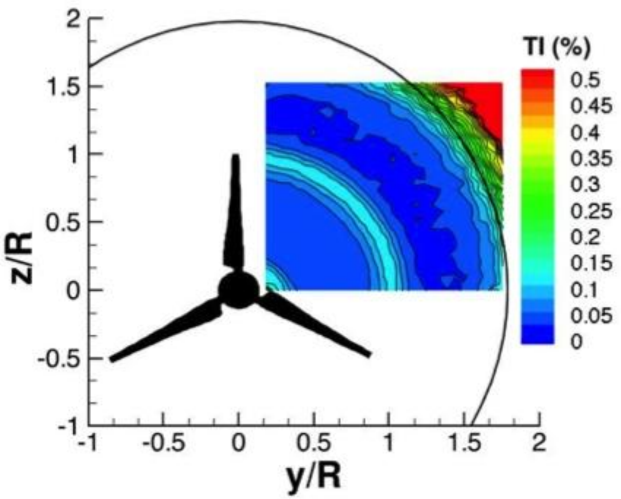


Baseline | Mie Vane | Tip injection

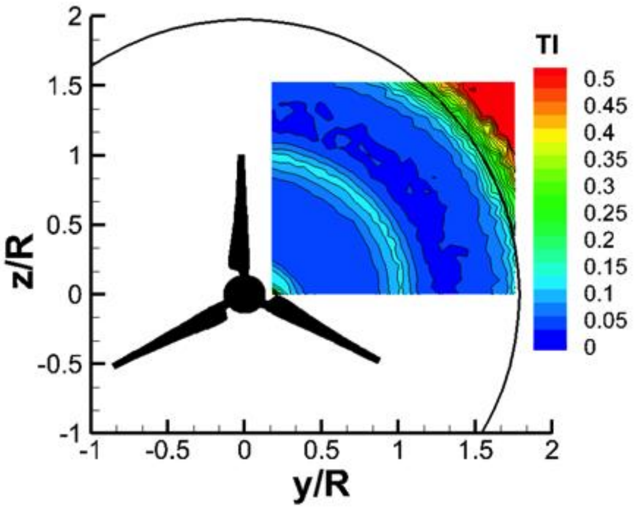
Abdulrahim, A., Anik, E., B., Uzol, O., 2016. Effects of Mie Vanes and Tip Injection on the Performance and Wake Characteristics of a HAWT. *AIAA SciTech, 4-8 January, San Diego, California*

Results

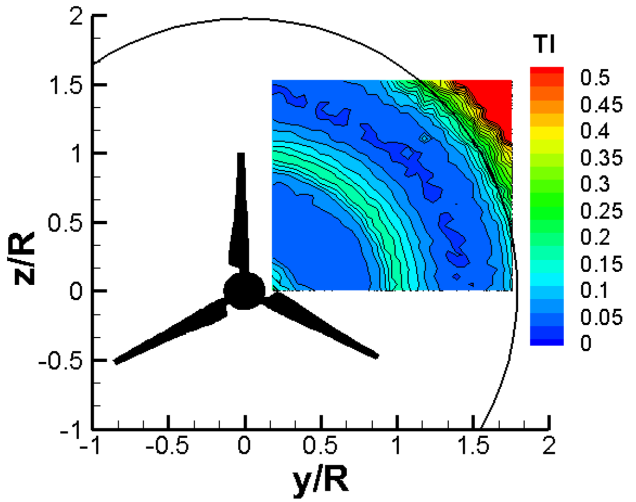
Wake Flow Field Measurements-0.5D Turbulence Intensity



Baseline



Mie Vane

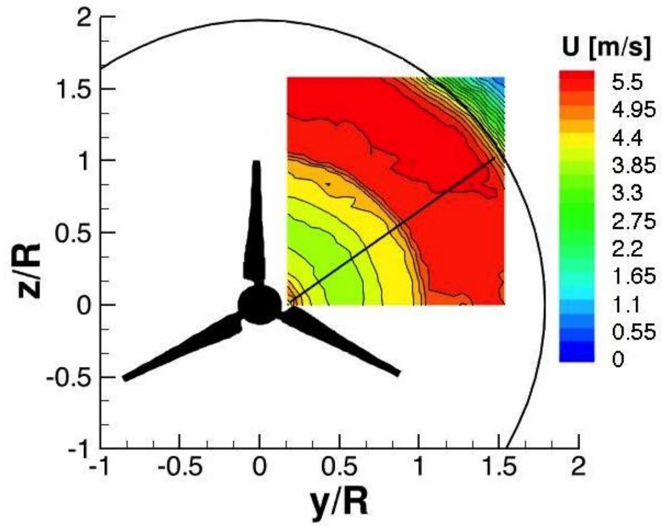


Tip injection

Abdulrahim, A., Anik, E., B., Uzol, O., 2016. Effects of Mie Vanes and Tip Injection on the Performance and Wake Characteristics of a HAWT. *AIAA SciTech, 4-8 January, San Diego, California*

Results

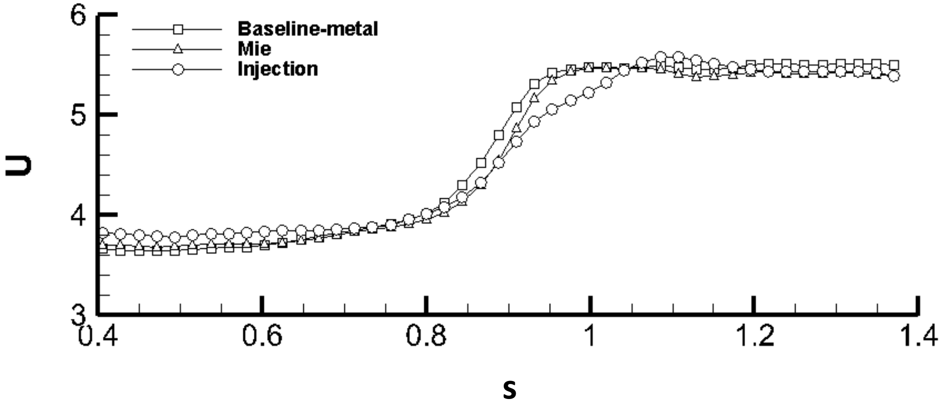
Wake Flow Field Measurements-0.5D Radial Variations

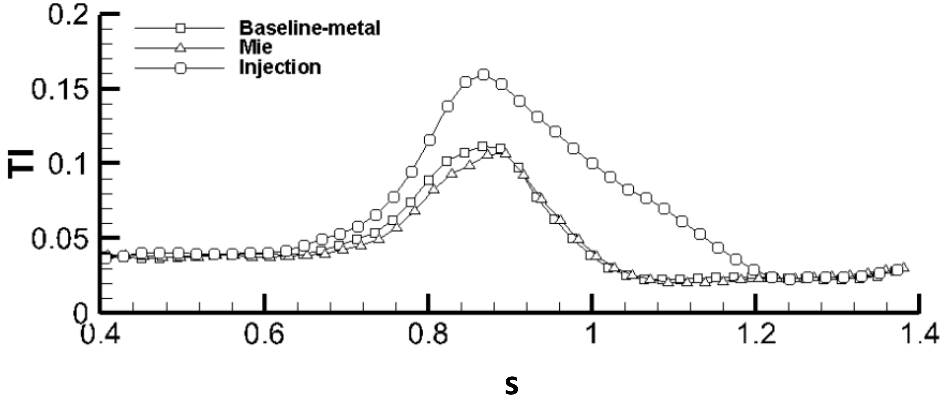


Radial direction at 0.5D downstream.

Results

Wake Flow Field Measurements-0.5D Radial Variations





Velocity (left) and turbulence intensity (right) variations along the radial direction at 0.5D downstream. *s* is the distance along the data extraction line shown in the previous figure.

Conclusions

- Tip injection and Mie Vanes do influence wake flow field and load characteristics.
- Power and thrust coefficients are increased at high TSR values.
- Tip vortex region gets widened and pushed radially outward.
- Velocity levels and gradients around tip vortex region get reduced for both.
- Turbulence levels are increased in tip vortex region for injection while Mie Vanes causes decrease in TI levels.
- Flow field needs further investigation (more load data at different wind speeds and injection cases and more wake data)

Acknowledgments:

This study is sponsored by:

- The Scientific and Technological Research Council of Turkey (TÜBİTAK) under the Grant No 112M105

- METU Center for Wind Energy (METUWIND)

Their support is greatly appreciated.