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3rd December 2004

Research and Development of Wind Energy at Mie University

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Department of Mechanical Engineering
Mie University, Japan

Introduction

1. Airfoil Study
2. Wind Tunnel Experiment
3. Field Rotor Experiment
4. Wind Assessment
   - Doppler SODAR Observation
   - Terrain Model Experiment
   - Rotor Wake Experiment

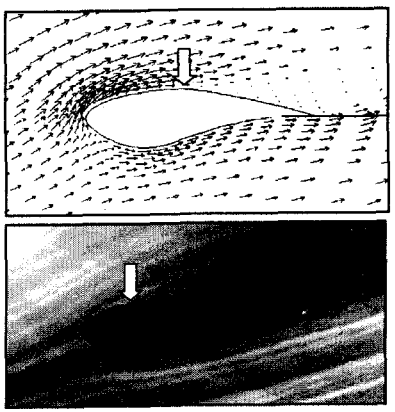
R&D Wind Energy

Wind Turbine Generator
Blade
Generator
Tower
Basement
Control

Siting
Wind Assessment
Ecological Assessment
Access
Grid
Visual Impact

Airfoil Study

Airfoil Study



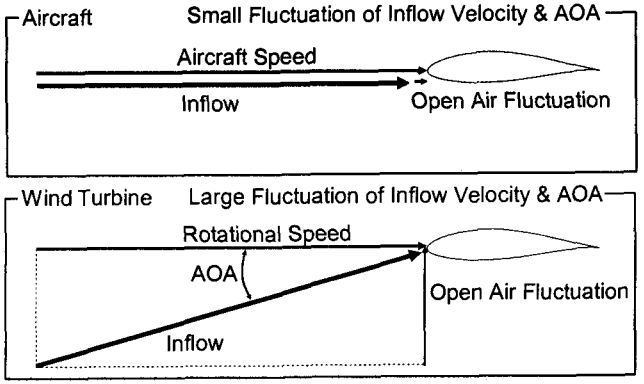
1st step

CFD

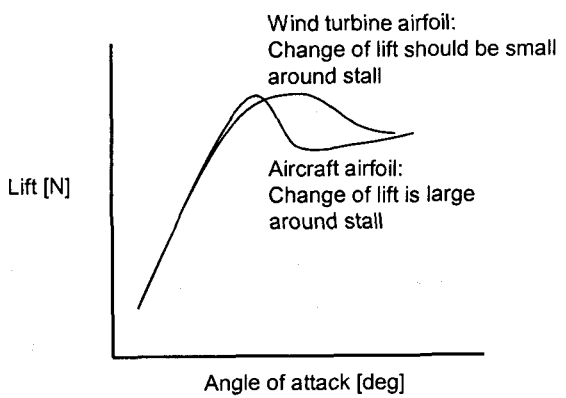
2nd step

Validation by Wind Tunnel Experiment

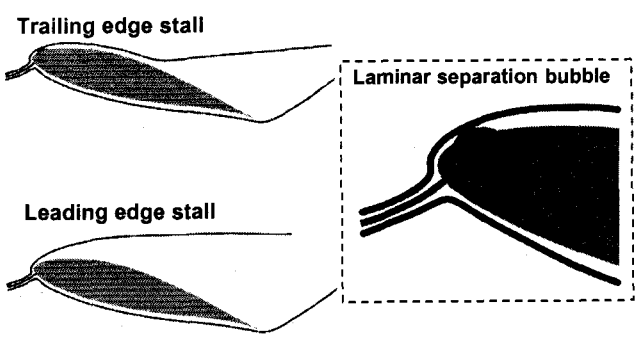
Unsteadiness of Wind Turbine Aerodynamics



Stall

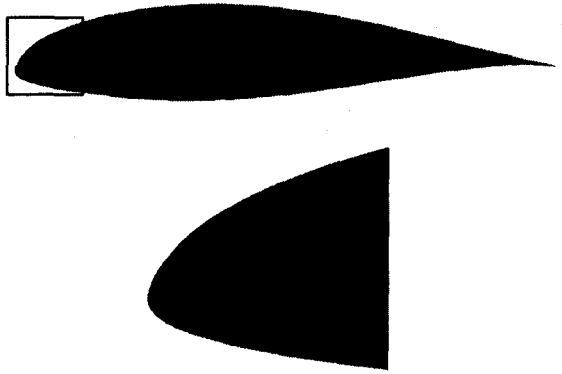


Separation



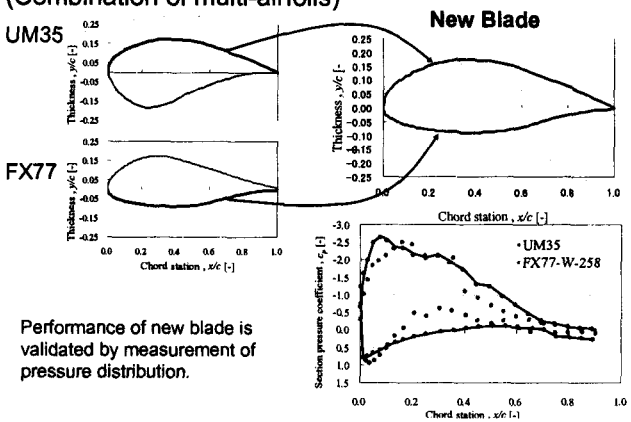
Airfoil Design

(Modification of well-known airfoil)



Airfoil design

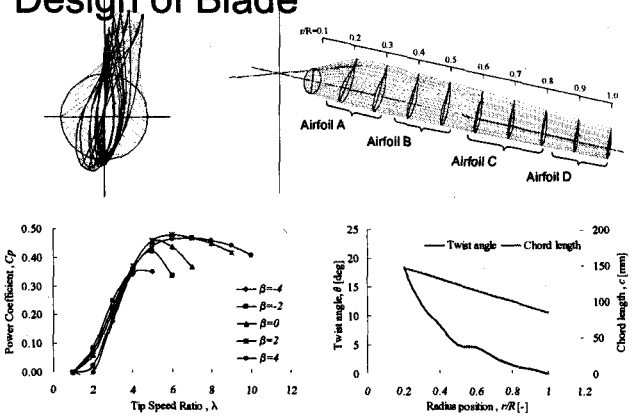
(Combination of multi-airfoils)



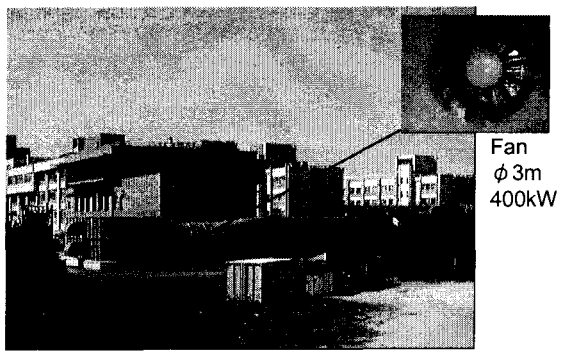
Performance of new blade is validated by measurement of pressure distribution.

Wind Tunnel Experiment

Design of Blade



Mie University Large Wind Tunnel



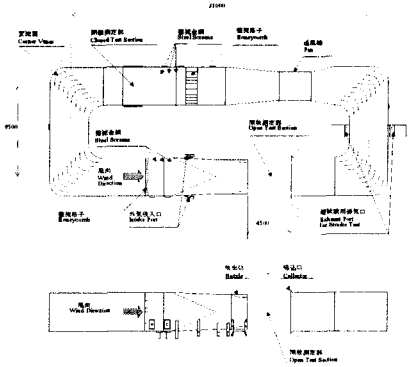
Fan
ϕ 3m
400kW

Mie University Large Wind Tunnel

One of the largest wind tunnel in Japan.

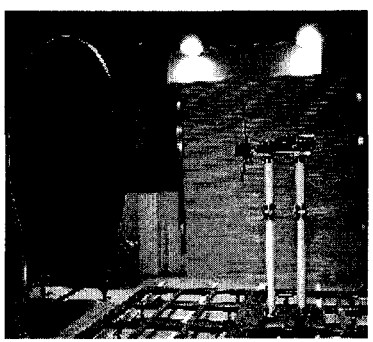
30m/s at tunnel outlet of 3.6m

R&D of low speed aerodynamics

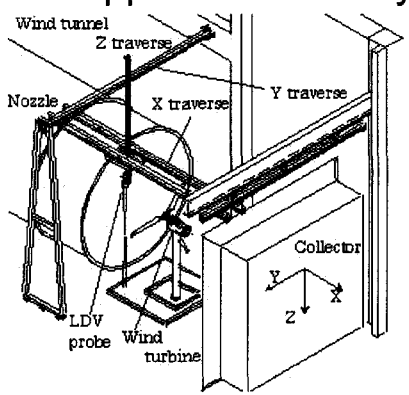


Model Rotor Experiment in Wind Tunnel

High performance or new concept wind turbines are developed in wind tunnel.

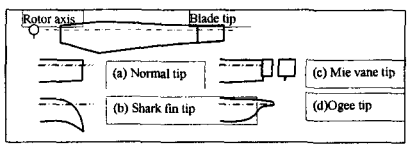


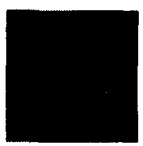
Velocity Field Measurement by Laser Doppler Velocimetry



Example of Velocity Field around Rotor

Flow Field near Blade Tip

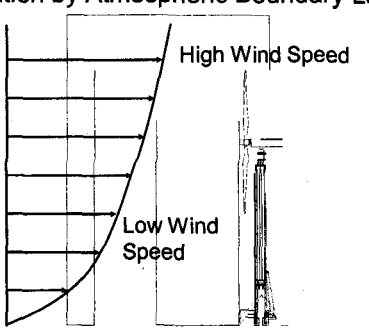




Field Rotor Experiment

Blade Performance

Unsteadiness by Open Air Speed
Fluctuation by Atmospheric Boundary Layer



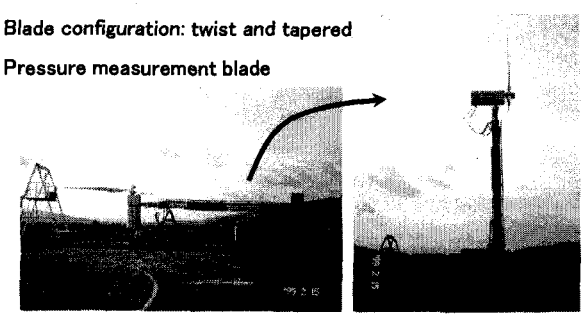
Open Air Rotor Research Facility of Mie University

3 bladed upwind horizontal axis wind turbine

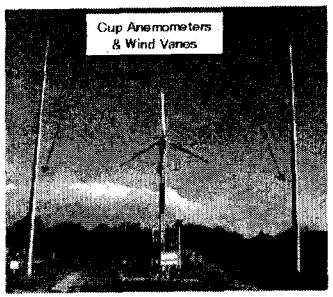
Rotor diameter: 10m

Blade configuration: twist and tapered

Pressure measurement blade



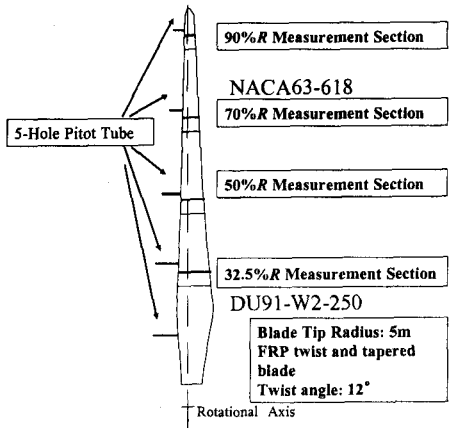
Open Air Rotor Research Facility



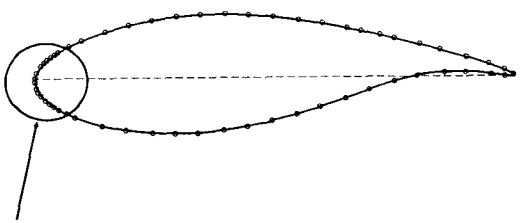
Rated Power: 30kW
Rotor Dia.: 10m
Hub Height: 13.3m

Control: Pitch
Generator Control: Variable Speed by Inverter

Pressure Measurement Blade

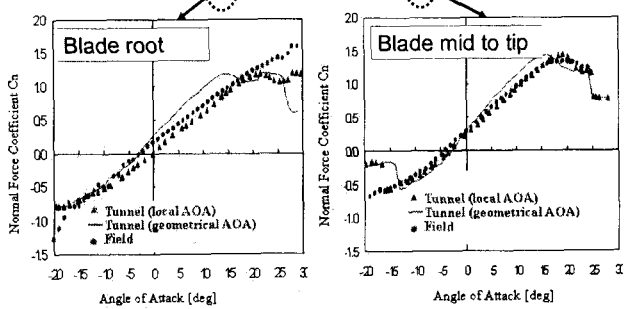


Position of Pressure Taps

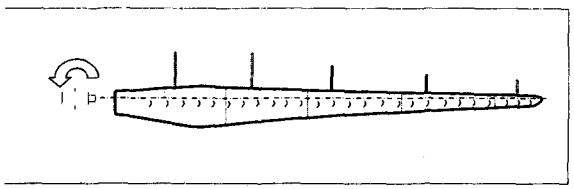


Pressure taps are concentrated at blade leading edge because pressure gradient is large at leading edge.

Effect of Rotation and Unsteadiness



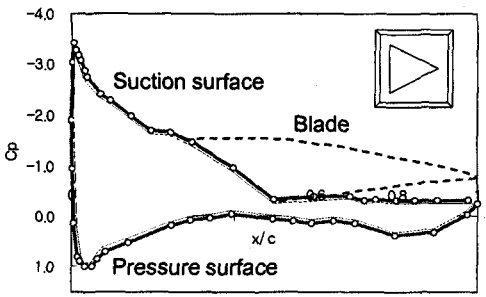
Tufts Visualization on Field Rotor Blade



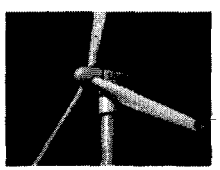
Yaw angle 0° Yaw angle −40° Yaw angle +40°

Pressure Distribution on Field Rotor

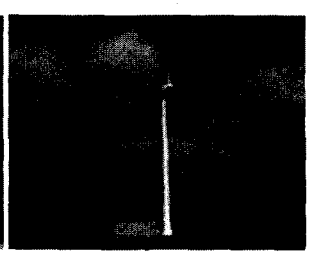
Lift is caused by pressure distribution on pressure surface and suction surface



100kW Machines



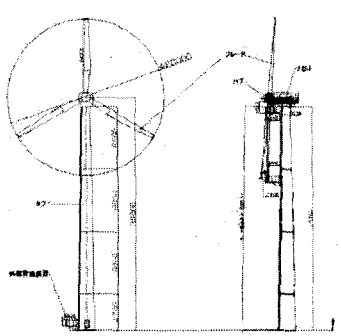
Demonstration Machine at University Main Campus



R&D Machine at University Farm

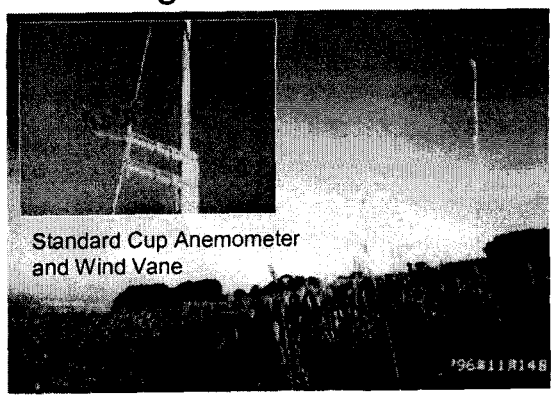
Specification of R&D Machine (University Farm)

Rated power	100kW
Type	Upwind HAWT
Rev. direction	Counter clockwise
Blade material	GFRP
Number of blades	3
Rotor diameter	20m
Hub height	30m
Tilt angle	5 deg
Rotor speed	20 - 80rpm
Control	Variable speed Full-span pitch
Cut-in	2.5m/s
Cut-out	25m/s
Rated wind speed	13m/s
Grid connection	AC=DC=AC by inverter
Direction control	Active yaw
Generator	3 phase 6 poles permanent magnet synchronous
Voltage	400V



Wind Assessment

Meteorological Mast



Purpose of Measurement of Higher Layer Wind

Japan: Limited space, Complex terrain

↓

Large wind turbine of hub height more than 60m

↓

Much risk: estimation of higher layer wind more than 60m using lower layer wind at 30m
WTG power is proportional to (wind speed)^3

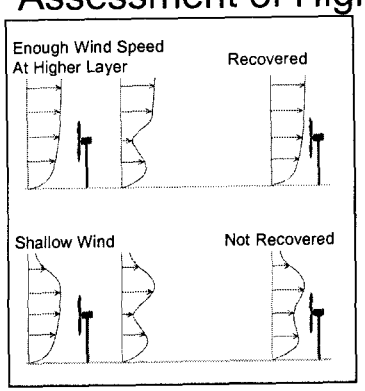
↓

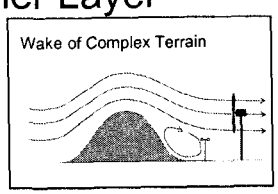
Necessity of direct measurement at high layer wind

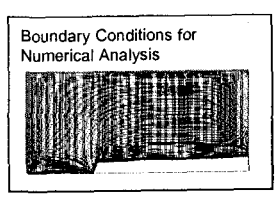
↓

Doppler SODAR, Captive Balloon, Pilot Balloon etc.

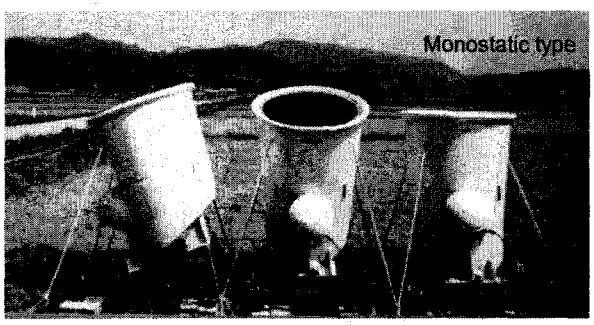
Application of Wind Assessment of Higher Layer



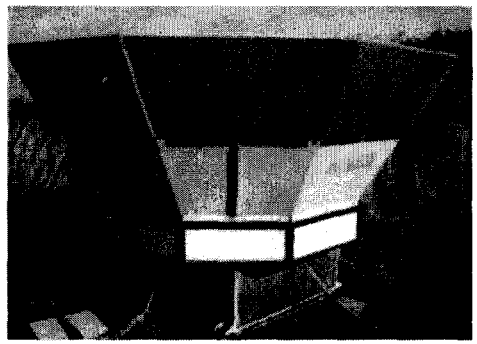




Doppler SODAR
(Doppler Sonic Rader)

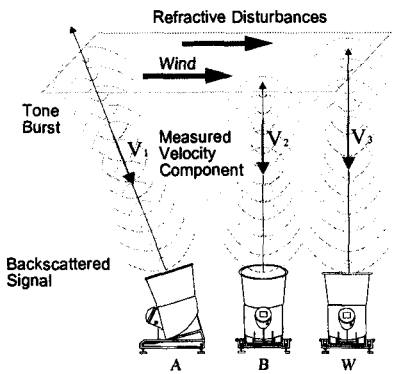


Doppler SODAR
(Doppler Sonic Rader)



Phased array type

Principle of SODAR Observation



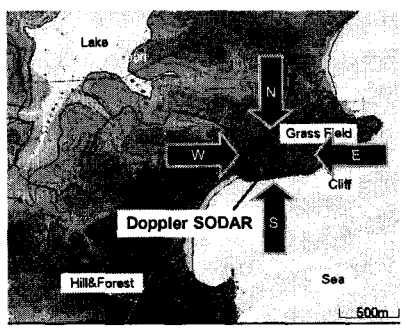
3 beams once every 10 sec
1 cycle = 30 sec

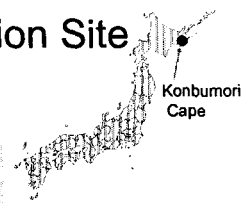
Calculation of wind speed:
by difference of frequency between transmitting sound and receiving sound

Simultaneous measurement at 32 layers:
by time interval between transmitting time and receiving time

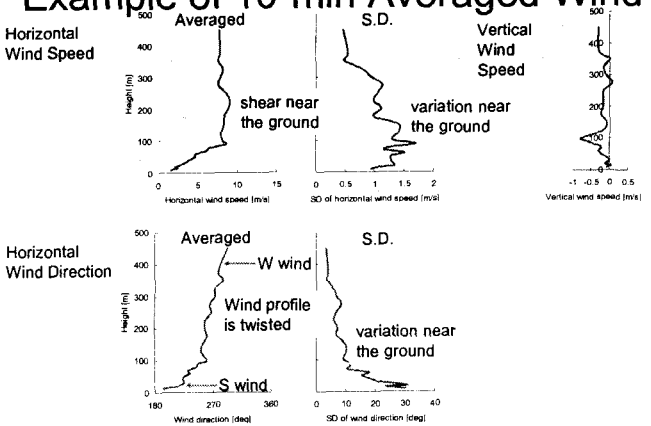
Height: up to 1000m
mixing pulses method
- short pulse: 10m – 200m
- long pulse: 200m – 1000m

Example of Observation Site

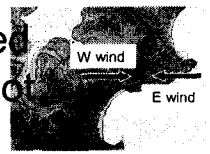




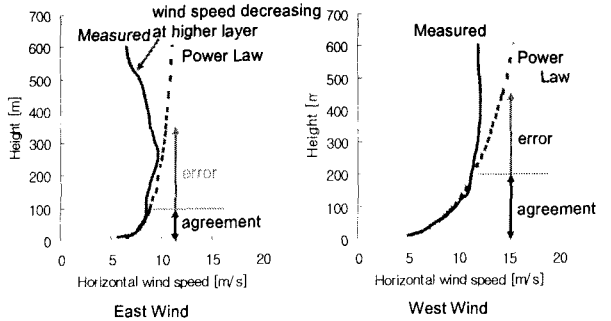
Example of 10-min Averaged Wind



Comparison of measured profile and power law plot



Power law plots are determined by measurement data of 10 to 100 meters high.



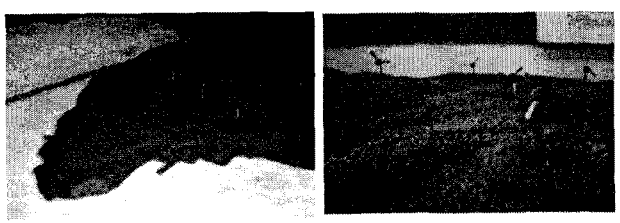
Terrain Model Experiment

(Wind Tunnel Experiment)

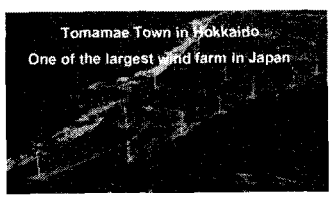
Wind Assessment

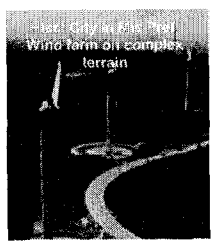
Layout of Wind Turbines

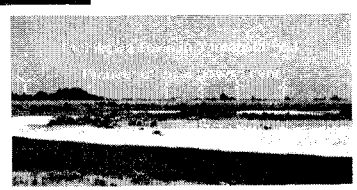
Comparison of SODAR Observation



Results of SODAR Assessment

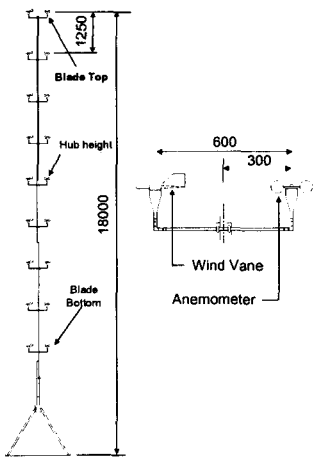




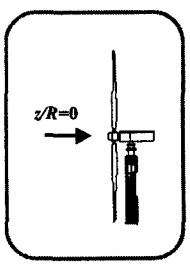


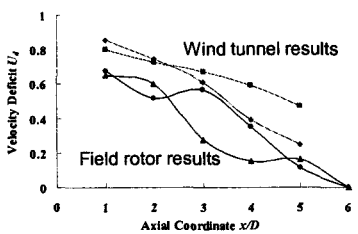
Rotor Wake Experiment

Field Rotor



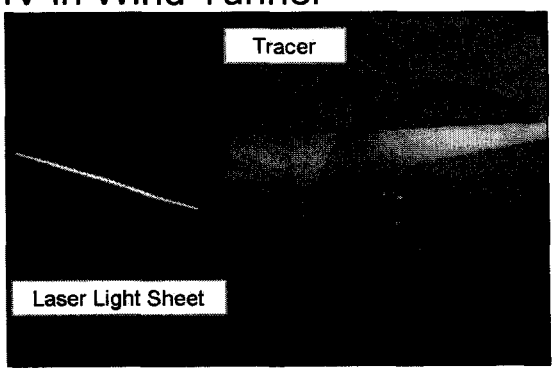
Velocity Deficit



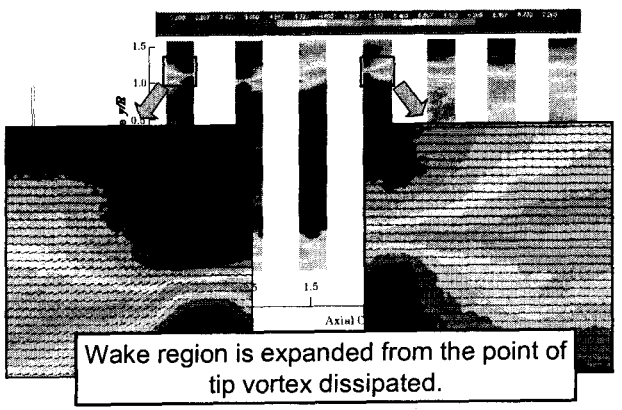


Wake velocity behind field rotor is recovered in shorter distance than those for the wind tunnel experiment.

PIV in Wind Tunnel



Tip Vortex by PIV Experiment



Wake region is expanded from the point of tip vortex dissipated.

Conclusion

For the future of Wind R&D in Japan

Present, Researchers of Fluid Engineering

⇩

Now increasing, Researchers of Electrical Engineering

⇩

Future, Material

Energy Storage

Design, Visual Impact

Ecological