

Wind Turbine Applications

Engineering
Flow-Measurement
Solutions



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Aeroprobe Technology:

Probes and Services

We have over 10 years' experience providing multi-hole probe solutions for difficult measurement applications. "Customization is our standard" – tell us about your application requirements and we will work with you to identify the best Aeroprobe geometry for you! We don't supply just the probes, but also the system support required for Aeroprobe measurement, including:

- Wind Turbine Air-Data Probes
- Standard & Custom Designs
- Stress/Deflection Analysis
- Various Mounting Options
- High-Accuracy Probe Calibrations
- NIST-Traceable Pressure Sensor Calibrations
- Pitot-Static Probes & Rakes
- Embedded Heater Option
- Purge System Analysis & Testing
- Frequency Response Analysis & Calibrations
- Consultation for Pressure Sensors & Scanners
- Data Acquisition & Reduction Software
- System Uncertainty Analysis

Installing the Aeroprobes

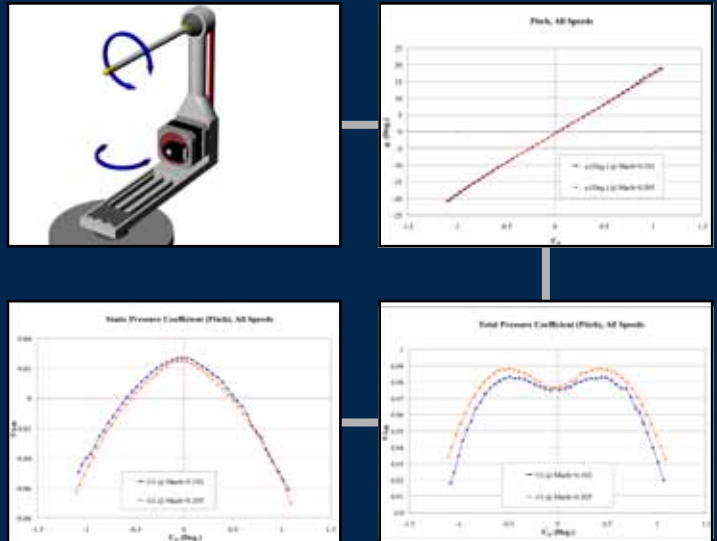
The Aeroprobes are typically installed by securing them to the blade spar. An option is to use a receptacle secured to the spar, so that the probe can be inserted and secured from the outside of the blade. It is easiest to accommodate the probes/receptacles as the blades are being manufactured, but retro-fitting blades is also possible.

How the Aeroprobes Work

The multi-hole probe is capable of measuring the 3D flow vector at the probe tip. A robust aerodynamic probe calibration is performed in which the pitch angle, yaw angle, total pressure and static pressure are mapped to the probe port pressures. On the turbine, the probe pressures are measured with pressure sensors or scanners, and digitized. The probe calibration is then used to determine the flow angles and speed relative to the probe (to within $\pm 0.15^\circ$, 0.35% FS speed). The probe reduction can be performed quickly, so that it can be implemented in a control routine.

Employ Aeroprobes to:

- Gather Data at the Position of the Operating Rotor
- Characterize Rotor Inflow for
 - Wind Shear
 - Turbulence
 - Terrain Effects
 - Wakes of Upstream Turbines
- Provide Information for Power Curve Determination
- Provide Information for Blade Pitch Control



**Clockwise From Upper Left:
Probe Calibration Mount, Graph of Angle of Attack
Coefficient, Graph of Total Pressure Coefficient, Graph of
Static Pressure Coefficient**

References

1. <http://wind.nrel.gov/amestest/>
2. Madsen, A.M., Fischer, A.F., "Wind Shear and Turbulence Characteristics from Inflow Measurements on the Rotating Blade of a Wind Turbine Rotor," EWEC Conference 2009, Marseille, France.

Know Your Flow!!

Wind shear and turbulence can detract from wind turbine performance. New, larger rotors means large variation of inflow over the rotor diameter. Accurate measurement of the inflow to the rotor with **Aeroprobes** mounted on the wind turbine blades leads to increase blade performance.



3mm Aeroprobe,
for Small Blades



8mm Aeroprobe with
Heater Option, for Large Blades

Aeroprobe Wind Turbine Applications:

NREL and Dept. of Energy

The NREL “Unsteady Aerodynamics” research wind turbine is extensively instrumented to measure structural loads and aerodynamic responses of a rotating airfoil. Five 3mm Aeroprobes were fabricated by Aeroprobe and installed on the black blade, as shown in the figures at right. The probes are installed on special booms mounted on the blade leading edge and rotate with the blade.



Five Aeroprobes Mounted on Instrumented
NRELDOE
Rotor Blade (Photo Courtesy NREL)



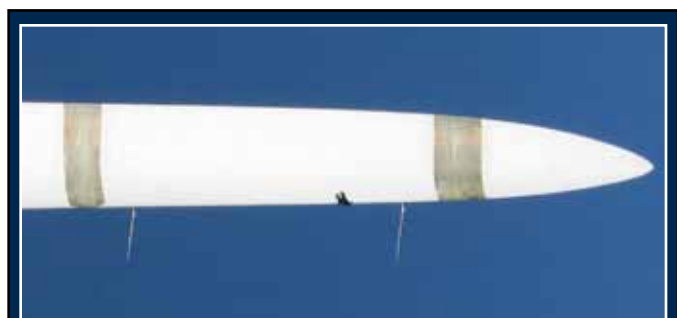
NREL-DOE Wind Turbine, with
Aeroprobes Mounted on Black Blade
(Photo Courtesy NREL)

Data and reports¹ summarizing results of the atmospheric turbine tests have demonstrated the dynamic nature of the typical wind turbine operating environment. Highly turbulent wind and sheared inflow conditions are major factors that contribute to the complexity of the inflow. The Aeroprobes allowed NREL to measure the inflow in these conditions, so that the performance of the blade could be determined.

Risoe National Laboratory (Denmark)

Aeroprobes mounted on a several different wind turbines have provided inflow data for tests performed by Risoe National Laboratory and their partners. Pictures of the probes mounted for one such test is shown at right. The data acquired over the rotorplane has been used to compare inflow at various parts of the rotor disc. Typical upstream tower measurements cannot provide this information.

Risoe has shown that the inflow data as input to a method that can calculate the wind shear and turbulence in the freestream². This method was demonstrated in tests on a 3.6MW turbine. It was found that wind shear and turbulence varied considerably from one position of the blade to another – a result made possible by application of the probes.



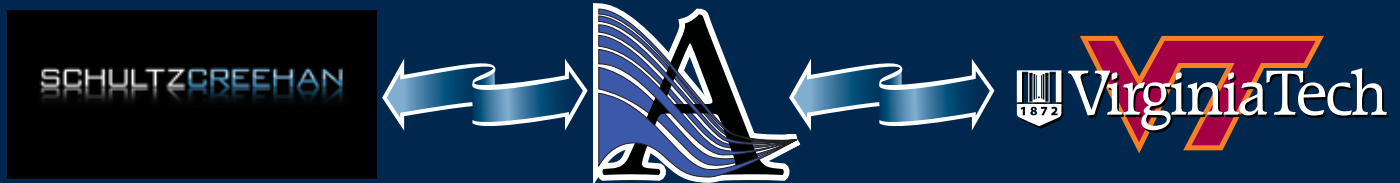
Aeroprobes Mounted on Blade Leading Edge
on 2MW, 80m Rotor
(Photo Courtesy Vestas/Siemens/Risoe National Lab)

Aeroprobe Mission:

Design, develop, manufacture, and deliver 21st -century technology air/liquid flow measurement probes characterized by miniaturization, high accuracy & fast response.

More About Aeroprobe:

Aeroprobe works closely with manufacturing partner Schultz-Creehan to design, test, and produce high-quality, custom-built measurement devices and equipment employing modular lean-manufacturing methods. Schultz-Creehan has unique mechanical and electronic design, test, and simulation capabilities, which are applied to meet specific customer needs.



A Virginia Tech spin-off, Aeroprobe Corporation is located in the VT Corporate Research Center. Maintaining close ties with VT enables Aeroprobe to perform basic and applied research aimed at advancing probe technology.

Aeroprobe Customers:

Risoe National Laboratory

Sandia National Laboratory

General Electric

Vestas

Siemens

National Renewable Energy Laboratory
(NREL)

International Business:

With distributors in 20 countries and approximately 50% of sales outside the USA, Aeroprobe is an internationally recognized name.

We have distributors in the following countries:

A globe with a grid overlay, showing the distribution of Aeroprobe's international business. The globe is centered on the Atlantic Ocean, with the Americas on the left and Europe and Africa on the right. The following countries are listed around the globe:

Argentina	Germany	Portugal
Australia	India	Singapore
Austria	Italy	Slovakia
Belgium	Japan	Spain
Brazil	Korea	Sweden
Czech Republic	Mexico	Switzerland
Finland	Netherlands	Turkey
France	Norway	U.K.

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