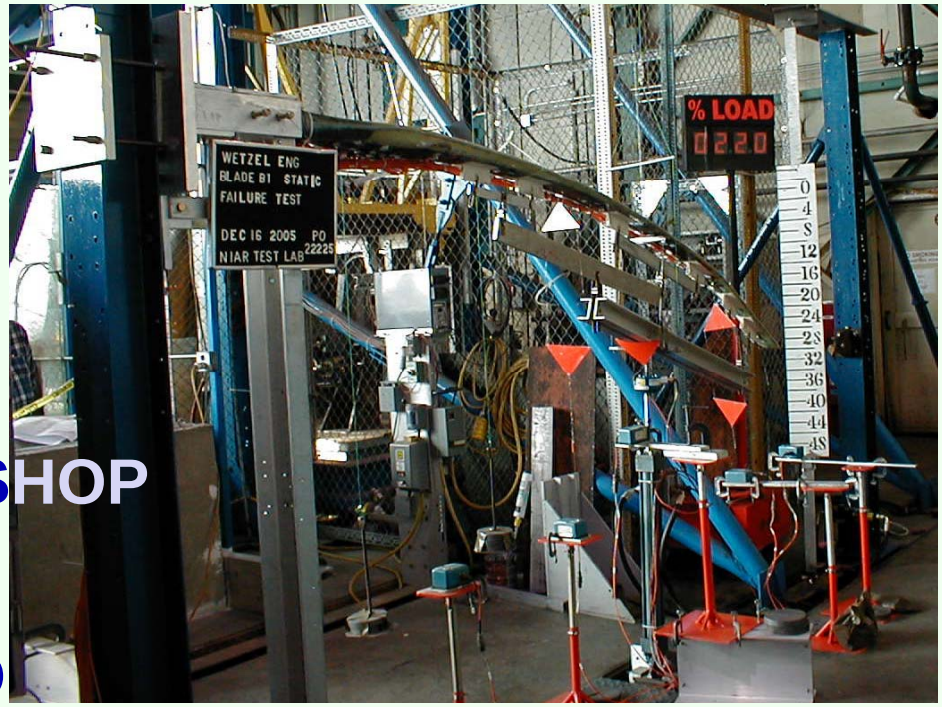
High-efficiency Engineered Blades for Small Turbines

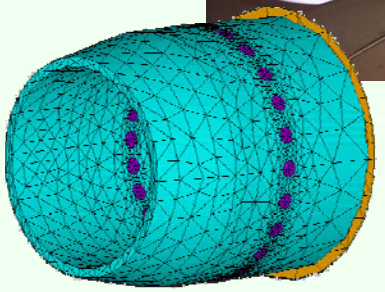
KYLE K. WETZEL, PH.D.
WETZEL ENGINEERING, INC.
LAWRENCE, KANSAS

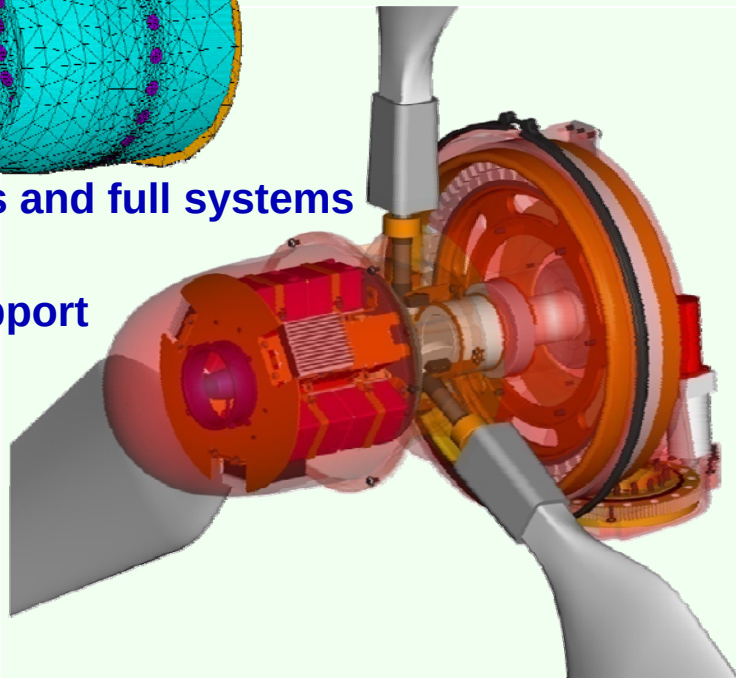


2008 SANDIA BLADE WORKSHOP
MAY 12-14, 2008
ALBUQUERQUE, NEW MEXICO

WETZEL ENGINEERING

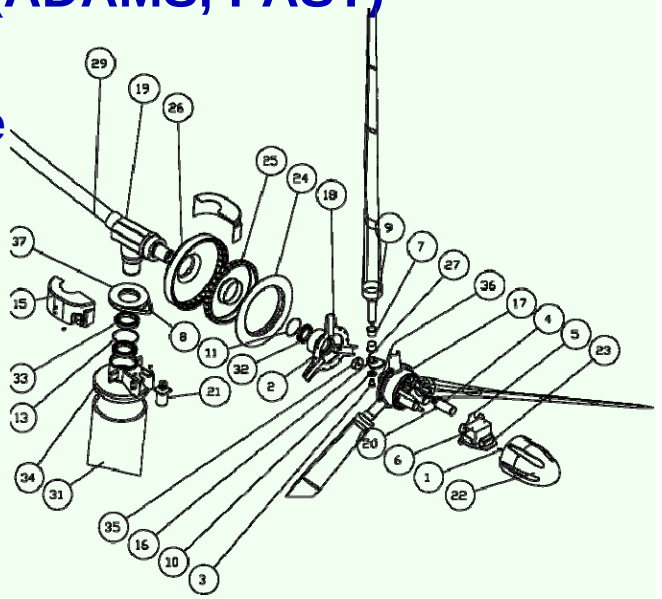
- In Business Since 2001
- Includes 7 Associated Consultants
- Engineering Services for the Wind Energy and Aviation Industries
- Clients include:
  - System and Component Manufacturers
  - Power Project Developers
  - Federal and State Government Agencies
  - Universities and Research Institutions
  - Legal and Financial Interests
- Services we provide include:
  - Concept Feasibility Studies – both components and full systems
  - Hardware Design and Analysis
  - Hardware Design Certification Engineering Support
  - Materials testing and certification support
  - Component testing and certification support
  - Intellectual Property Technical Expertise





WETZEL ENGINEERING

- Structural Analysis (ANSYS, NASTRAN)
- Structural Testing (Coupon & Blade) with 3rd Party Labs
- Dynamics, Loads, & Performance Analyses (ADAMS, FAST)
- Aerodynamics
  - Airfoil Design using XFOIL and Eppler's Code
  - Computational Fluid Dynamics (CFD)
  - Wind Tunnel Model Construction & Testing
- Wind Turbine Design
  - Rotor Aerodynamic and Structural Design
  - Composites Manufacturing Engineering
  - Conceptual Development
  - Drivetrain Design and Analysis
  - Wind Turbine Performance Analysis
- Wind Energy Economics & Feasibility Analysis

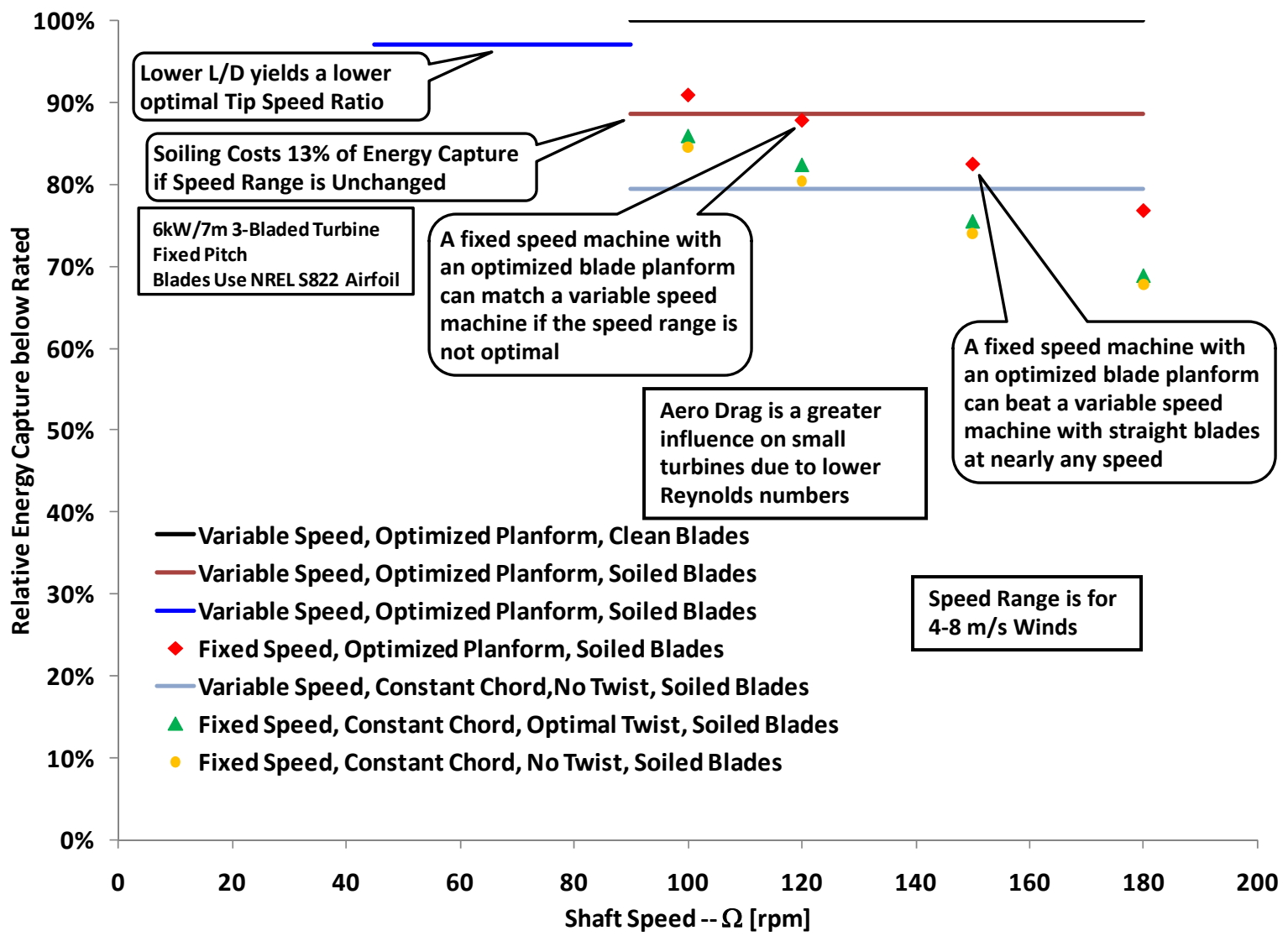


Wind Turbine Configurations

	Utility Scale			Small Wind			
Variable Shaft Speed	NO	NO	YES	NO	NO	YES	YES
Blade Pitch Regulation	NO	YES	YES	NO	NO	NO	NO
Blade Taper	YES	YES	YES	NO	YES	NO	YES
Blade Twist	YES	YES	YES	NO	YES	NO	YES

Obsolete →

Small Wind Turbine Performance

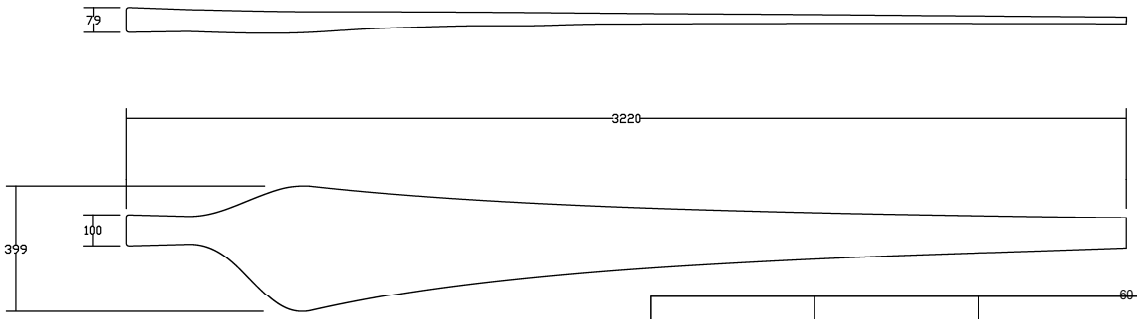


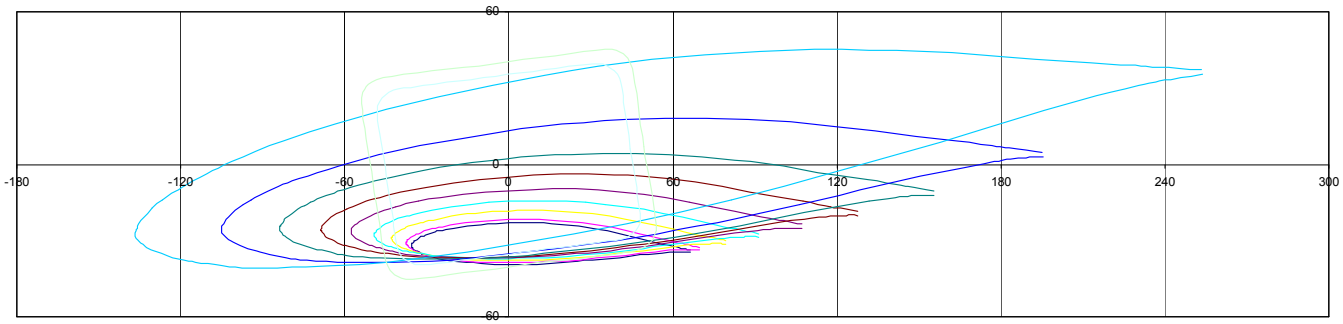
WETZEL ENGINEERING
SMALL BLADE VENTURE

- Design & Manufacture Aerodynamically & Structurally Efficient Blades for Turbines Up to 100kW (~12 m)
  - Optimized twist & taper
  - High-quality structural design
  - High-quality manufacturing → VARTM
  - Glass and Carbon
  - Advanced concepts (e.g., aeroelastic tailoring)
- Custom Designs
- Standard Designs

Aerodynamic Planform Design

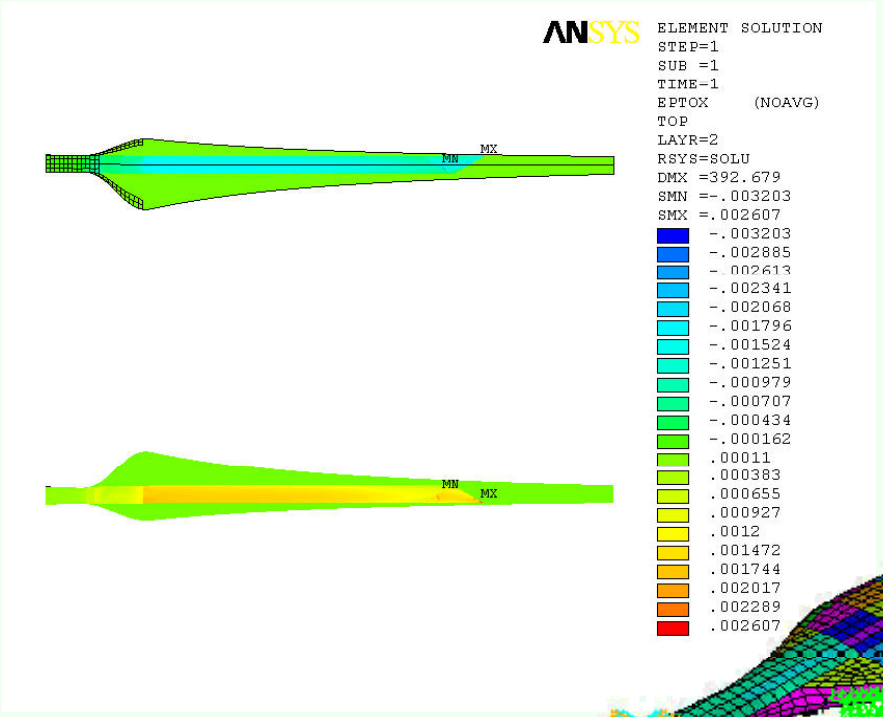
- Not a point design for 1 Tip Speed Ratio
- Design Maximizes energy capture over the entire range of below-rated wind speeds, considering:
  - shaft speed schedule (e.g., fully or limited variable or fixed)
  - pitch schedule optimization (if applicable)
  - Reynolds number and soiling effects
- Iterative and/or GA routines

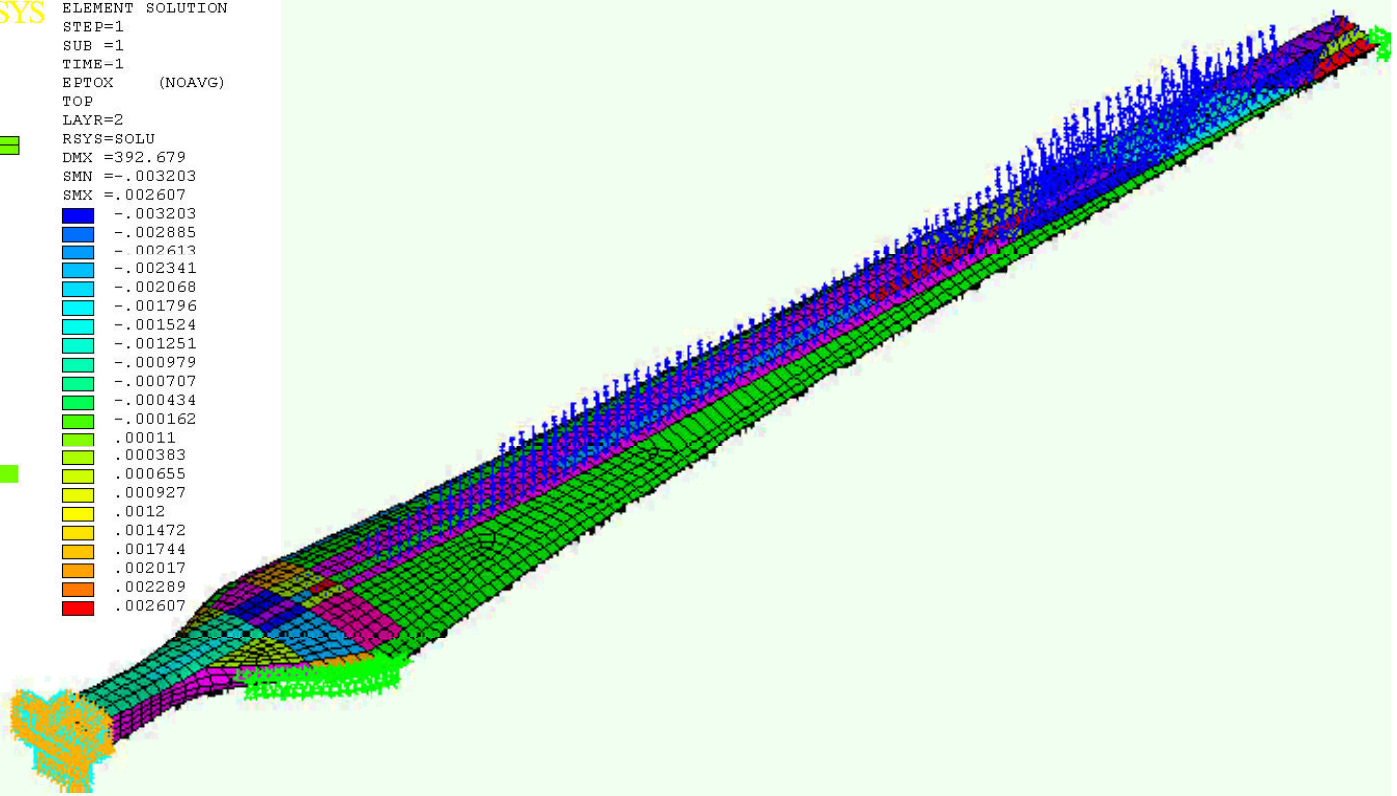




Structural Design

- In-house optimization tools determine the spar and shell designs to minimize blade mass/cost
- Full FEA of all Structural Components
- All analysis to Germanischer Lloyd requirements



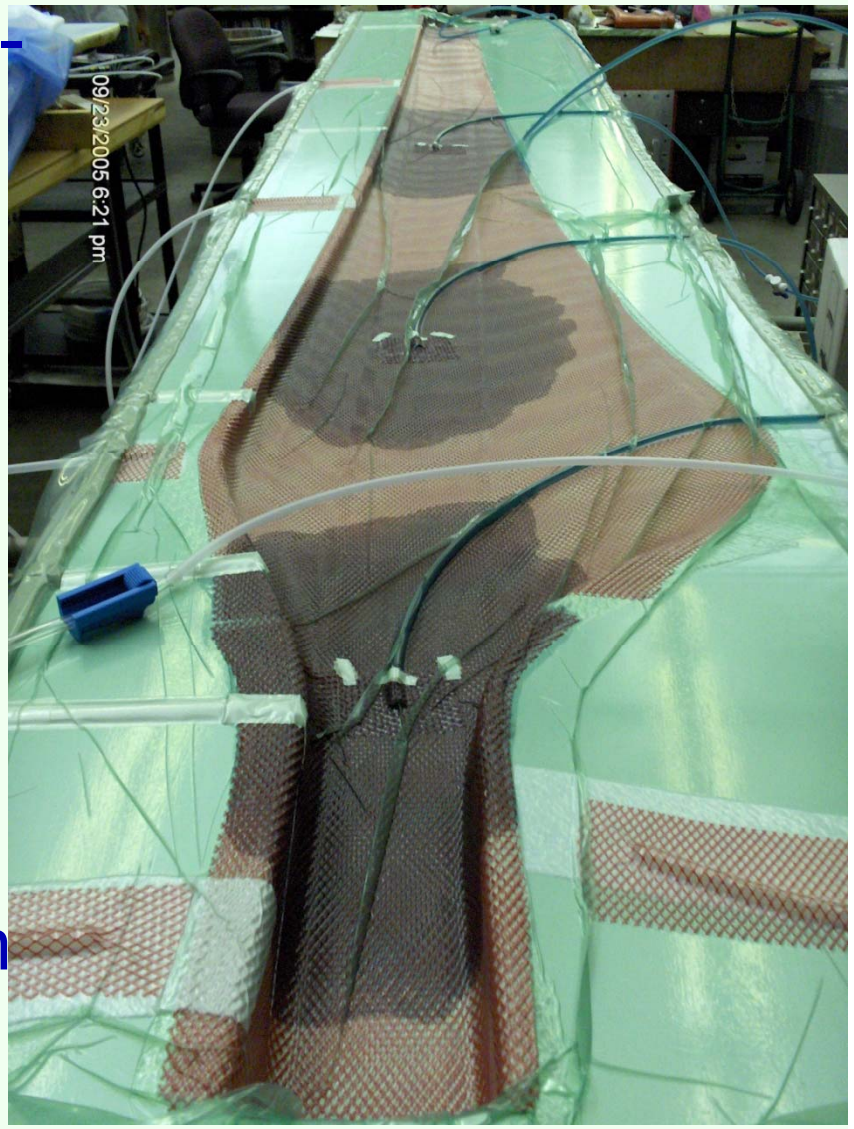


Blade Fabrication
Open Clamshell VARTM

- VARTM shells in Clamshell Tools
- Tools from CNC routed mandrels
- Glass & Carbon Fabrics from 1-40 osy
- Carbon from 3k-80k tows successfully infused

Blade Fabrication
Open Clamshell VARTM

- Shells are infused using vacuum-assisted resin transfer molding
  - Nearly Full vacuum
  - 5-25 psi back pressure, depending on permeability of fabric and viscosity of resin.
  - Heat with Si rubber heaters during infusion and cure cycle
  - 4-10 minutes to infuse one 3.5m blade shell
- In volume production could produce two blades per day from one set of tools.

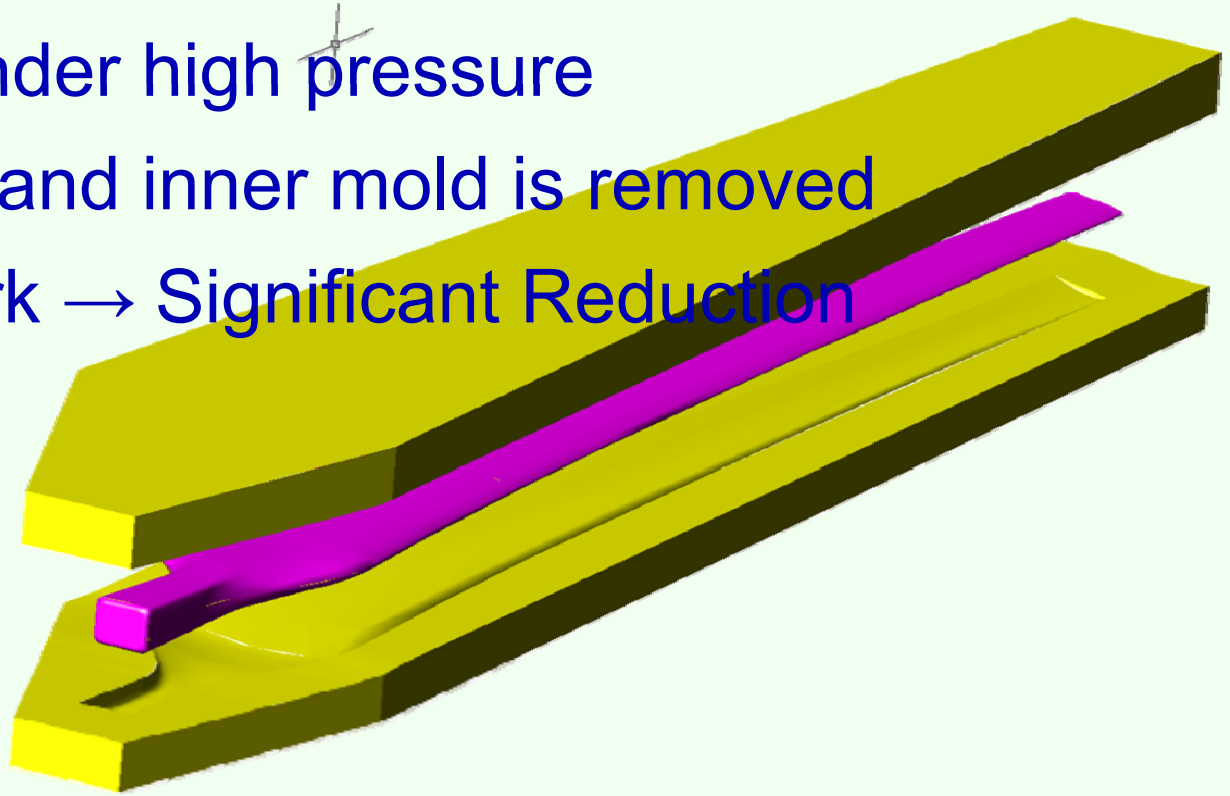


Blade Fabrication
Open Clamshell VARTM

- Cured shells are demolded & trimmed
- Shear webs are fabricated using wet layup
- Shells and webs are bonded in a secondary process
- Finished blades are post-cured at 200F for 8 hours in an oven

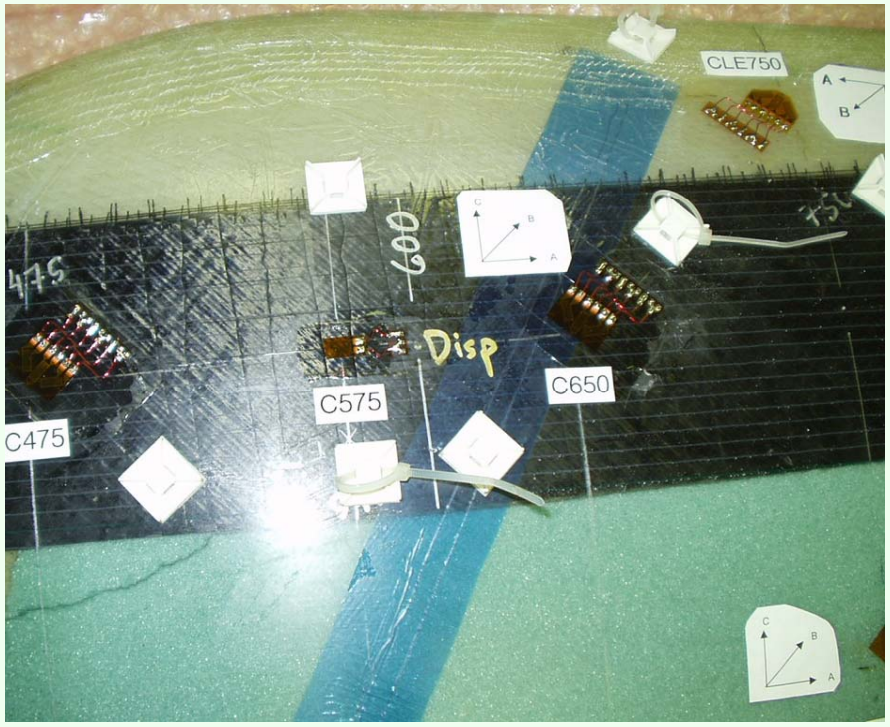
Blade Fabrication
Closed Mold RTM

- Current Development
- Shell and web fabrics are laid up on the lower shell and a multi-piece inner mold
- Top shell is closed and sealed
- Resin in injected under high pressure
- Blade is demolded and inner mold is removed
- Very little finish work → Significant Reduction in Blade Labor

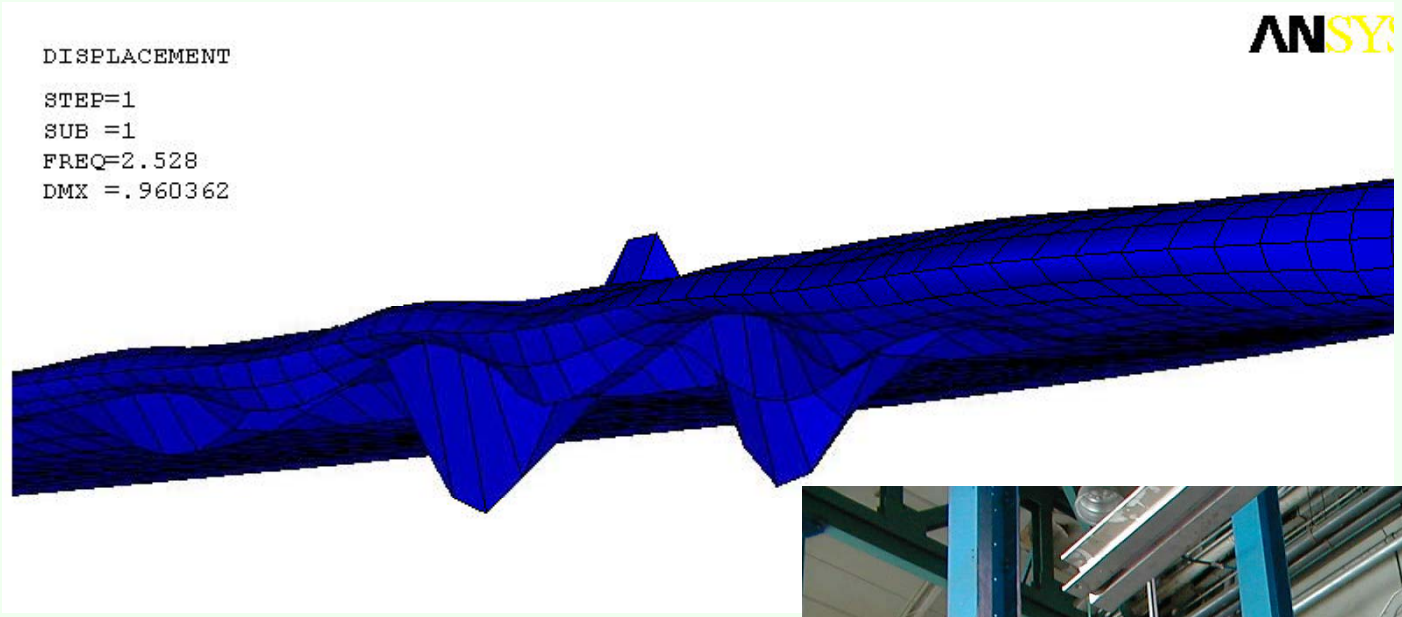


STRUCTURAL TESTING

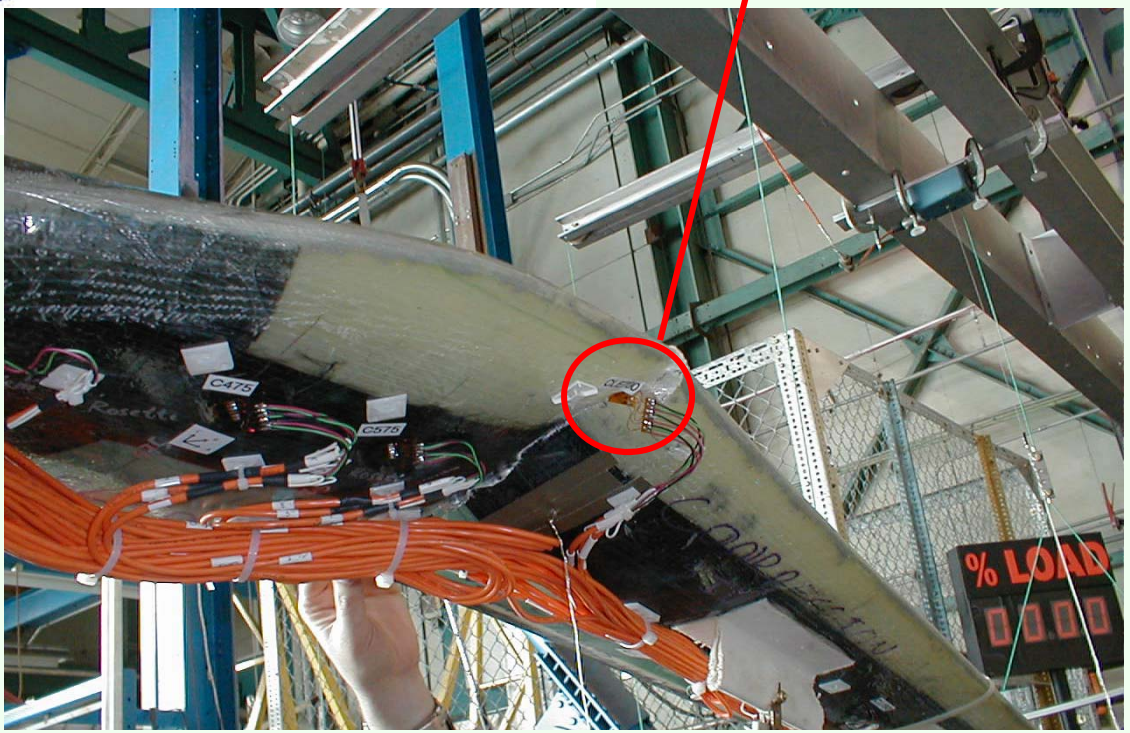
- New Blade Designs are Tested to Static Failure (beyond IEC/GL requirements)
- Accelerated Life Fatigue Testing is Conducted
- 6-point Whiffle Tree Static Load
- 32-128 channels of strain per blade
- Displacement at Multiple Spanwise Stations



STRUCTURAL TESTING



Rosette Placed to Capture Buckling



For More Information:

Kyle K. Wetzel, Ph.D.
Wetzel Engineering, Inc.
P.O. Box 4153
Lawrence, Kansas 66046

785-331-5321
KyleK.Wetzel@KWetzel.com
www.KWetzel.com