Composite Technology Development, Inc.

Engineered Material Solutions

Advanced Composites for Marine Energy

Composite Manufacturing Workshop

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U.S. Department of Energy

Sandia National Laboratories

Voith Hydro Power Generation

PennState ARL

Composites - What are they?

- **Composite - "consisting of two or more parts"**
  - **Composite Material**
    - **Two or more distinct constituent materials**
    - **Usually, these two materials have significantly different physical properties**
    - **Together they have a performance advantage**
  - **General Composite Material Make-up**
    - **Matrix (resin) – thermosets, thermoplastics, metal, etc.**
    - **Reinforcement (fiber) – glass, carbon, Kevlar, etc.**
  - **Advanced Composites**
    - **Typically, Carbon fiber + epoxy**

Why use composites?

- **Lots of reasons…**

1. **High strength (and modulus) to weight ratio**
   a. **Carbon fiber composite can be 5X stronger than 1020 steel, but is 1/5th of the weight**
   b. **High modulus carbon fibers are much stiffer than any metallic**
2. **Durable**
   a. **Corrosion resistant**
   b. **Withstand most environmental conditions**
   c. **Higher fracture toughness than plastics**
3. **Allow greater design options**
   a. **Can mold parts that cannot be easily machined**
   b. **Mold to near net shape – less finish work, less scrap**
4. **Often can be fabricated cheaper than similar metallic parts**
   a. **Less waste**

Example: Sports Car

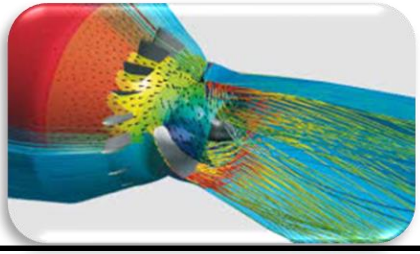
Composite Hydroturbine Runner (Blade) Program

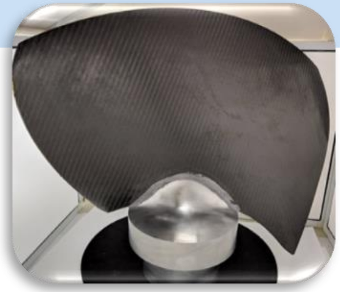
Project Summary

- **Project goal: Verify that composite materials are a reliable and economic alternative to traditional metallic runners to reduce costs and increase energy capture.**

Project Objective & Impact

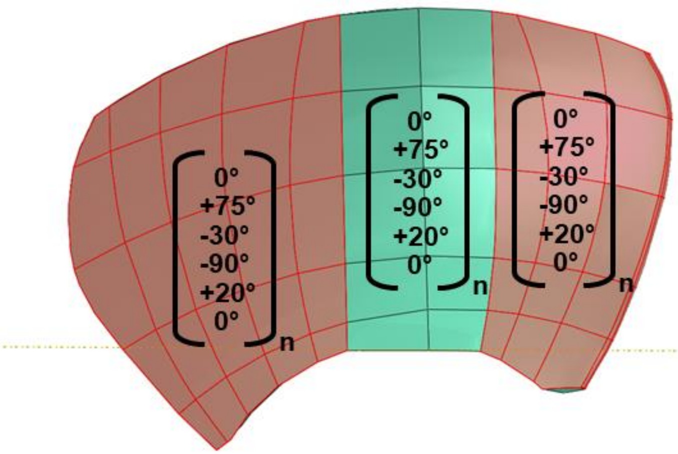
- Prototype a weight-efficient, fatigue resistant, low-maintenance turbine runner using composite materials to reduce mass and extend service life.
- Improve runner reliability by developing a high-performance coating system that resists cavitation and sediment erosion.
- Provide performance test data of the composite runner/coating in true hydropower turbine operating conditions.

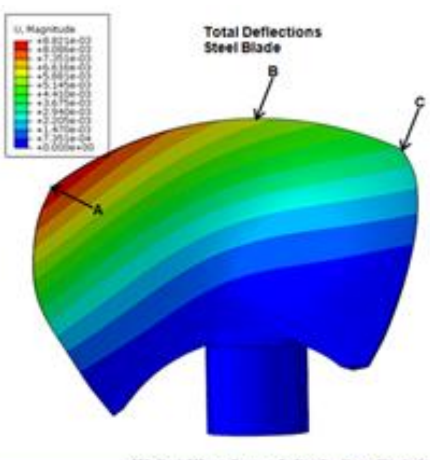


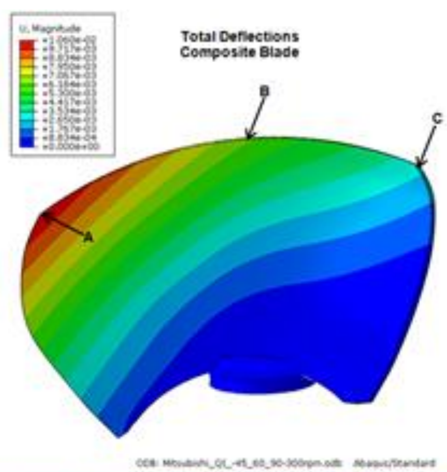


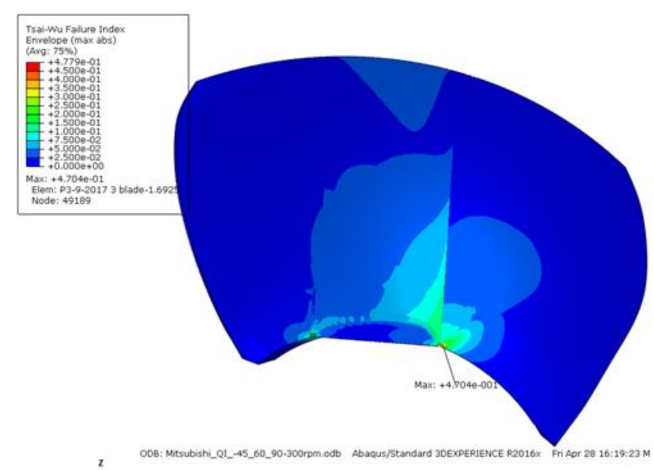
Runner Manufacturing

- **Design**
  - **Determine governing performance requirements**
    - **Stresses, strains, stiffness?**
    - **For Composite Runner – driving requirement was stiffness and deflection at tip**
  - **Select materials**
    - **CTD-KO8 Resin/high modulus carbon fiber**
  - **Perform Finite Element Analysis**





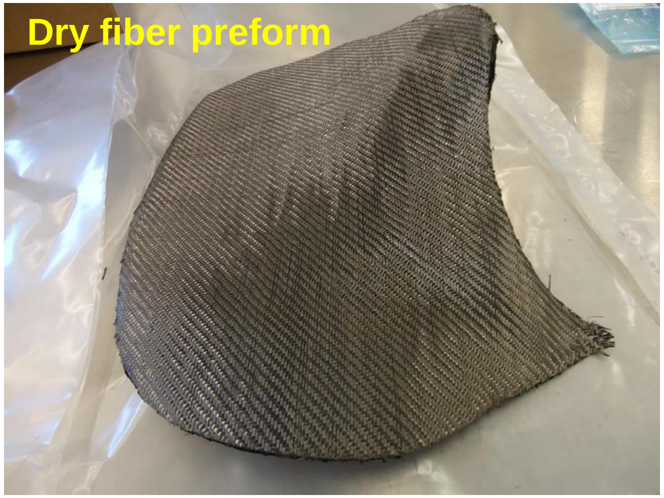


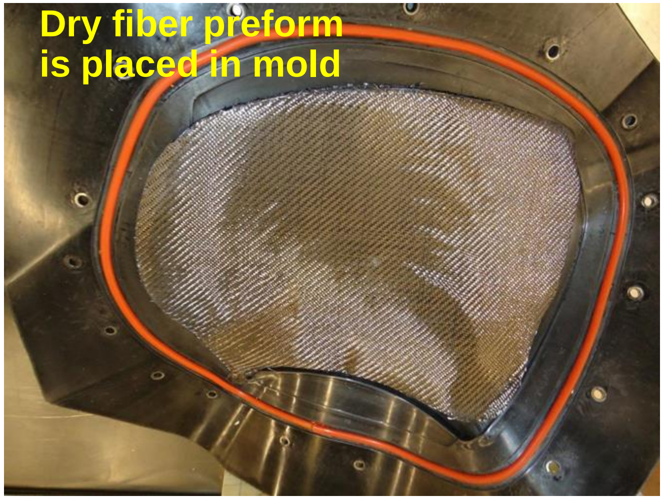


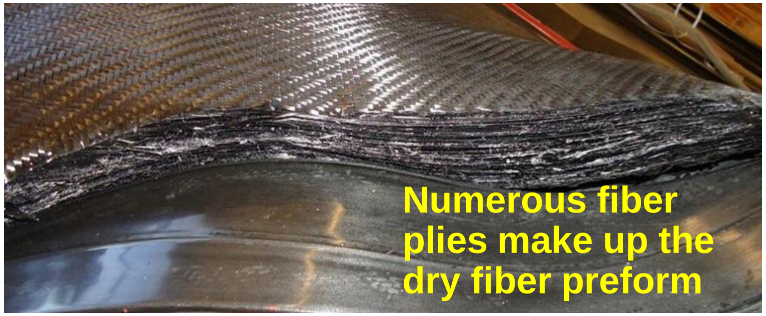
	A	B	C	Allowable Radial Deflection
Composite Blade Total Deflections	0.011"	0.006"	0.003"	
Composite Blade Radial Deflections	0.002"	0.0"	-0.001"	0.018"

Runner Manufacturing

- **Composite Manufacturing**
  - Select process
    - Liquid resin infusion, prepreg/vacuum bag, vacuum assisted RTM, etc.
  - VARTM process selected
    - One or two-part mold (2 part for blades)
    - Dry fiber preform placed inside 2-part mold
    - All air evacuated from mold
      - Placed under vacuum to reduce voids
    - Resin degassed and injected into mold
      - Some resins require heating to reduce the viscosity
    - Resin/part cured in oven



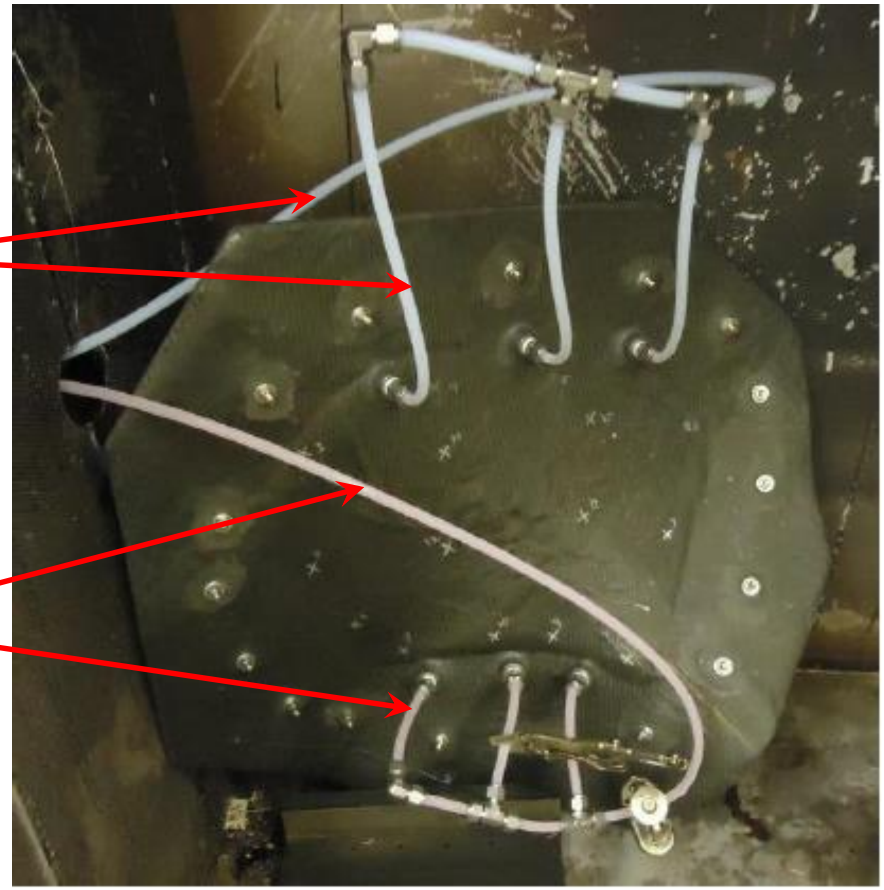




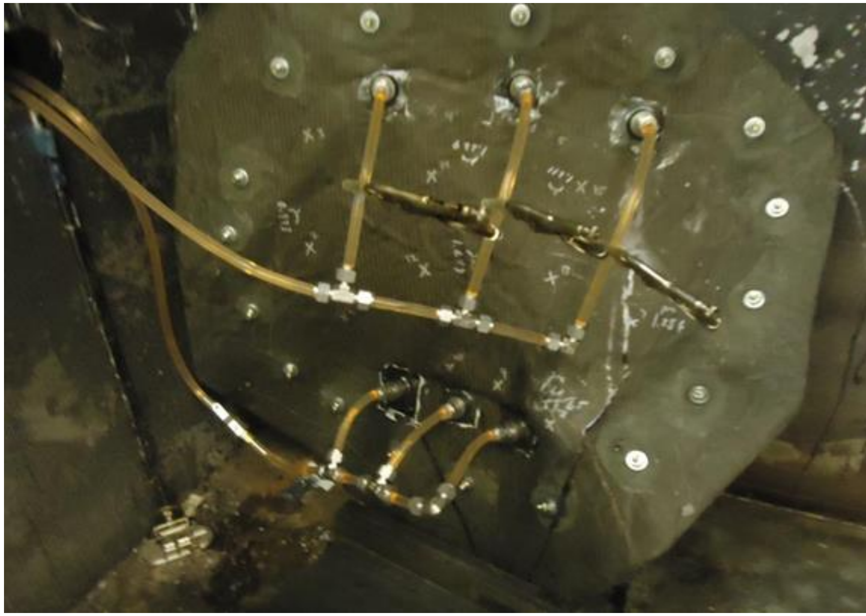
Mold in Oven

Vacuum/resin exit lines

Resin inlet lines

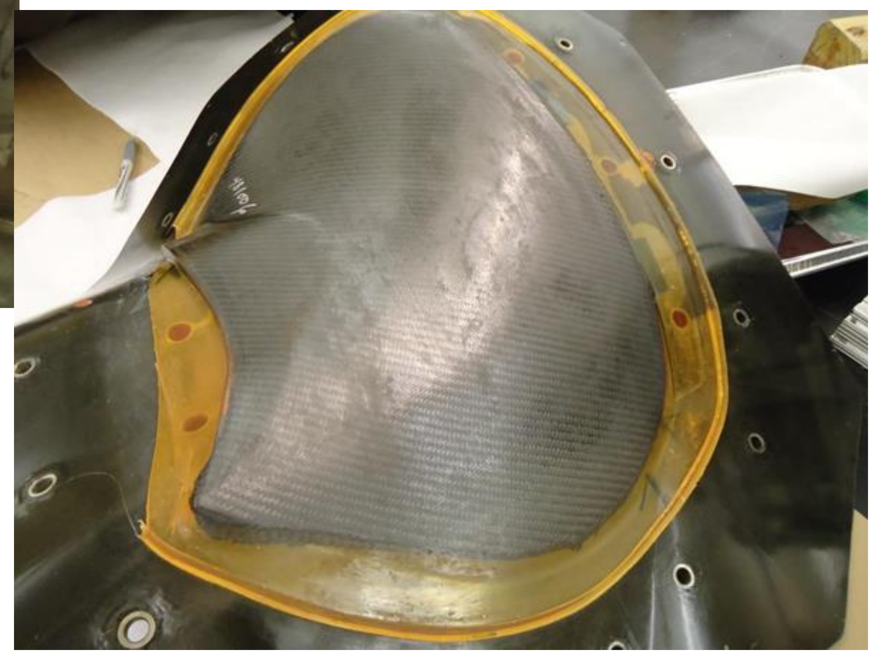


Runner Manufacturing

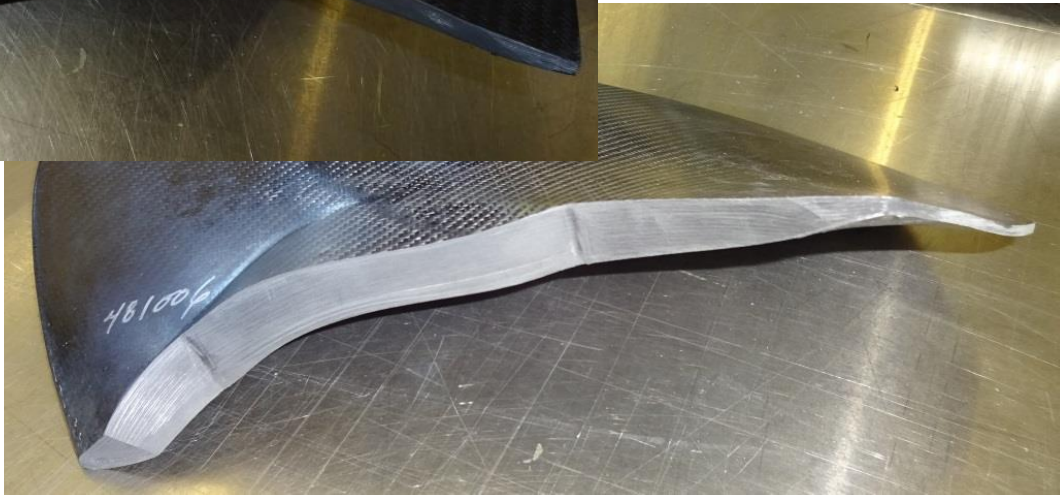


Mold is closed up, plumbed, degassed, and resin fed into mold

Following cure, part is removed from mold

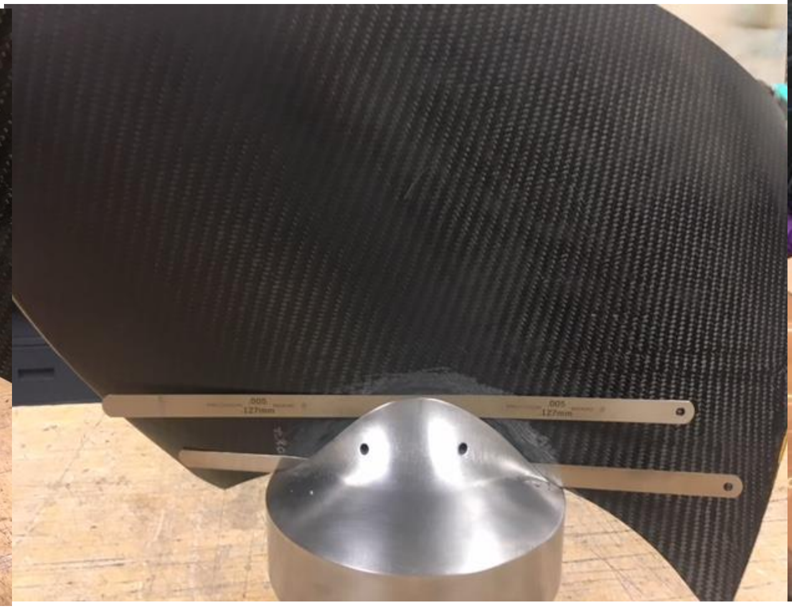


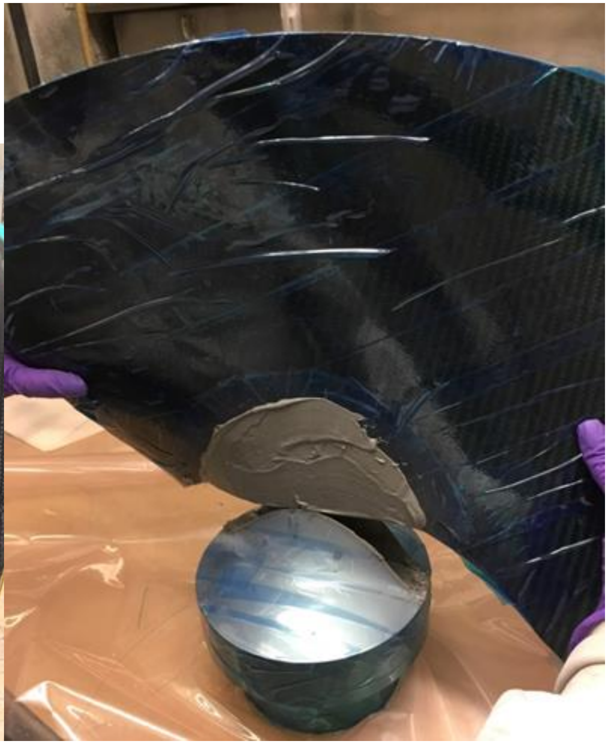
Post-Fabrication Machining



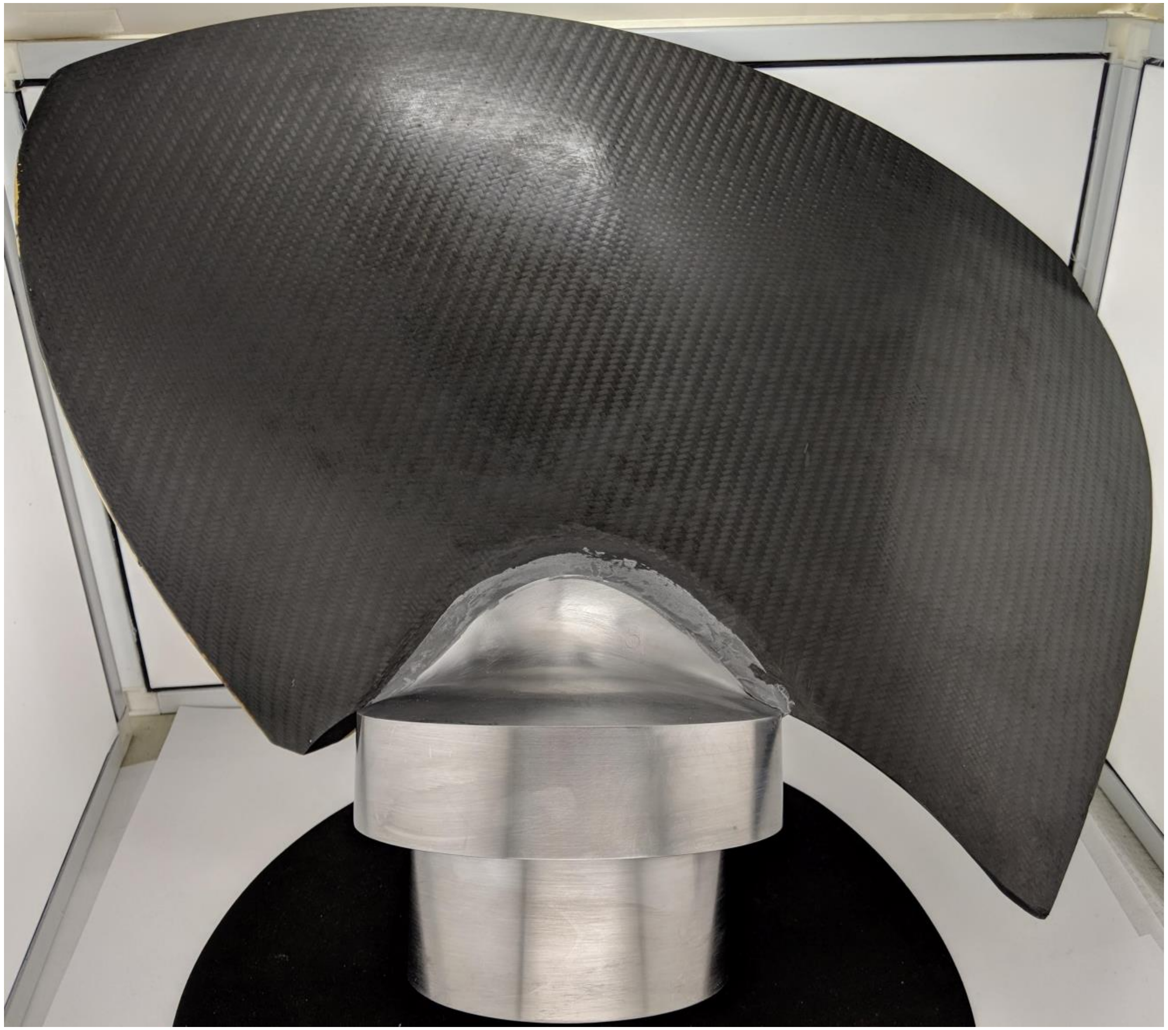
Composite Blade-to-Hub Bonding

- Blade sanded to final thickness at metallic interface area
- Measured spacing between blade and hub interface to ensure proper bond line thickness
- Surface prep and bond parts using a suitable adhesive



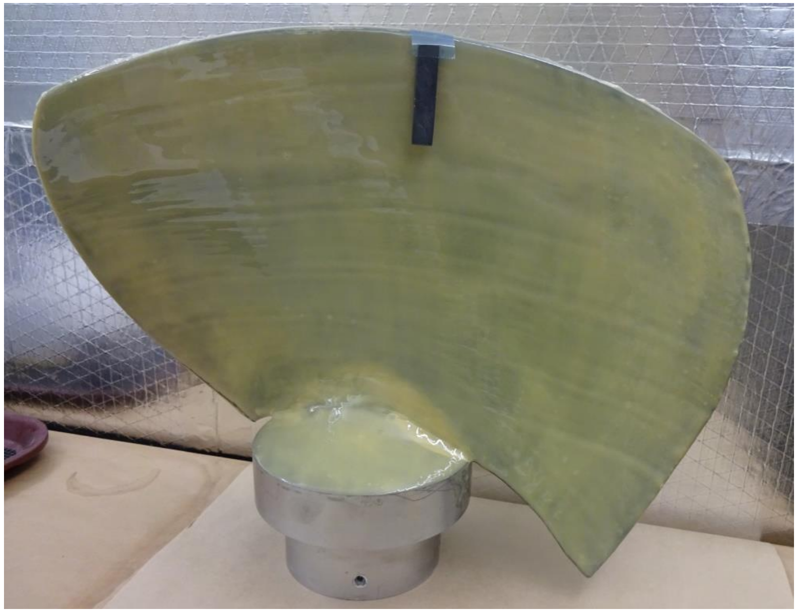


Finished Blade/Hub Insert Assembly



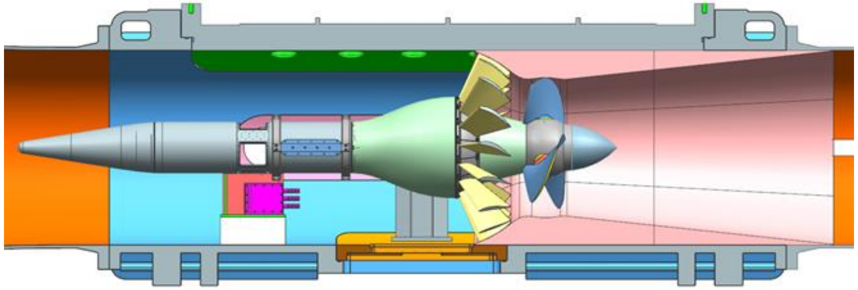
Final Step – Coating Application

- **Cavitation Resistant Coating**
- **Using CTD-133 soft coating**
  - **ARL cavitation erosion tests showed CTD-133 the best coating**
  - **Application trials performed on coupons to start**
  - **Curing must be done at elevated temperatures in oven**



Conclusions

- High quality composite hydroturbine runners were fabricated
- Many different processes used during manufacturing
  - VARTM composite fabrication process
  - Post-fabrication machining
  - Adhesive bonding of composites to metallics
  - Polymer coating
- Proved through static and fatigue mechanical testing that composite parts behaved similar to 410 Stainless steel that is typically used for runners
- Cavitation resistant coating should provide longer use life in use
- Lighter weight runners (by more than 50%) will make replacing the blades in hydroturbines much easier
- A set of three runners is awaiting testing at PSU-ARL’s 48” water tunnel



Questions?