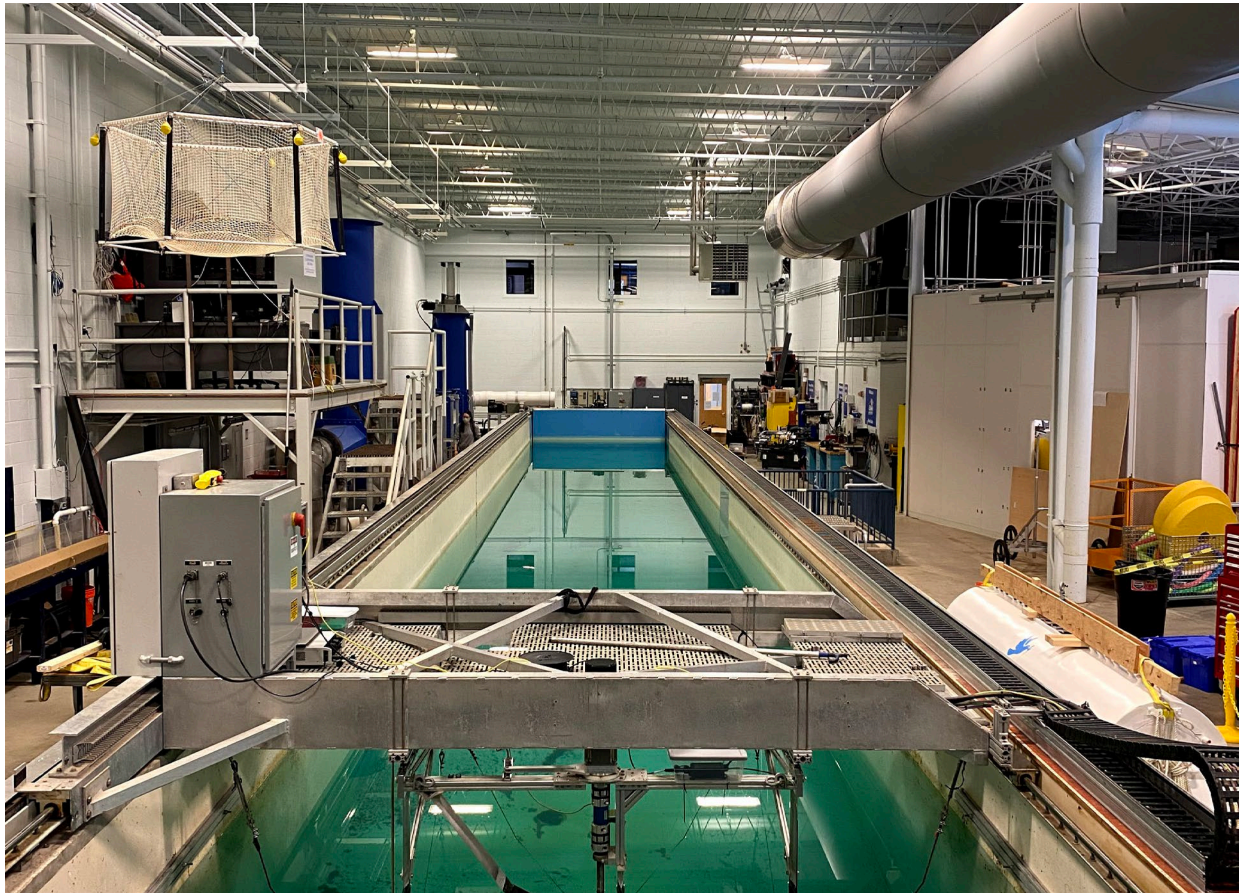
# DE-EE0008386:- Design of High-deflection Foils for Marine Hydrokinetic Applications



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# Project Overview

## Project Summary

Model-scale tank testing and fluid-structure-interaction (FSI) simulations were used to investigate the behavior of foils with large deflections and the effect of these deflections on crossflow turbine performance with the goal of determining the maximum allowable deflections consonant with efficiency and a robust, durable structure. A validated modeling and simulation approach was used in the design of a full-scale turbine. This updated rotor design provides a 24% increase in energy efficiency over the baseline. This represents a 19% reduction in levelized cost of energy (LCOE).

## Intended Outcomes

- The project investigated the interaction of structural deflections with hydrodynamic performance for crossflow turbines
- A public access data set was developed for tests of model scale crossflow turbines in various configurations and materials
- Analytical Fluid-structure interaction tools were developed and validated using the model scale data sets
- These tools were applied to an ORPC commercial turbine design, which led to improvements in LCOE for the power system

## Project Information

**Principal Investigator(s)**

- Dr. Martin Wosnik
- Dr. Budi Gunawan

**Project Partners/Subs**

- University of New Hampshire
- Sandia National Laboratories

**Project Status**

Completed

**Project Duration**

- 09/01/2018
- 12/31/2021

**Total Costed (FY19–FY21)**

$742,635

# Project Objectives: Relevance

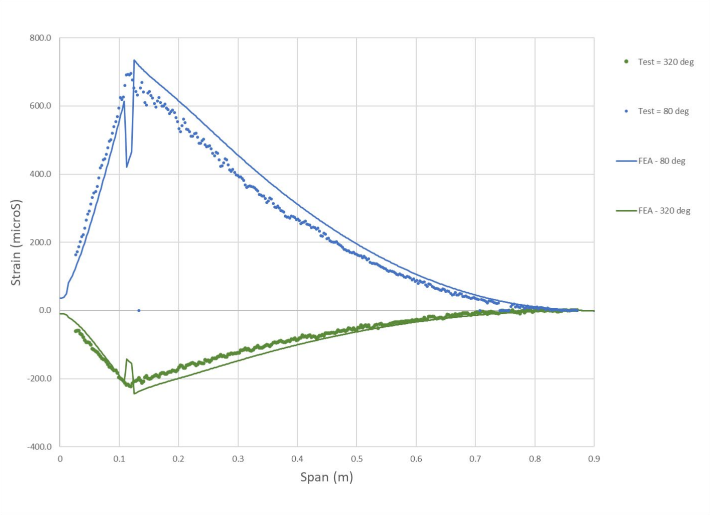
## Relevance to Program Goals:

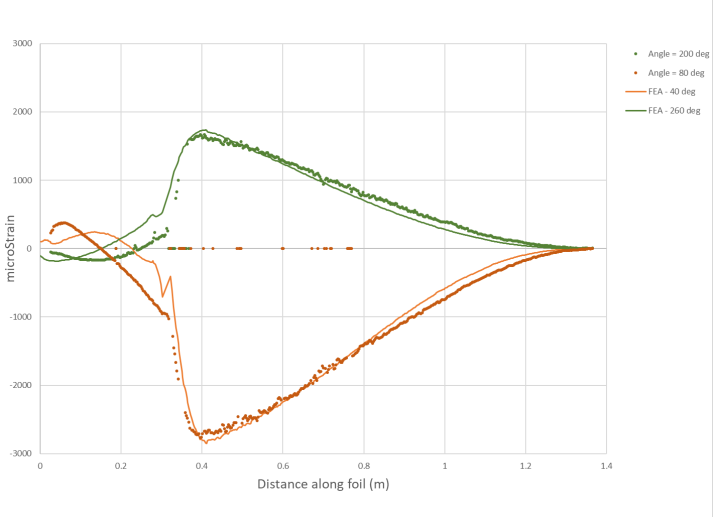
- Evaluated performance of composite and other novel materials for marine energy converter systems
  - Testing of carbon and glass composites and comparison with metallic 3D printed materials
  - Leverage new manufacturing and materials to dramatically lower costs of components and systems
- Validated foundational modeling tools with data from water testing projects
  - Widespread understanding of fluid structure interactions and use of advanced computational design tools and/or control strategies for new MHK device designs with improved energy extraction
- Disseminated data sets and models
  - Publicly available data set for scale model tests
- Collected, analyzed, and published data to generate new foundational understanding of marine energy devices and identify promising areas for additional research
  - Generated insights into behaviors of crossflow turbines in various test configurations.
- Implemented embedded real time strain sensing techniques in model scale testing
  - Developed digitalization systems and advanced sensor suites to enabler data-driven O&M
- Diversified the pool of students participating in WPTO workforce development
  - Provided funding for graduate students at the University of New Hampshire

# Project Objectives: Approach

## Approach:

- Developed a scale model test program for
  - Alternative foil materials (stiffness)
  - Alternative foil supports (stiffness)
  - Alternative foil arrangements (straight vs helical)
- Embedded real time strain sensing
- Concurrent data for performance and structural response for a wide range of configurations
- Developed opensource FSI approach
- Validated the analytical models using test data
- Applied analytical models to a full-scale design

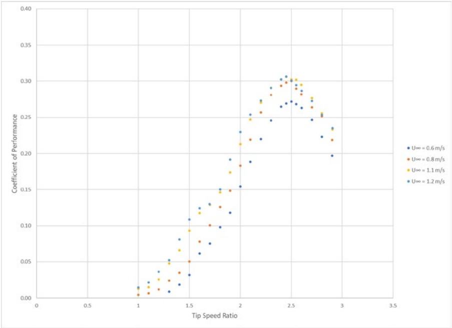


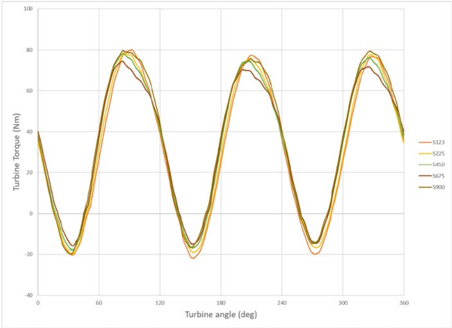



# Project Objectives: Expected Outputs and Intended Outcomes

## Outputs:

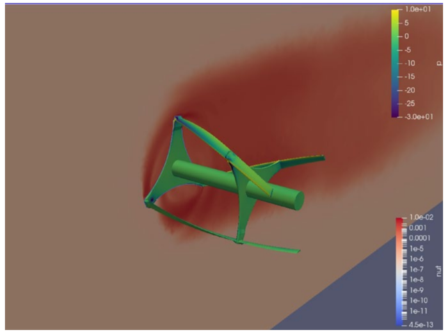
- Public data set for crossflow turbines with a wide range of materials and configurations
- Development of embedded strain sensing for hydrokinetic systems
- Validated analytical FSI model for design of hydrokinetic turbines

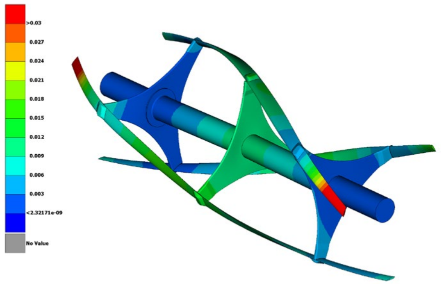



## Outcomes:

- Improvements in speed and accuracy of analytical tools for crossflow turbines
- Improvements in system reliability
- Improvements in system performance
- Reduction in system costs





# Project Timeline

## FY 2019

- Project management plan complete
- Intellectual property management plan complete
- Risk management plan complete
- Risk register complete

## FY 2020

- Test plan complete
- Design of scale model foils complete
- Design tool overview complete
- Straight carbon foils constructed
- Straight glass foils constructed
- Scale model testing begins

## FY 2021

- Helical glass foils constructed
- 3D metallic foils constructed
- Scale model testing complete
- FSI models of scale model tests completed
- FSI models of full-scale turbine completed
- Final technical report completed

- Project proceeded to plan overall except with schedule delays
  - COVID-19 work restrictions

# Project Budget

| Total Project Budget – Award Information | | |
|---|---|---|
| **DOE** | **Cost-share** | **Total** |
| $571,699 | $159,307 | $731,006 |

| FY19 | FY20 | FY21 | Total Actual Costs FY19–FY21 |
|---|---|---|---|
| **Costed** | **Costed** | **Costed** | **Total Costed** |
| $66,569 | $259,477 | $416,589 | $742,635 |

- University of New Hampshire provided budgeted cost share
- ORPC provided cost overrun cost share
- FY19 represented a slow beginning to the project
- COVID-19 schedule impacts meant that work was heavily biased to 2021.

# End-User Engagement and Dissemination

- Project provides the industry with a high-quality opensource data set for crossflow turbines
- Project provides experiential learning on the use of embedded strain sensing for hydrokinetic applications
  - Moves towards real time embedded sensing in open water applications
  - Moves toward prognostic health monitoring for marine renewable energy systems
- Project provides ORPC with a validated analytical toolset for crossflow turbine design and optimization
  - This leads to lower LCOE and improved economics for hydrokinetic river and tidal projects
  - Increased uptake of hydrokinetic power systems by the market
  - Increased hydrokinetic energy production for the US

# Performance: Accomplishments and Progress

- Provides a high-quality opensource data set for tow tank testing of multiple configurations of crossflow turbines
- Illustrates the benefits of high resolution, real time embedded strain sensing
- Develops a validated fluid structure interaction tool for use in hydrokinetic system optimization
- Turbine efficiency and material cost are the basic technoeconomic metrics used in the project
  - Translated into Annualized Energy Production, Capital Cost, and Levelized Cost of Energy
  - Project resulted in a 19% reduction in LCOE as compared with the projected reduction of 16%.

# Performance: Accomplishments and Progress (cont.)

- No patent filings were made as a result of the project
- New intellectual property was developed
  - Means & methods of implementing analytical tools for FSI analysis of crossflow turbines
- Technical papers will be published
  - ICOE 2022
  - Further publications based on PhD studies of UNH student

# Q&A