Nantes Métropole

WEAMEC
Research, Education & Innovation in Pays de la Loire FOR MARINE ENERGY

OPIN Workshop

Advanced Materials and Manufacturing (Composite focus)

12/11/19, Nantes

Bernadette A. Hernandez-Sanchez

Principal Member of Technical Staff/Sandia National Laboratories

Evaluation of Composite Materials for Marine Renewable Energy Technologies

SAND2019-13723 PE

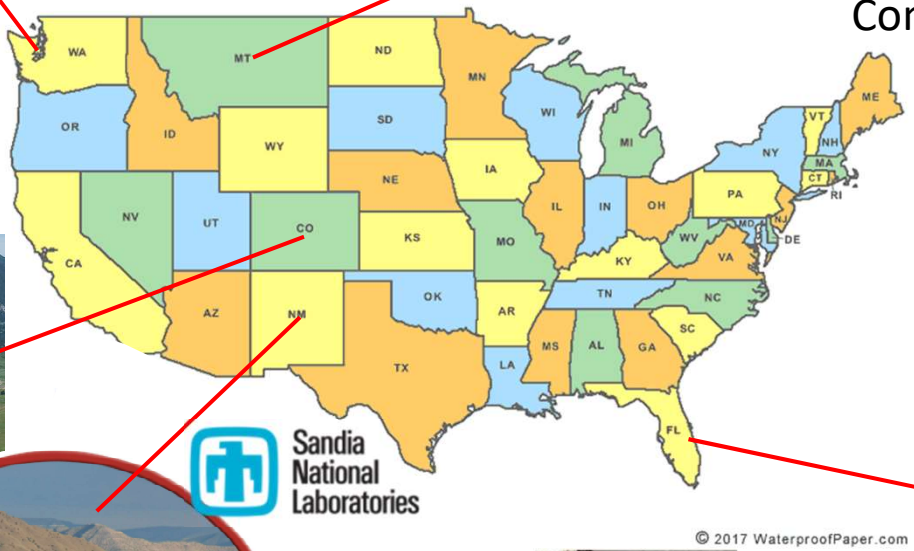
Sponsored by the US Department of Energy, Office of Energy Efficiency and Renewable Energy (US DOE-EERE) Water Power Technologies Office
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

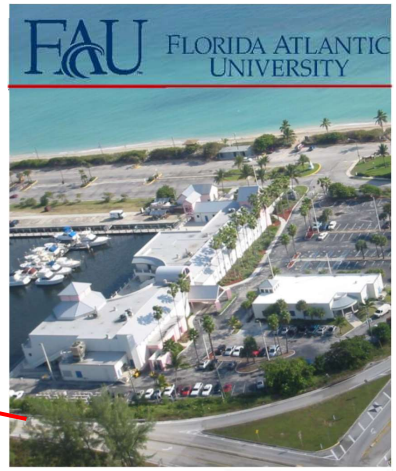
Materials Team

Marine Science Laboratory

George Bonheyo: Biofouling

David Miller: Composite Performance





Scott Hughes: Substructure Testing

Francisco Presuel-Moreno: Corrosion

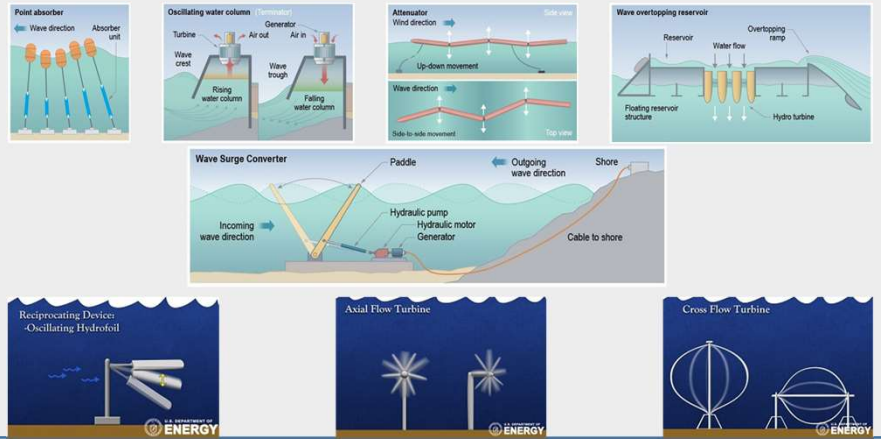
Bernadette A. Hernandez-Sanchez: (PI) Materials Chemistry

Budi Gunawan: Loads & FBG Sensors

Materials Challenges for Marine Renewables

Proper structural/component materials and coatings are critical to reducing engineering barriers, COE, and commercialization time.

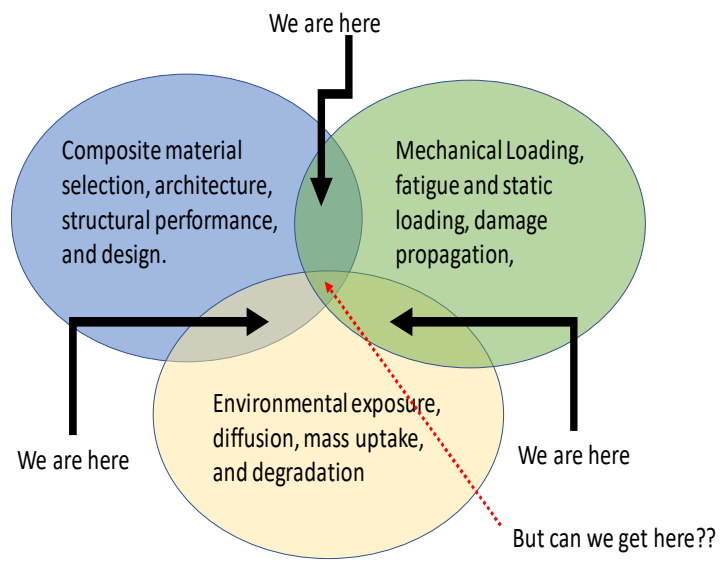
Design Challenge: Several Design Configurations & Operational Conditions



Significant Periodic Loading:

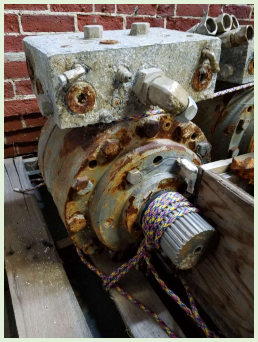
- Interaction with PTO & Control System
- Site Conditions
- IEC Design Standard (Fatigue/Ultimate)

Composites Research Needed



Coating & Environmental Challenges

Corrosion

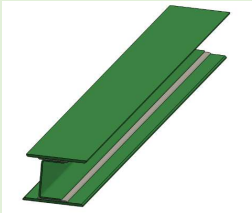


Courtesy of Resolute Marine Energy

Biofouling

http://www.racerocks.ca/

Joined Materials

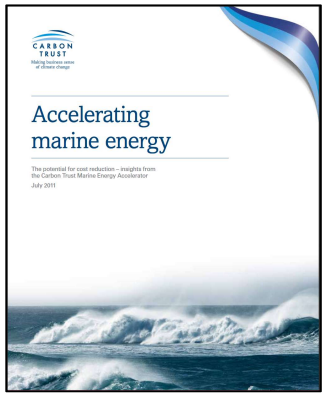


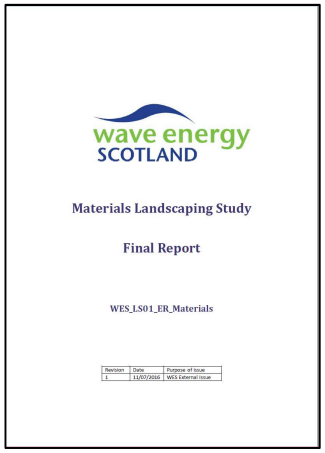
Adhesive joint beams

Hernandez-Sanchez et al 13th EWTEC Proceedings

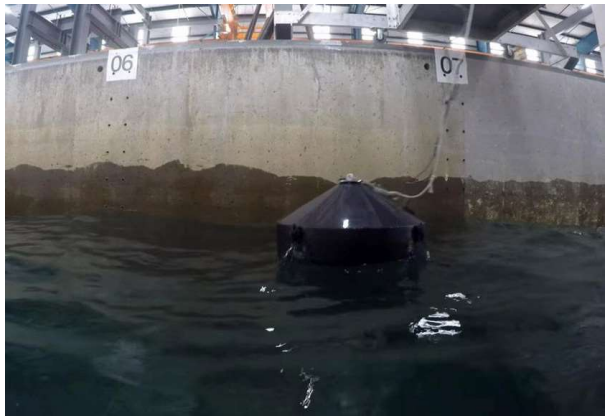
Materials Can Impact Cost and…

- Structure
- Designs and manufacture
- Accelerate manufacturing or Advanced manufacturing strategies
- Testing of novel materials or materials from marine industries to reduce risk
- Open water testing on materials for validation
- Reliability & Survivability
- Operation & Maintenance
- Certification & Safety



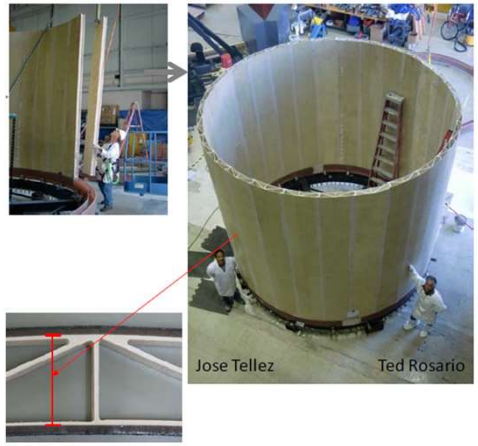


MHK Designs Exploring Composite Materials



AquaHarmonics

Columbia Power Technologies



Lockheed Martin-OTEC Cold Water Pipe

Ocean Renewable Power Company

Resolute Marine Energy

Verdant Power

All Photos Obtained From Company Websites and Literature References

US MHK Composites Program

Coupons provided by:

- Composites Engineering Research Lab
- Composites Technology Development
- Hygrateck
- Janicki
- Industries
- Polyone
- Ocean Renewable Power Company
- Verdant

FY17

(5) 8x1 in
(5) 10x1 in

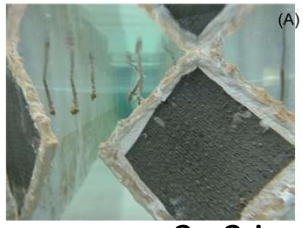
Salt Water Effects on Composite Performance Testing (coupons)

Biofouling & Environmental Effects on Composites

For 1 data point:
(3) 8x8 in panels
(3) 3x3 in
(3) 4x4 in
(3) 1x1 in

FY18

Metal – Carbon Fiber Composite Interconnects in Seawater

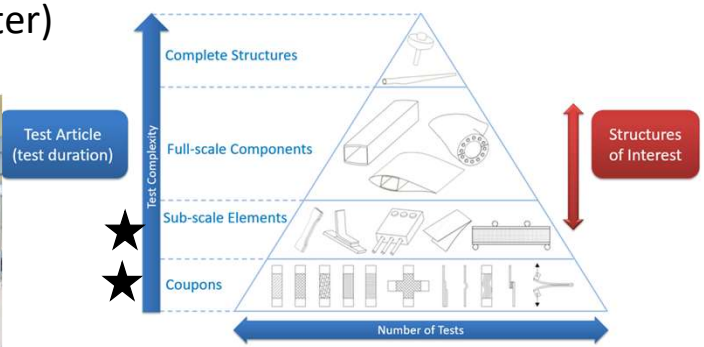


3 x3 in

Industry directed sub scale elements & joined coupon fabrication/testing (Artificial & Actual Seawater)

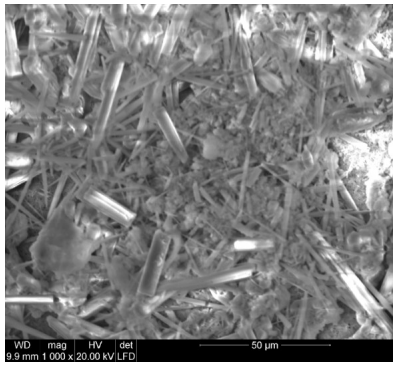
FY19-20

Industry directed full scale subcomponent testing (Artificial & Actual Seawater)



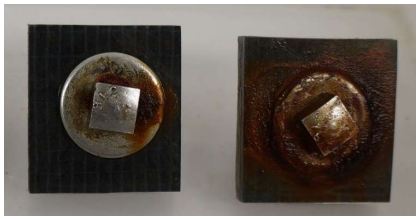
Environmental Effects on Composites

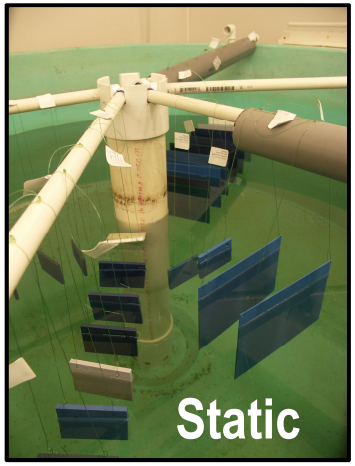
Corrosion can occur on metals connected to carbon fiber composite materials (i.e., CF composite to metal interconnects).



Calcareous deposit from corrosion study
CF/VE8084 + anode

Corrosion Studies on Connections





Biofouling Studies on Composites & Coatings

MRE relevant Velocities
0.1 m/S and
2.6 m/s

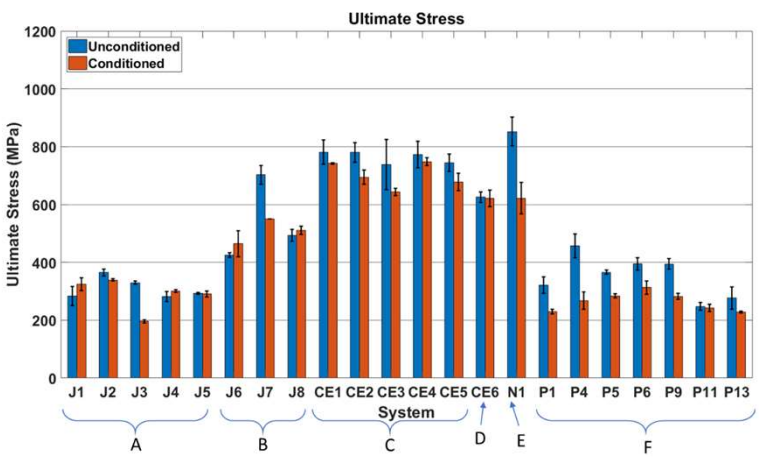
0-22 month Exposures

Building Block Approach to Structural Validation

Coupon Performance

MSU Material	Layup	Average V_f for static tests %	% Moisture	Longitudinal Direction			Transverse Direction		
				E, GPa	UTS, MPa	% strain	E, GPa	UTS, MPa	% strain
CE1	$[V/(+/-45)g/0c]_s$	40.9	0	56.1	786	1.38	10.7	98.3	3.17
			1.2	58.3	787	1.33	8.54	68.3	1.84
CE2		35.8	0	54.8	773	1.40	9.02	83.3	3.26
			1.33	55.3	725	1.30	7.79	58.9	1.84
CE3		40.7	0	54.1	792	1.43	9.96	95.3	3.67
			1.1	52.1	691	1.31	8.62	68	1.92
CE4		36.1	0	53.7	774	1.36	8.91	83.9	3.69
			1.2	53.1	712	1.30	8.18	60.5	1.82
CE5		36.4	0	56.5	733	1.29	9.69	77.8	3.54
			0.34	57.9	695	1.15	8.05	63.6	2.05
CE6	[V/0/45/-45/0/V]	42.3	0	29.2	695	2.69	12.0	109	2.52
			0.36	28.7	590	2.36	16.6	126	2.36

Hybrid carbon & glass thermoset: moisture diffusion affects mechanical behavior

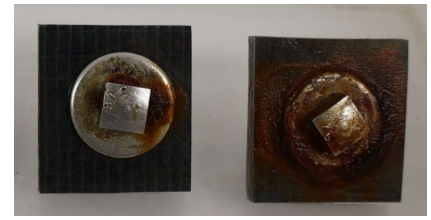


Group	Fiber	Matrix	Layup Type
A	Glass	Thermoset	Quasi-Isotropic
B	Carbon	Thermoset	Quasi-isotropic
C	Hybrid	Thermoset	[45/-45/0]s

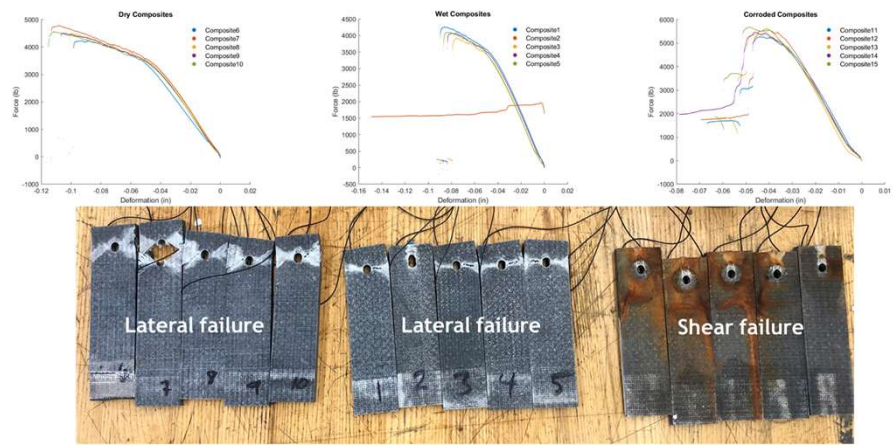
Group	Fiber	Matrix Type	Layup Type
D	Glass	Vinyl ester	[0/45/-45/0]
E	Glass	Elium	[0b]s
F	Glass	Thermoplastic	[0/90]n

Degradation in strength & increase in failure strain

Corrosion Studies on Connections



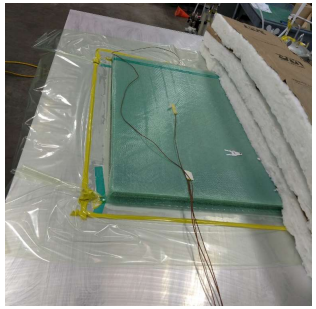
Joined Material Load Behavior

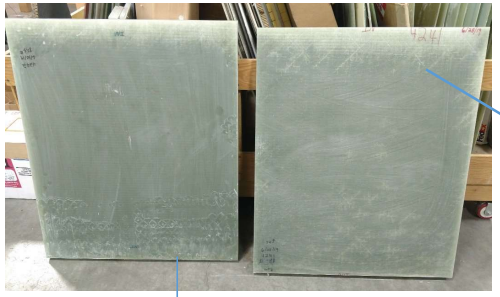


Unconditioned | Artificial Salt Water | Actual Seawater & Corrosion

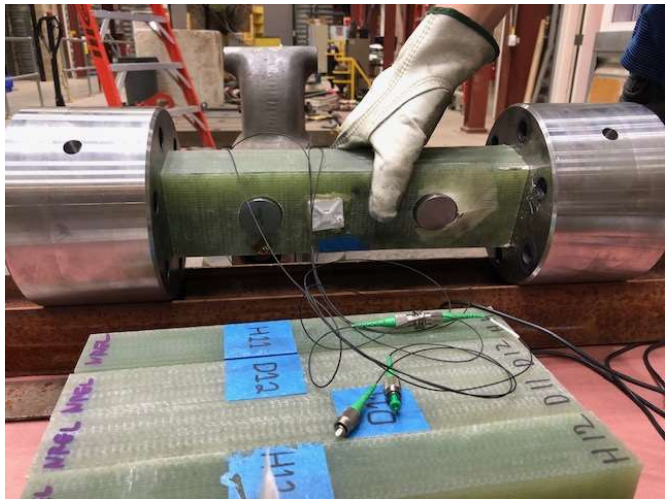
Building Block Approach to Structural Validation

Subcomponent Fabrication

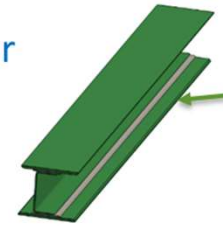




609 mm x 730 mm x 43 mm
85 lbs



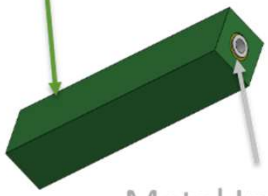
Adhesively shear specimens



Composite

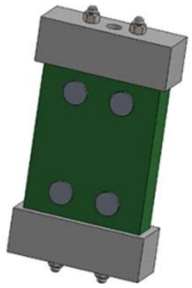
Adhesively bonded inserts

Adhesive bondline

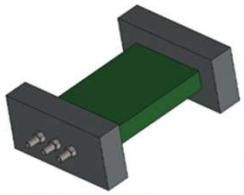


Metal Insert

T-bolt connections

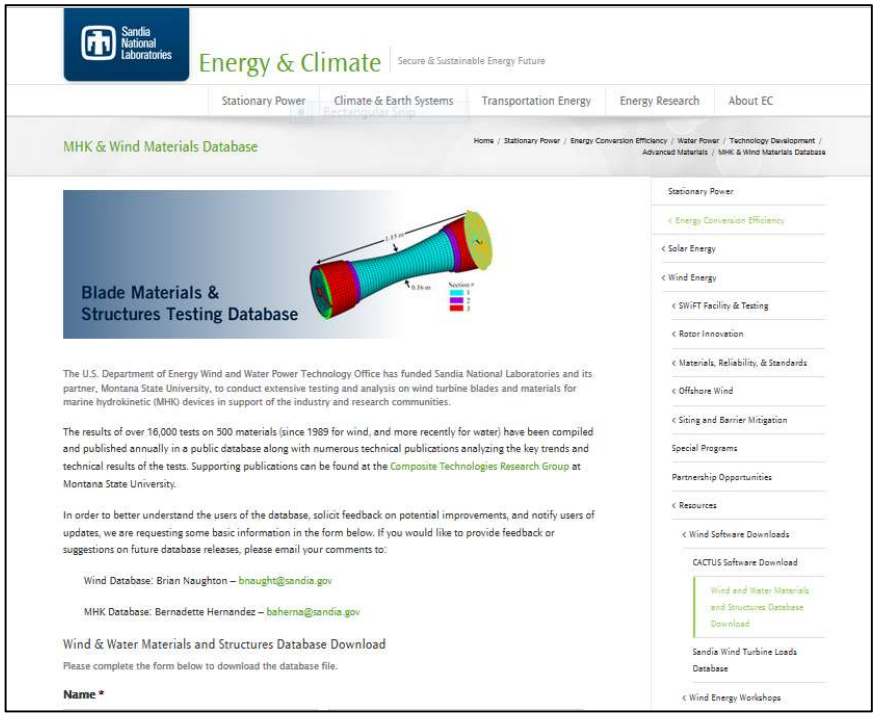


Compression Relaxation specimens



MHK Databases

Wind & Water Materials and Structures



http://energy.sandia.gov/energy/renewable-energy/water-power/technology-development/advanced-materials/mhk-materials-database/

OpenEI
Open Energy Information

https://openei.org/wiki/Main_Page

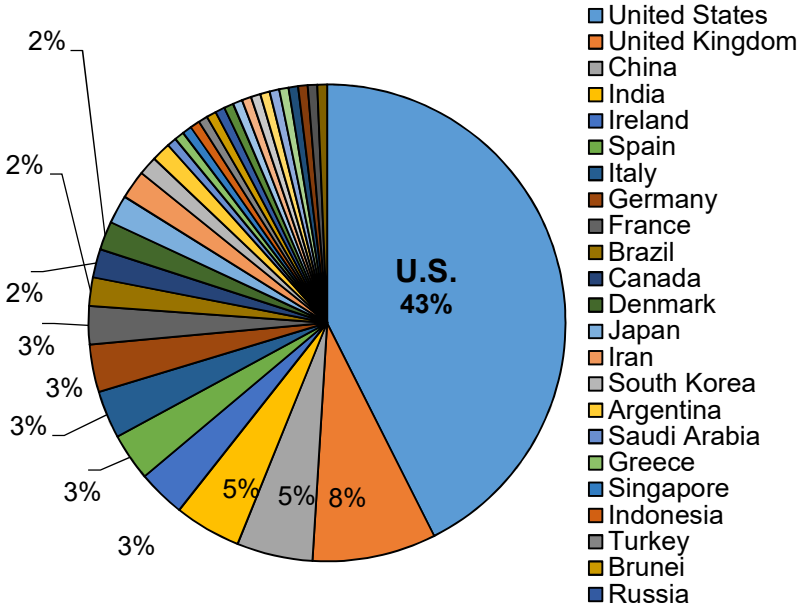
TETHYS

https://tethys.pnnl.gov/

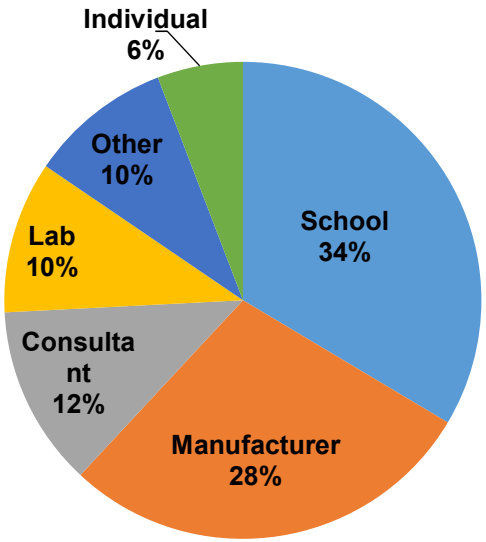
U.S. DOE MHK Composite Materials & Structures Database:

Benefits: Open Source, Industry Advised, Backed with Publications.

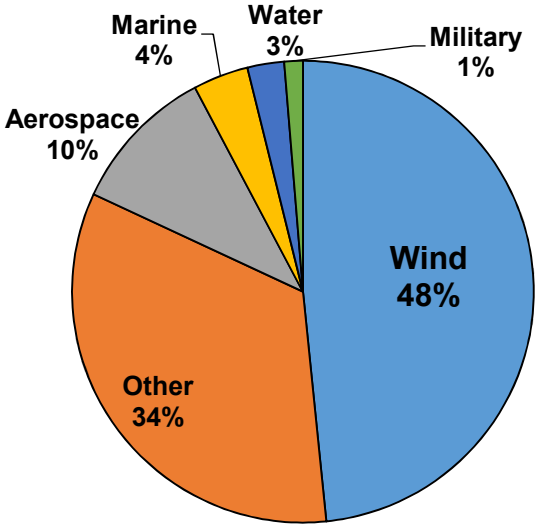
Country



User Type



Institution



Future

"Provide a better understanding of the materials science and engineering of composites to avoid costly redesigns."

- Material Studies:
  - Explore Mid to Long Term Needs
  - Advanced Manufacturing
  - Structural Health

- Collaborations: Yes!
  - Deployment Sites
  - Validation
  - Standards

2016 Marine Energy Technology Symposium

MARINE AND HYDROKINETIC (MHK) ENERGY COMPOSITES DATABASE WORKSHOP

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Sandia National Laboratories

Bernadette A. Hernandez-Sanchez, Timothy N. Lambert, Brian Naughton
Sandia National Laboratories
David A. Miller
Montana State University
4/27/2016

INTRODUCTION

The Marine and Hydrokinetic (MHK) Energy Composites Database Workshop was held on May 13–14, 2015 at Sandia National Laboratories in Albuquerque, New Mexico. Participants were tasked to identify "What are the critical composite materials related needs that must be addressed for the MHK Energy Industry to have success in their device's design, manufacture, operation, maintenance, and reliability?" Attendees represented MHK wave and tidal device manufactures, composites industry, academic, national laboratory, and U.S. Naval perspectives. This paper summarizes the workshop goals and results.

Images of workshop participants.

Representatives from wave & tidal energy, composites industry, academic, national laboratories, and Naval laboratories are shown here.

This two-day workshop was used to identify what are the composite materials related needs that must be addressed for the MHK Energy Industry to have success. To aid in these decisions, the workshop participants focused on the following activities to direct composite initiatives.

Workshop Goal 1: Introduction to the Water Power Composite Materials Database.

- Data is being collected on MHK Composite Performance by Sandia National Laboratories & Montana State University to aid in composite materials selection for design, manufacture, performance, reliability, operation, and maintenance.

Desired Outcome 1: Water Power Materials Database Development

- The pubic Water Power Technologies Materials Database will provide MHK composite performance data to aid in composite materials selection for design, manufacture, performance, reliability, operation, and maintenance.
- Advisement on additional parameters is needed.
- **A successful database will have the merits of the Wind Power Materials Database.**

Countries | Industry | Organization Type

http://energy.sandia.gov/energy/renewable-energy/water-power/technology-development/advanced-materials/mhk-materials-database/

DOE-SNL-MSU Wind Composites Database statistics from users who download performance data.

Workshop Goal 2: Identify Composite Related Barriers.

- Participants will identify composite materials related manufacturing science and engineering barriers that increase the cost of MHK construction, deployment, operation, maintenance, and reliability

Desired Outcome 2: Direct Composites Development.

- Successful identification will direct database performance data and impact future research that will reduce costs and improve these critical areas.

The diverse workshop attendees represented the following communities:

1. U.S. Department of Energy: EERE
2. MHK Wave (Columbia Power Technologies, Resolute Marine Energy)
3. MHK Tidal (Ocean Renewable Power Company, Aquantis Inc.)
4. Composites Industry (Ershigs, Inc., Janicki Industries, PPG Industries, Saertex)
5. Academic (Florida Atlantic University, Montana State University)
6. National Laboratory (Sandia National Laboratories, National Renewable Energy Laboratory)
7. U.S. Naval Research Laboratory

WORKSHOP OUTCOMES

Outcomes of the workshop identified key areas for future research needs, and were divided into Short Term, Mid-Term and Long Term goals.

Short term needs identified for the MHK industry

1. Improved Loads & Tolerances for devices
2. Saturated testing/Maintenance schedules for devices
3. Material selection aids for MHK devices
4. Cores and connections R&D
5. Improved relationships between manufacturers and suppliers
6. Reliable database of composite material properties.
7. Leverage similarities in Oil/gas, submarines, piers and, waterfront structures in terms of case studies

Mid-term needs identified for the MHK industry

1. Expanded material properties included into the database
2. Expanded research of water uptake effects on substructures and loaded elements
3. Increase development of biofouling agents specific to MHK devices
4. Develop long term damage tolerant design and corresponding O+M practices
5. Expand the types of items tested to include adhesives, substructures, coatings
6. Expand the types of tests to include cyclic pressure effects, creep, coatings, full scale testing, impact and critical failure analysis, complex shapes, and effects of defects on laminates
7. Development of robust quality management systems for manufacturing of MHK devices
8. Improved education and available design assistance to include smart structures, analytical model improvements, and fatigue predictions

Long Term needs identified for the MHK industry

1. Incorporate certification agencies with the DOE/SNL MHK efforts
2. Improve standardization across design and manufacturing for the MHK industry
3. Improve biofouling and water uptake issues with material engineering solutions
4. Advance modeling efforts to include fluid structure interaction, and coupled modeling of moisture uptake and laminate performance
5. Advanced manufacturing techniques to include on site assembly of MHK devices
6. Manage, extend, and improve materials database organization and content through user feedback
7. Develop structural health monitoring systems for MHK systems
8. Develop long term damage tolerant design and corresponding O+M practices
9. Develop full scale durability test facility including non-MHK subsea industry needs

Penalties of Not Having A Database

The following areas of concern were determined if public data was not available.

- Increased margins leads to increased cost which leads to decreased performance
- Impacts from cost of energy, efficiency, increased mass, time to deploy, failure will further delay industry.
- Repeated experimentation to increase confidence
  - Hard to do for fatigue analysis
  - Aging situations (worthwhile to determine uncertainty on database)
  - High cost in developers performing own tests

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Q&A

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Research, Education & Innovation in Pays de la Loire FOR MARINE ENERGY

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Thank you!