SAND2019-13723PE

OPIN Workshop
Advanced Materials and Manufacturing (Composite focus)

12/11/19, Nantes

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & 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.

Bernadette A. Hernandez-Sanchez

Principal Member of Technical Staff/Sandia National Laboratories

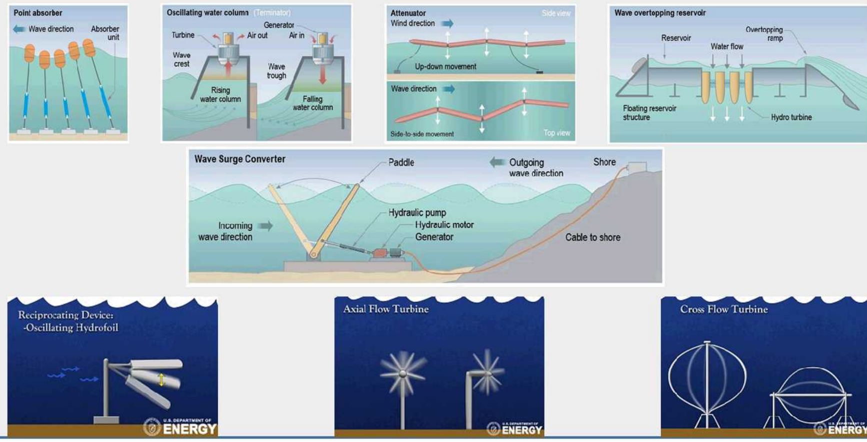
Evaluation of Composite Materials for Marine Renewable Energy Technologies

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 Challenges for Marine Renewables

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

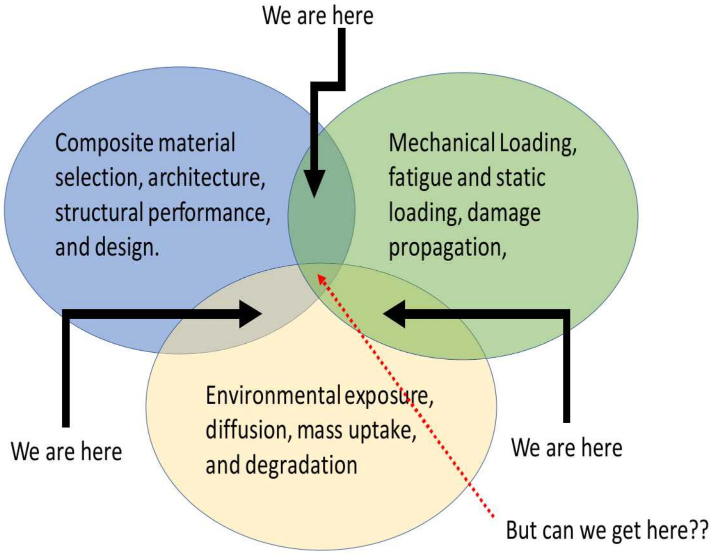
Design Challenge: Several Design Configurations & Operational Conditions



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

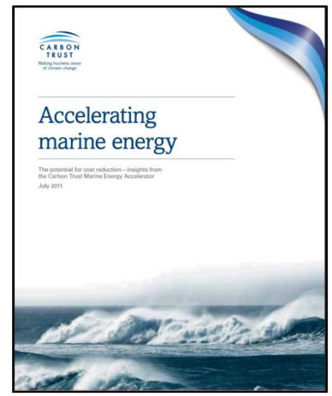
Adhesive joint beams

Hernandez-Sanchez et al

13th EWTEC Proceedings

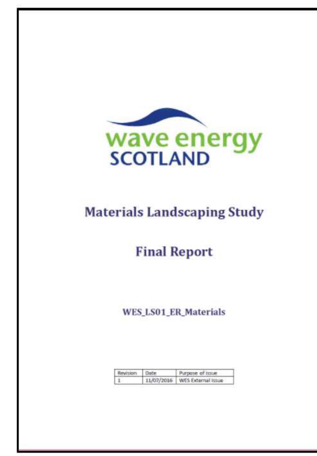
Materials Can Impact Cost and…

- Structure costs
- 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


CARBON TRUST

Accelerating marine energy

The potential for cost reduction – insights from the Carbon Trust Marine Energy Accelerator
July 2011

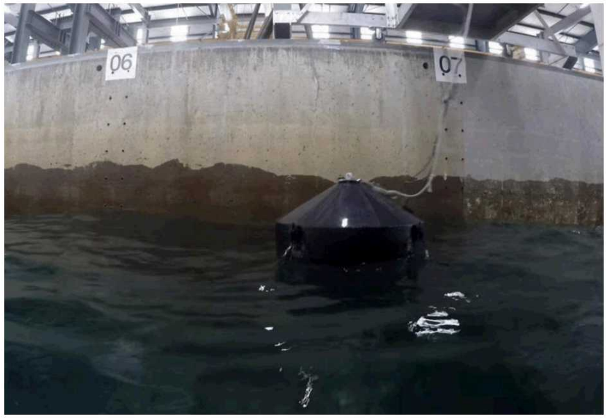

wave energy SCOTLAND

Materials Landscaping Study

Final Report

WES_LS01_ER_Materials

MHK Designs Exploring Composite Materials



AquaHarmonics

Columbia Power Technologies

Lockheed Martin-OTEC Cold Water Pipe

Ocean Renewable Power Company

Resolute Marine Energy

Verdant Power

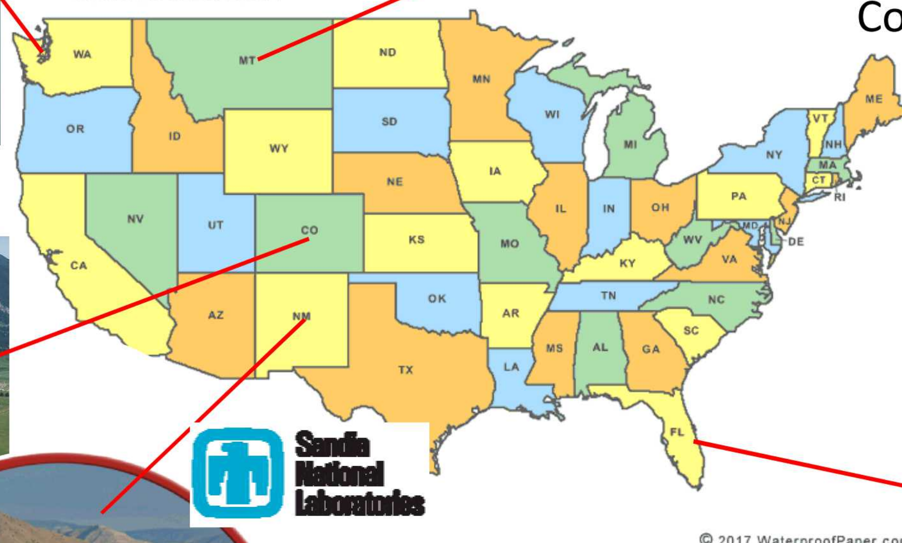
All Photos Obtained From Company Websites and Literature References

Materials Team

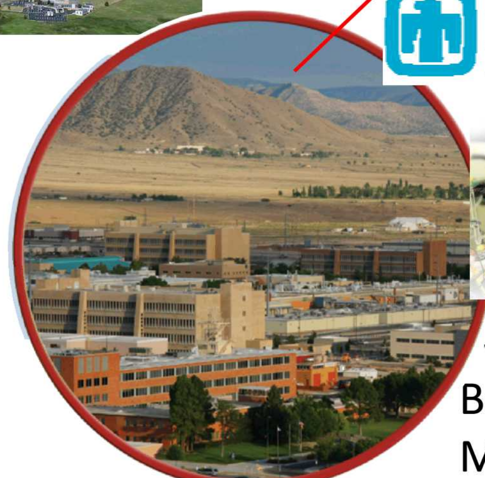
George Bonheyo: Biofouling

Marine Science Laboratory

David Miller: Composite Performance



Scott Hughes: Substructure Testing



Francisco Presuel-Moreno: Corrosion

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

Budi Gunawan: Loads & FBG Sensors

Interreg
North-West Europe
OPIN
European Regional Development Fund

US MHK Composites Program

Sandia National Laboratories

Coupons provided by:

Composites Engineering Research Lab

Composites Technology Development,

Hygrateck,

Janicki,

Industries,

Polyone,

Ocean Renewable Power

Company

Verdant

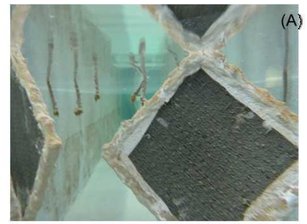
FY17

Salt Water Effects on Composite Performance Testing

Biofouling & Environmental Effects on Composites

FY18

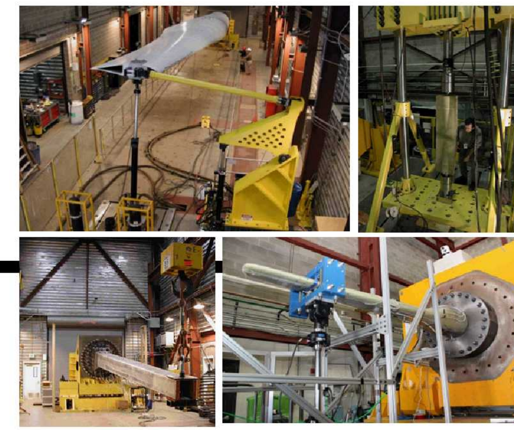
Metal – Carbon Fiber Composite Interconnects in Seawater

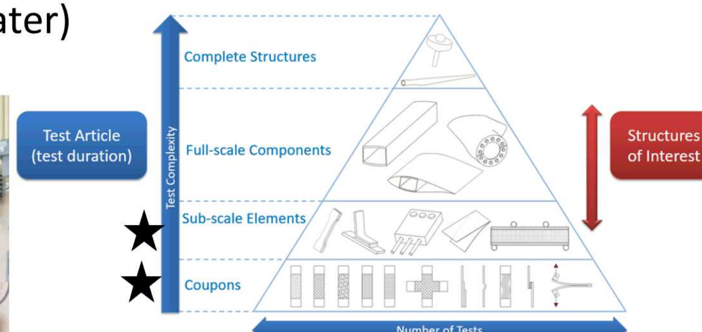


Industry directed sub scale elements & joined coupon fabrication/testing (Artificial & Actual Seawater)

FY19-20

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





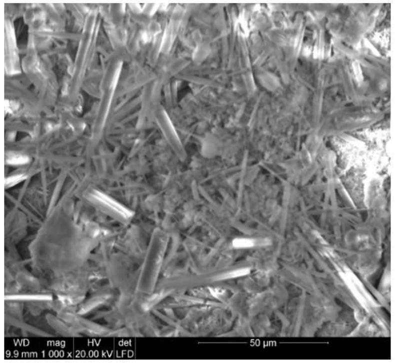
MONTANA STATE UNIVERSITY
FAU FLORIDA ATLANTIC UNIVERSITY
NREL NATIONAL RENEWABLE ENERGY LABORATORY
Pacific Northwest NATIONAL LABORATORY
WEAMEC Research, Education & Innovation in Pays de la Loire FOR MARINE ENERGY
Nantes Métropole

Interreg North-West Europe OPIN
European Regional Development Fund

Environmental Effects on Composites

Sandia National Laboratories

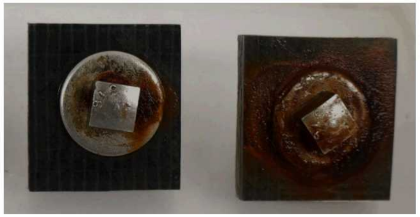
Corrosion can occur on metals connected to carbon fiber composite materials (i.e., CF composite to metal interconnects).

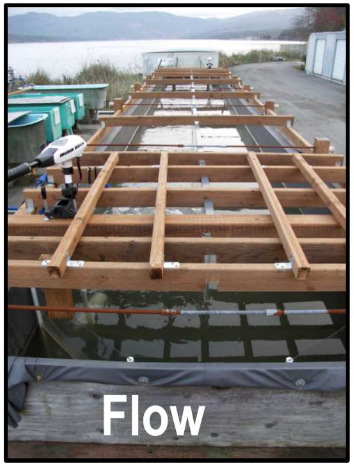


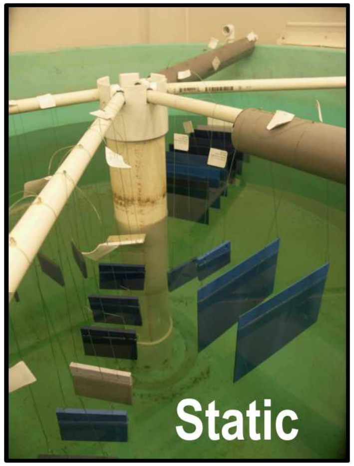
Calcareous deposit from corrosion study

CF/VE8084 + anode

Corrosion Studies on Connections







Biofouling Studies on Composites & Coatings

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

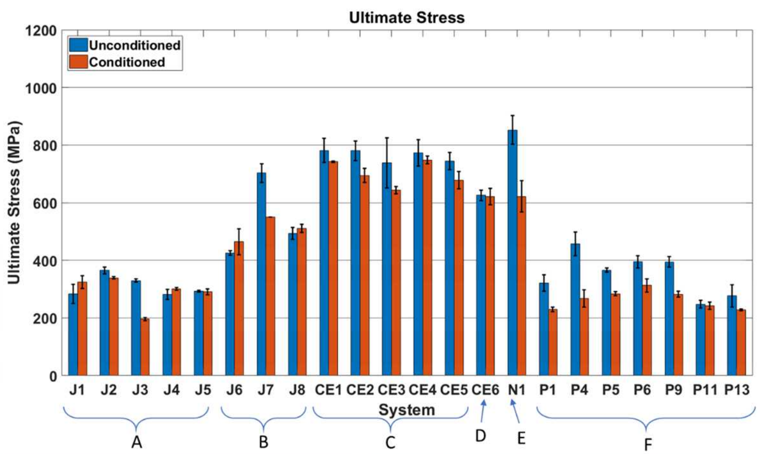
0-22 month Exposures

MONTANA STATE UNIVERSITY
FAU FLORIDA ATLANTIC UNIVERSITY
NREL NATIONAL RENEWABLE ENERGY LABORATORY
Pacific Northwest NATIONAL LABORATORY
WEAMEC Research, Education & Innovation in Pays de la Loire FOR MARINE ENERGY
Nantes Métropole

Building Block Approach to Structural Validation

Coupon Performance

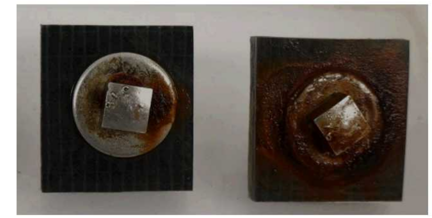
MSU Material	Layup	Average V_f for static tests %	% Moisture	Longitudinal Direction			Transverse Direction		
				E, GPa	UTS, MPa	% strain	E, GPa	UTS, MPa	% strain
CE1	[V/(+/-45)g/0c]s	40.9	0	56.1	786	1.38	10.7	98.3	3.17
			1.2	58.3	787	1.33	8.54	68.3	1.84
CE2		35.8	0	54.8	773	1.40	9.02	83.3	3.26
			1.33	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



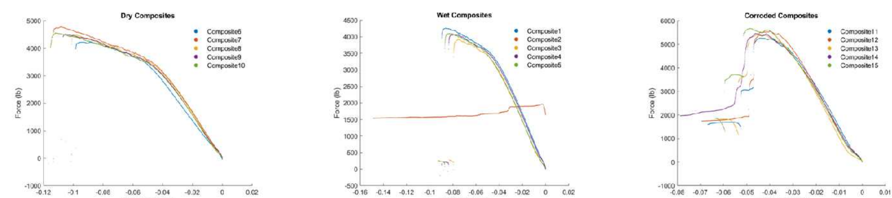
Group	Fiber	Matrix	Layup Type
A	Glass	Thermoset	Quasi-Isotropic
B	Carbon	Thermoset	Quasi-isotropic
C	Hybrid	Thermoset	[45/-45/0]s

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

Corrosion Studies on Connections



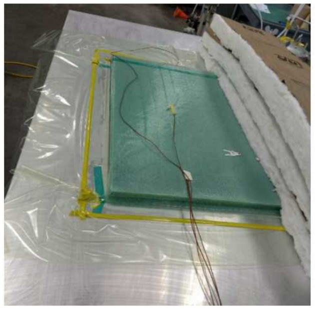
Joined Material Load Behavior

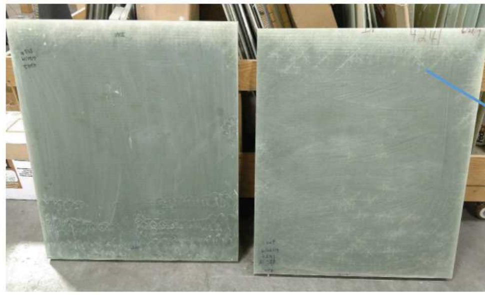


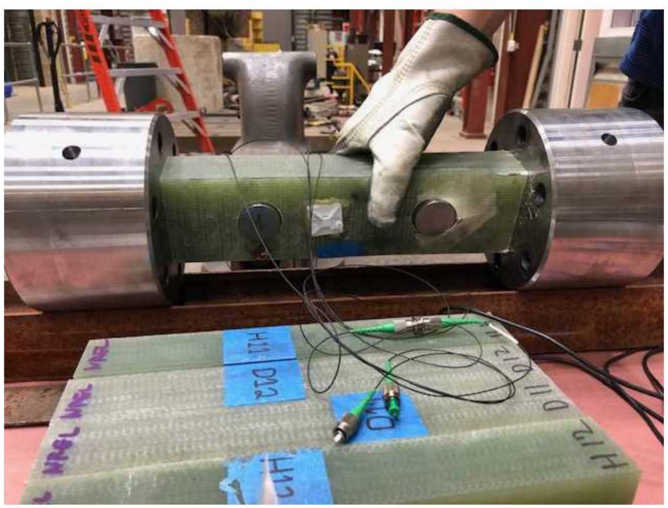
MONTANA STATE UNIVERSITY
FLORIDA ATLANTIC UNIVERSITY
NREL NATIONAL RENEWABLE ENERGY LABORATORY
Pacific Northwest NATIONAL LABORATORY
WEAMEC Research, Education & Innovation in Pays de la Loire FOR MARINE ENERGY
Nantes Métropole

Building Block Approach to Structural Validation

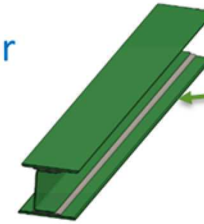
Subcomponent Fabrication







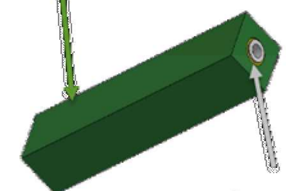
Adhesively shear specimens



Composite

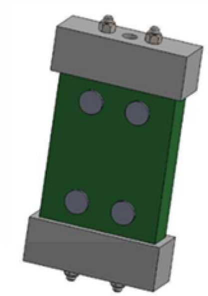
Adhesive bondline

Adhesively bonded inserts

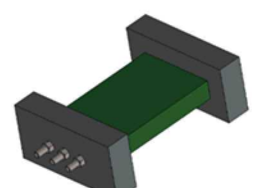


Metal Insert

T-bolt connections



Compression Relaxation specimens



Interreg North-West Europe OPIN

European Regional Development Fund

MHK Databases

Wind & Water Materials and Structures

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

Open Energy Information

https://openei.org/wiki/Main_Page

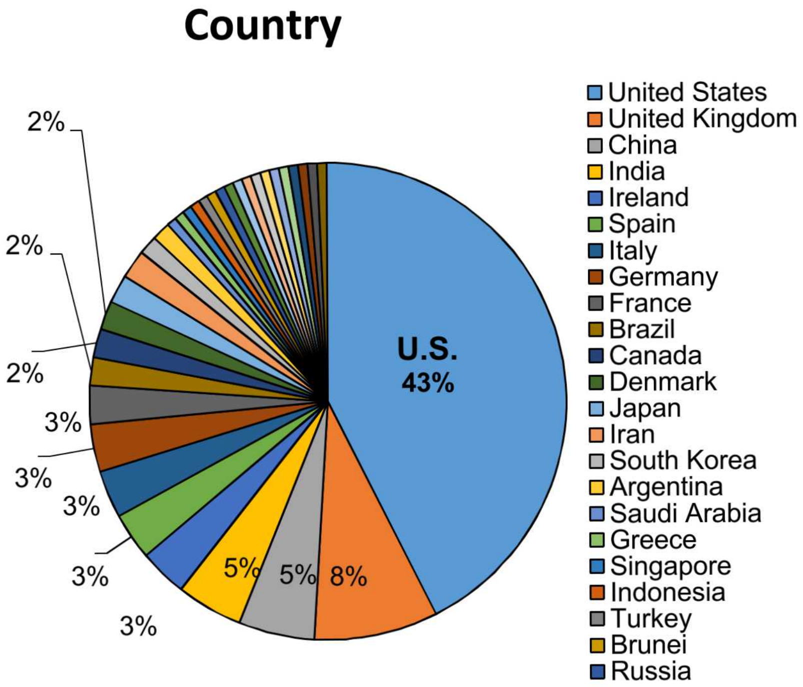
TETHYS

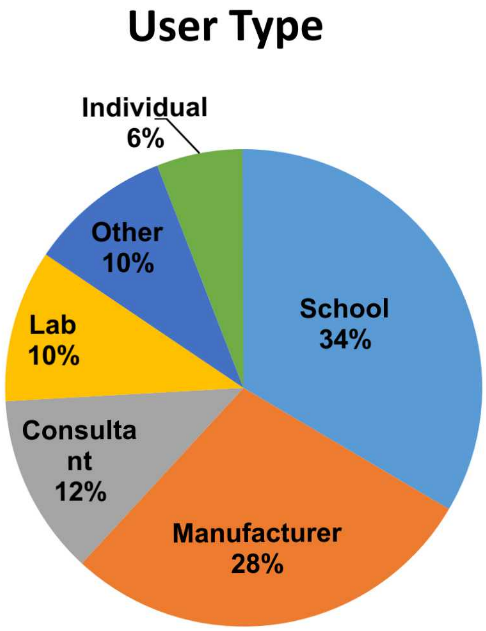
https://tethys.pnnl.gov/

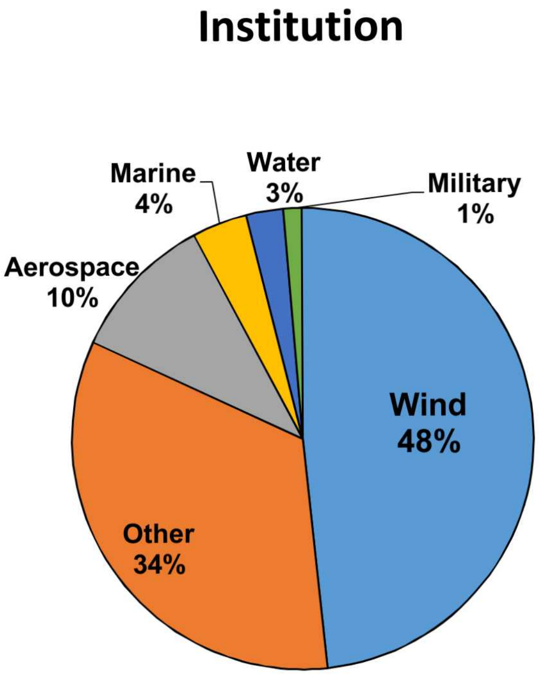
Montana State University · Florida Atlantic University · NREL National Renewable Energy Laboratory · Pacific Northwest National Laboratory · WEAMEC Research, Education & Innovation in Pays de la Loire for Marine Energy · Nantes Métropole

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

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







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

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

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy — Sandia National Laboratories

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.

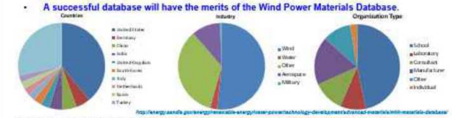
This two-day workshop was used to identify what are the composite materials related needs that must be addressed for the MHK Energy Industry to have success. To aid in these decisions, the workshop participants focused on the following activities to direct composite initiatives.

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.**



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

This work was funded by the U.S. Department of Energy's Wind and Water Power Technologies Office. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

MONTANA STATE UNIVERSITY — FAU FLORIDA ATLANTIC UNIVERSITY — NREL NATIONAL RENEWABLE ENERGY LABORATORY — Pacific Northwest NATIONAL LABORATORY — WEAMEC Research, Education & Innovation in Pays de la Loire FOR MARINE ENERGY — Nantes Métropole

Q&A

Interreg

EUROPEAN UNION

North-West Europe

OPIN

European Regional Development Fund

Thank you!