WindSTAR

Wind-Energy Science, Technology, and Research
Industry/University Cooperative Research Center

2017 ANNUAL REPORT

UMass Lowell ✦ UT Dallas

MESSAGE FROM OUR CENTER DIRECTORS

Center Director
Christopher Niezrecki, Ph.D.
University of Massachusetts Lowell

Site Director
Mario Rotea, Ph.D.
University of Texas at Dallas

Dear IAB Members,

On behalf of the WindSTAR I/UCRC Directors and Faculty members we would like to thank you for your sustained support and Membership. The Center has now completed its third year with 8 research projects currently being executed. As the awareness and engagement of WindSTAR continues to grow, more people in the wind industry are learning that the Center is a platform that allows universities, industrial partners, and government to collaborate on wind energy related problems. We are working toward a goal of lowering the LCOE and helping to make the use of wind energy more widespread within the United States and globally. Without leveraging the infrastructure of a National Science Foundation I/UCRC, this level of commitment and value to industry would not be possible. For every dollar coming from a Full IAB member, 14.4 dollars are invested in the Center from another source. For small business IAB members the leveraging is approximately 40:1.

As we enter our fourth year of operation, we hope to grow the Center, strengthen existing collaborations, and increase awareness of WindSTAR in the wind industry community. The WindSTAR Center is working to meet the challenge of improving performance and reliability of wind energy conversion systems to help drive down the cost of wind-generated electricity. Through continued advancements in technology we believe that wind power will be a major player in the future of the Nation's electricity portfolio.

In the ever changing energy business climate, we will look for creative solutions to help grow and expand the Center. We are happy you are participating in the WindSTAR I/UCRC and look forward to working with you in the years to come.

Sincerely,

Christopher Niezrecki, Ph.D.
Professor and Chair, Department of Mechanical Engineering
Co-Director, Structural Dynamics and Acoustics Systems Laboratory
Director, WindSTAR I/UCRC
University of Massachusetts Lowell

Mario Rotea, Ph.D.
Erik Jonsson Chair in Engineering and Computer Science
Professor and Head, Department of Mechanical Engineering
Site Director, WindSTAR I/UCRC
University of Texas Dallas

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A NATIONAL SCIENCE FOUNDATION SUPPORTED INDUSTRY-UNIVERSITY COLLABORATION DRIVING DOWN THE COST OF WIND POWER

MISSION STATEMENT

The mission of WindSTAR is to bring together university and industry researchers to conduct basic and applied research on topics that relate to the advancement of wind turbines and the wind industry, combine state-of-the-art capabilities and knowledge to advance projects relevant and of mutual interest to industry partners, train students in the advanced technologies that are important to industry members, and foster a community for networking, interactions, and collaborations.

WindSTAR is an NSF-funded Industry/University Cooperative Research Center for Wind Energy, Science, Technology and Research, established in 2014. A collaboration between UMass Lowell, the University of Texas at Dallas, and its members, the Center aims to solve the pressing needs of the wind industry.

The University of Massachusetts Lowell is the lead WindSTAR site and focuses on projects that advance the materials, manufacturing, reliability, testing, and monitoring of the blades and turbines. The University of Massachusetts Lowell is a public national research university in Lowell, Massachusetts.

The University of Texas at Dallas is a WindSTAR site with foci on high-fidelity simulation of power production and loads, LiDAR measurements for wind plant diagnostic and model validation, control systems for wind turbines and wind farms and grid integration. The University of Texas at Dallas is a public research university in Richardson, Texas.

CURRENT IAB MEMBER COMPANIES

WindSTAR's industry membership is diverse across the wind energy supply chain, including wind farm owner-operators, turbine and blade manufacturers, material suppliers, control-system developers and other organizations with a stake in the growth of the wind energy market.

2017-2018 IAB Chair

Ben Rice
Senior Manager, Operations Engineering
Pattern Energy

2017-2018 IAB Vice Chair

Nick Althoff
Sr. Advanced Manufacturing Engineer
GE Renewable Energy

2016-2017 IAB Chair

Steve Johnson
Senior Engineering Manager, Wind Advanced Technologies
GE Renewable Energy

2016-2017 IAB Vice Chair

Paul Haberlien
Director, Business Transformation
Pattern Energy

Past IAB Chairs:

2015-2016: Justin Johnson, EDP Renewables
2014-2015: Steve Nolet, TPI Composites, Inc.

Previous Members include:

Massachusetts Clean Energy Center, National Instruments, Maine Composites Alliance, NRG Renew, Keuka Energy

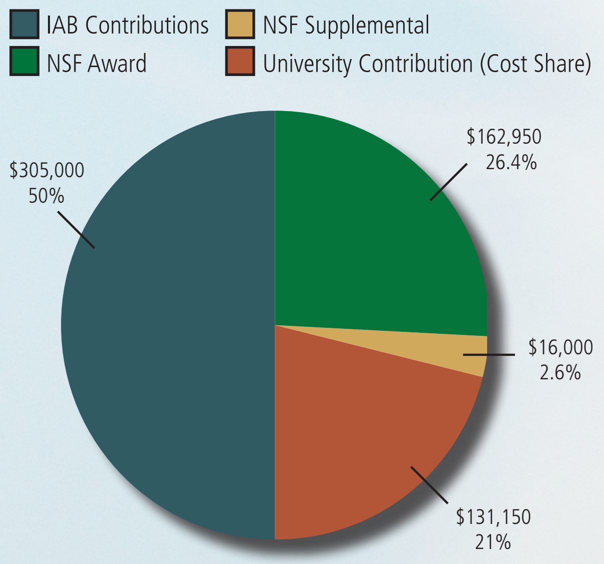
FINANCIAL OVERVIEW: RETURN ON INVESTMENT

MEMBERSHIP LEVELS 2016-2017

Full
$40,000 Annually

Associate Small Business
$15,000 Annually

REVENUE FOR 2016-2017



TOTAL INVESTED: $615,100

PAST PROJECTS

- Design for Composite Wind Turbine Blade Manufacturing
  Project ID: A1-14
- Large Area Turbine Blade Inspection
  Project ID: D1-14
- Extremum Seeking Control for Wind Turbine Power Maximization
  Project ID: E2-14
- Two-layer Optimization for Maximizing Wind Farm Power Output
  Project ID: E3-14

PROJECTS FUNDED

2016-2017: 8 Completed Projects

2016-2017 PROJECTS

- Self-Healing Materials for Wind Turbine Blades
  Project ID: A3-14
- Low-Cost Wind Turbine Blade Structural Health Monitoring
  Project ID: B1-15
- Diagnosis of Electrical Faults of Wind Turbine DFIGs
  Project ID: B1-16
- Proactive Detection of Under-Performing Wind Turbines Combining Numerical Models, LiDAR and SCADA data
  Project ID: C1-16
- Mechanical Property Enhancement Prediction for Matrix Materials
  Project ID: A5-16
- Performance Effects of Adhesive Bond Defects
  Project ID: A6-16
- Automation for Blade Manufacturing
  Project ID: A3-16
- Evaluation of Nested Extremum Seeking Wind Farm Control with SWiFT Facility
  Project ID: D1-16
- Effects of Manufacturing Induced Defects
  Project ID: A4-16
  (Project extended to 2018)

CUMULATIVE INVESTMENT
During 3 years of center operation

Cumulative Research Investment by IAB Members
2014-2017: $978,750

Cumulative Investment in Center
2014-2017: $2,333,060

PROJECT HIGHLIGHTS

NOTE:
Due to the proprietary nature of Project ID: A3-14 (Self-Healing Materials for Wind Turbine Blades), information about this project was not included in the published report for public release.

Low-Cost Wind Turbine Blade Structural Health Monitoring

Principal Investigator:
Murat Inalpolat, University of Massachusetts Lowell

Co-Principal Investigator:
Christopher Niezrecki, University of Massachusetts Lowell

Student Researcher:
Christopher Beale, University of Massachusetts Lowell

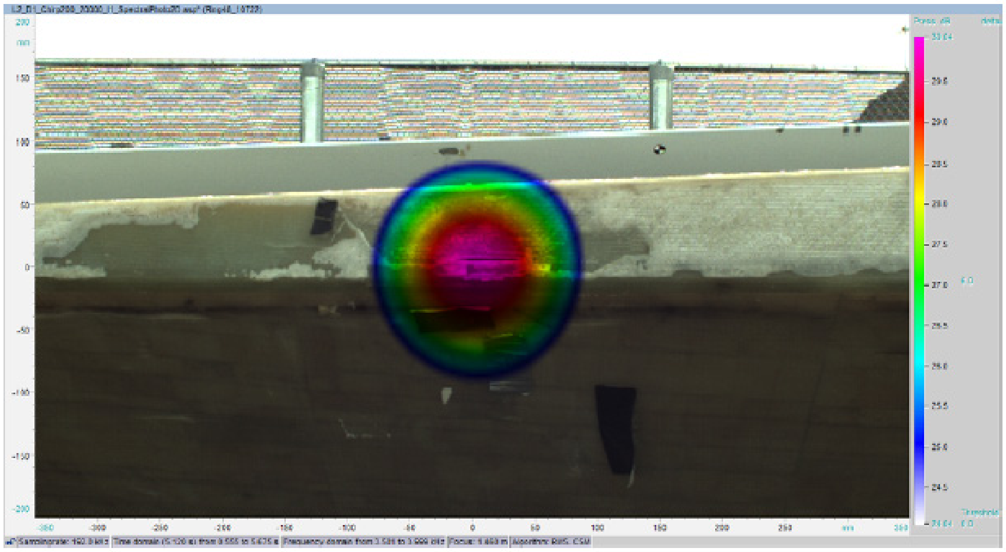
IAB Mentors:
Adam Johs, EDPR
Dushyant Tank, Pattern Energy

This project enabled the team to initiate the development of a state of the art acoustics-based structural sensing and health monitoring technique which requires efficient algorithms for operational damage detection from wind turbine blades. The team initially focused on the active acoustic detection aspect of the project. A 9m CX-100 blade has been procured to investigate the acoustic detection rate and the influence of environmental conditions on the diagnostics process.

The "active sensing" approach, which involves mounting an audio speaker (with controlled output frequency and level) inside of the blade to excite the internal cavity acoustics, has been tested under different conditions with different specimen. This study is also complemented by the computational investigations of the acoustics of the blade's internal cavity. A finite element based approach has been used in order to better understand the sensitivity of the technique to damage type, size and location. Ansys, a commercially available computational tool, has been used to model the CX-100 blade section to investigate the acoustic radiation patterns with and without the addition of prescribed damage at different locations of the blade.

The team has also worked on the passive detection part of the project. For this part of the project, UMass Lowell's Wind Tunnel has been utilized to experimentally simulate external wind flow conditions and test the "passive damage detection" technique. This approach leverages the energy caused by the wind/flow-induced noise, exterior to the cavity. It is inexpensive, in-situ, and effective to detect holes, cracks and leading/trailing edge splits in bonded surfaces. The blade can be continuously monitored and when damage is originated, the internal acoustic signature should change due to the changes in the transmission loss (caused by the hole or crack) and/or the distorted acoustic pressure field. The sound field inside the blade should be significantly different when the blade cavity is no longer sealed to the fluid passing over the exterior of the blade. A single microphone inside the blade cavity can be used to track the differential noise component caused by the damage which essentially couples the blade cavity to the exterior airflow (like a Helmholtz resonator or the noise generated by the airflow over a glass bottle).

After the aforementioned initial stages of the project, the team has focused on the active damage detection tests on a full scale wind turbine blade at the Wind Technology and Testing Center (WTTC) located in Boston, MA and developing a suite of preliminary damage detection algorithms that will be used to detect damage under operation. This final report will mostly highlight the results obtained from the active detection tests at the WTTC.



Sound Pressure Map betweeen 3500 and 4000 Hz of the damaged blade during a 200 to 20000 Hz chirp excitation.

PROJECT ID: B1-15

Diagnosis of Electrical Faults of Wind Turbine DFIGs

Principal Investigator:
Siavash Pakdelian, University of Massachusetts Lowell

Co-Principal Investigators:
Murat Inalpolat, University of Massachusetts Lowell
Babak Fahimi, University of Texas Dallas

Student Researcher:
Ehsan Qiyassi, University of Massachusetts Lowell

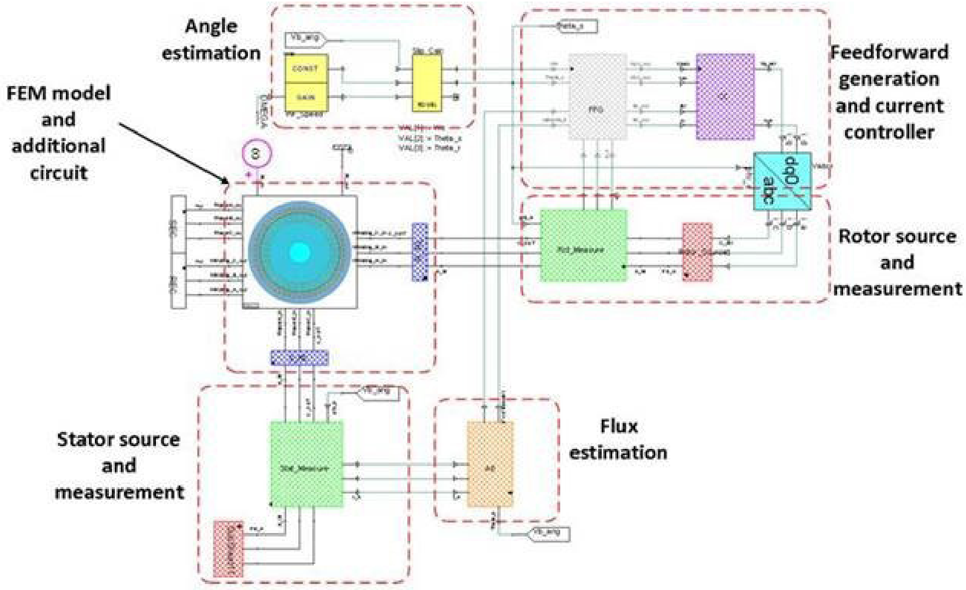
IAB Mentors:
Veronica Hernandez, Bachmann Electronic Corp
Paul Haberlein, Pattern Energy

During the first quarter of the project, two different models for the analysis of a wind turbine system were developed. The first model is an ideal model implemented in MATLAB/Simulink and the second model is a numerical one to be analyzed with finite element method. At the first step, these models were verified with the parameters drawn from experimental tests performed at UT Dallas. All of the models are based on given specifications of this machine which is a 10 HP DFIG.

The Finite Element Model (FEM) of the machine was connected to an external controller implemented in Simplorer, which is a multi-physic environment compatible with our FEM. Since the Finite Element Analysis (FEA) is a very time-consuming process, the controller was implemented in a way to be able to test the speed of the simulations both with the discrete and continuous solver. Simulations were configured with the continuous solver settings that yield a good accuracy and the best simulation speed time.

Even though some of the faults and non-idealities being studied could be implemented outside the FEM, other faults such as dynamic eccentricity of the rotor and stator and rotor short circuit faults would be best implemented using the FEM, which was carried out next. Different methods for implementation of stator and rotor short circuit fault were tried, and the ones that produce the most stable and fastest simulations were executed. Processing the results using Fast Fourier Transform (FFT) confirms that operation of the current controller masks all the known fault signatures in the rotor and stator current. However, our findings indicate that voltage and current space vector and two control voltage vectors in the synchronous reference frame could be used to identify the fault.

The main focus of this study is on the rotor asymmetry and stator and rotor inter-turn short circuit faults. For each of the faults, various simulations are carried out to identify the fault signatures and the severity of the fault that could be detected. This choice is made based on the frequency of the occurrence of these faults. However, since rotor asymmetry alone comprises more than half of the generator failures, special attention has been paid to studying the effect of other practical non-idealities of the operation field and generator conditions, such as grid voltage unbalance and eccentricity.



PROJECT ID: B1-16

Proactive Detection of Under-Performing Wind Turbines Combining Numerical Models, LiDAR and SCADA data

Principal Investigator:
Giacomo Valerio Iungo, University of Texas Dallas

Co-Principal Investigator:
Stefano Leonardi, University of Texas Dallas

Student Researchers:
Stefano Letizia, Christian Santoni, Lu Zhan
University of Texas Dallas

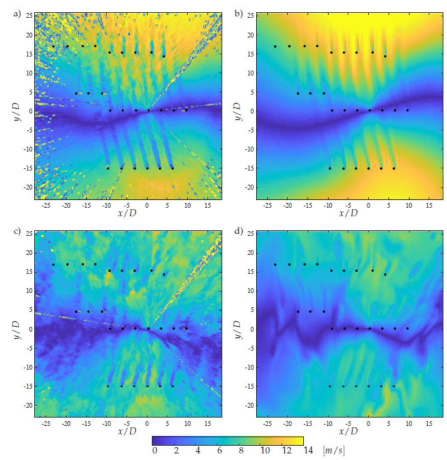
IAB Mentors:
Patrick Pyle, Pattern Energy
Neha Marathe, EDPR
Hector Figueroa, Leeward

This project focuses on the development of a framework for proactive detection of underperformance of individual turbines in a wind turbine array. This research endeavor encompasses an experimental campaign for an onshore wind farm, development of a RANS model for prediction of wind turbine wakes, wake interactions and power capture, and simulations carried out through WRF to predict the wind field around and within the wind farm, and turbine power production.

For this project, a wind farm in North Texas was made available for LiDAR deployment, while providing meteorological and SCADA data as well. The LiDAR was deployed on site for a total duration of eight months. Wake measurements were performed for a broad range of wind atmospheric conditions and turbine settings. The diagnostic study has shown that the wind farm under examination is characterized by an average power loss due to wake interactions equal to 4% of the total power production under nighttime stable atmospheric conditions, while of only 2.4% for daytime convective conditions. Wind turbines have generally collected higher wind power under convective regimes than stable conditions.

We were able to successfully developed a 2D parabolic RANS solver for simulations of wind turbines wakes produced by the entire wind farm, while predicting power harvesting from each wind turbine. At this stage, accuracy in predicting power capture is about 2.8%, while for hub height wind velocity at turbine location is 4% (50th percentile), with a computational cost of about 8 minutes to predict 10-minute operation of the entire wind farm.

The WRF simulations showed a good level of accuracy in reproducing the meteorological data acquired during the experiment by a met-tower present on site. Furthermore, ad-hoc modeling of the wind turbines allowed accurate simulations of the wind farm power capture for the entire daily cycle of the atmospheric stability.



Color Contours of the absolute value of the radial velocity obtained from the LiDAR measurements (a,c) and virtual LiDAR from MTKE numerical simulations (B,d) during stable (a,b) and unstable (c.d) atmospheric boundary conditions at an elevation angle of 3 degrees, synchronized in time. The turbine position is denoted by a solid circle.

Photos of the site and experimental setup.

PROJECT ID: C1-16

Mechanical Property Enhancement Prediction for Matrix Materials

Principal Investigator:
Alireza V. Amirkhiz, University of Massachusetts Lowell

Co-Principal Investigator:
Christopher Hansen, University of Massachusetts Lowell

Student Researcher:
Joshua Morris, University of Massachusetts Lowell

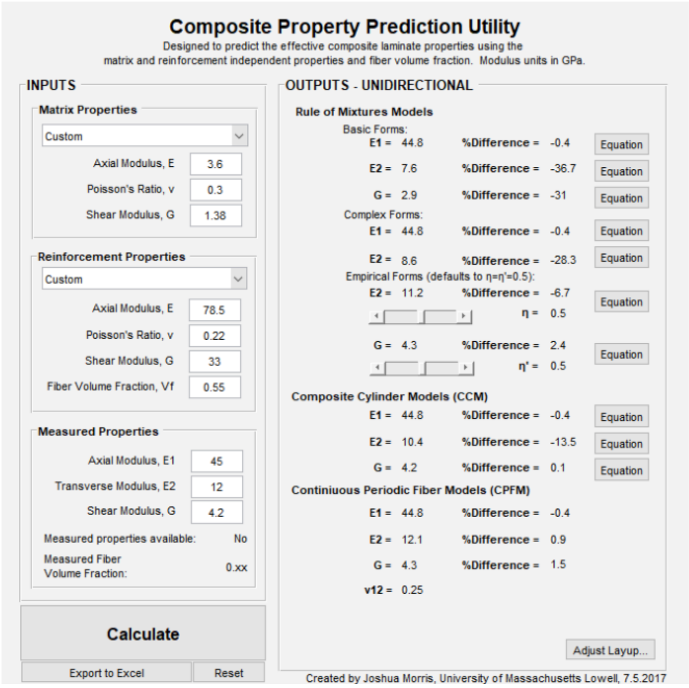
IAB Mentors:
Stephen Nolet, TPI Composites
Hui Zhou, Huntsman
Marc Chouhinard, Huntsman

Optimization of the resin properties could offer a substantial boost to wind turbine blade transverse and shear strength. Failure modes with complex deformations, such as twisting, experience high transverse and shear stresses that can cause delamination or trailing edge splitting. The composites resistances to these stresses are heavily dependent on the resin mechanical properties. Micromechanical models that could be used to predict composite stiffness properties and guide resin research efforts are critically inaccurate for transverse and shear response. A more reliable micromechanical model needs to be developed that can be used to characterize the influence of the resin properties on a full scale turbine blade.

Traditional micromechanical models were examined for discrepancies and improved upon using a newly developed model called the Continuous Periodic Fiber Model (CPFM). The model was validated using experimentally obtained data provided by TPI Composites. The difference between the measured moduli and the CPFM determined moduli is 3% for the axial tensile modulus, 12% for transverse, and 3% for shear. This is twice the accuracy of the next best model. A tool was created in MATLAB that performs the modulus prediction and applies layup adjustments to accurately determine the effective composite properties using several micromechanical models, including CPFM. The sensitivity of the results indicate the need for an accurate micromechanical model, namely CPFM, in order to correctly analyze the influence of resin on the blade response.

A numerical study was performed to determine the effective composite stiffness dependence on the resin properties. The study was performed for several resin modifications and layups so that a catalog of expected influence factors could be created. An increase of the resin Young's modulus, and proportionally its shear modulus, was determined to be the most beneficial pathway to improving the composite transverse and shear response. For a 20% increase to the matrix Young's modulus, the composite's effective transverse and shear moduli rose by 16%. Applying this enhanced resin in structural analysis of a utility scale wind turbine blade presented various distinct advantages, such as higher calculated buckling load and higher structural rigidity (as measured by tip displacement for a unit load).

This research indicates that optimization of the resins used to produce composite wind turbine blades is a suitable pathway to strengthen blades against transverse and shear failure modes. Researchers and manufacturers can use the tool and analysis results to determine whether materials with enhanced properties can be economically introduced and enable the potential advances to blade design that result.



PROJECT ID: A5-16

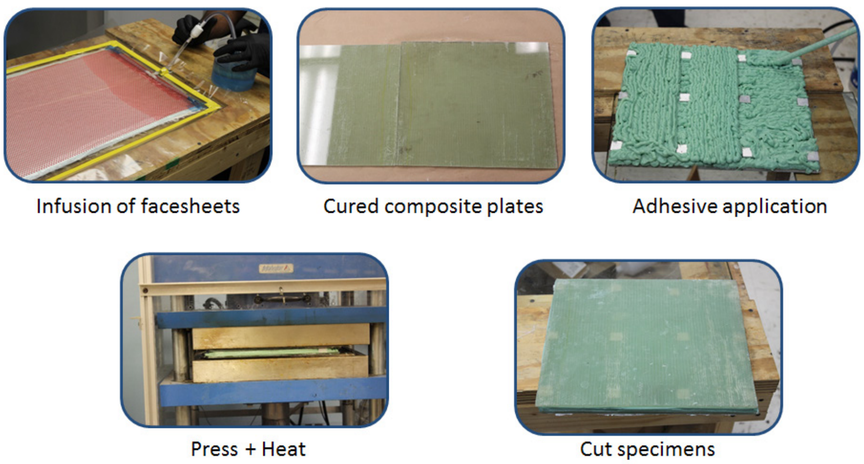
Performance Effects of Adhesive Bond Defects

Principal Investigator:
Scott Stapleton, University of Massachusetts Lowell

Co-Principal Investigator:
Christopher Hansen, University of Massachusetts Lowell

Student Researchers:
Alessandro Cassano, Siddharth Dev
University of Massachusetts Lowell

IAB Mentor:
Nick Althoff, GE Renewable Energy
Paul Ubrich, Hexion



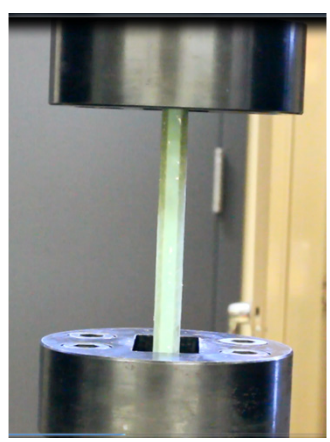
Bonded joint manufacturing process.

Bondline failure is a key critical failure mode in wind turbine blades. Substantial variation in bondline thickness can result in different thermal histories for the adhesive layer due to the exothermic curing of common adhesives. Predictive guidance regarding the impact of this variability in adhesive cure temperature cycles is extremely limited. Without guidelines of acceptable variability, excess resources may be placed into avoiding damage by processing at excessively low temperatures and longer processing cycles which produce no discernible benefits.

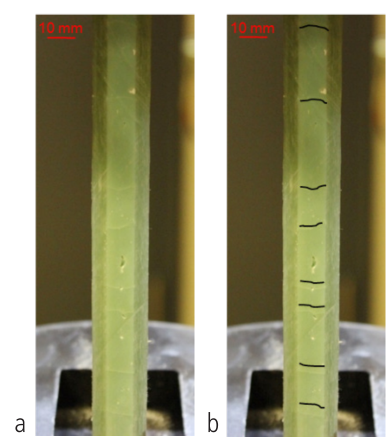
In this research, two studies were carried out to characterize the behavior of thick adhesive bondline. The first study focuses on the mechanical characterization of the adhesive system as a function of the curing temperature. The second study is to describe the curing of the adhesive system and develop a predictive tool to capture the thermal and curing histories for any type of geometry.

The mechanical characterization of the adhesive leads to a better understanding on how the cure temperature effects the stiffness and the strength of the adhesive system. The goal of the research is to find a correlation between mechanical properties and curing temperature. Extensive experimental testing has been performed on neat adhesive specimens in the curing temperature range from 70°C to 180°C.

Due to the high exothermic behavior of thick adhesive bondlines, an FEM model was developed to simulate the cure cycle of the adhesive in a joint configuration. In fact, the temperature in the middle of the adhesive reaches higher values than the imposed cured temperature. Once the kinetic parameters from the resin system are determined and implemented in the model, it will be possible to trace the adhesive thermal and curing histories and the gradients developed through the bondline thickness.



Mechanical testing of 10 mm bonded joint specimen. Tensile test set up.



Mechanical testing of 10 mm bonded joint specimen. a) Crack propagation through the thickness b) Highlighted cracks with marks.

PROJECT ID: A6-16

Automation for Blade Manufacturing

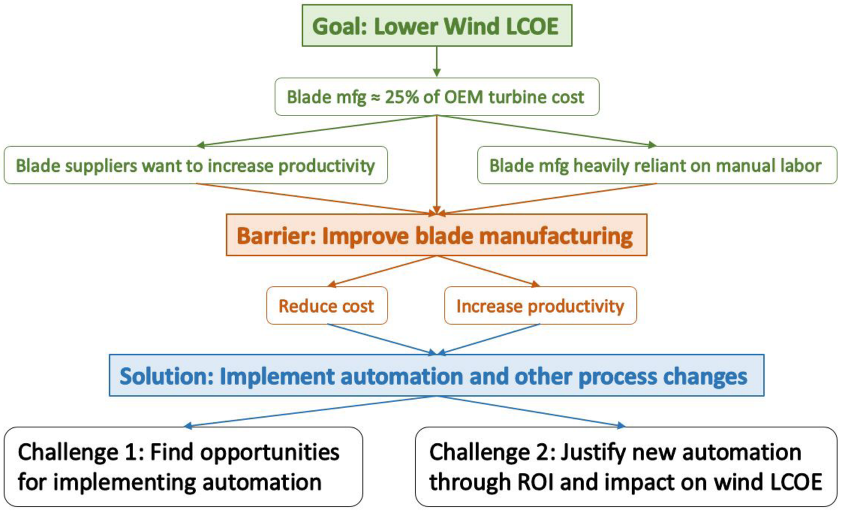
Principal Investigator:
James Sherwood, University of Massachusetts Lowell

Student Researcher:
Matteo Polcari, University of Massachusetts Lowell

IAB Mentor:
Steve Nolet, TPI Composites
Nick Althoff, GE Renewable Energy

Wind blade suppliers could realize a reduction in overall manufacturing cost and cycle time through the implementation of cost-effective automation. Currently, up to a third of the total OEM wind blade manufacturing cost comes from labor. The use of automation is limited to (1) cranes that move pieces on the factory floor, (2) pump systems for resin infusion, and (3) machines for cutting fabric and core material and painting and machining finished blades. Attempts to further implement automation for wind blade manufacture have historically been unsuccessful, primarily due to prohibitive capital costs. Other composite manufacturing sectors, i.e. aerospace and automotive, have successfully utilized high levels of automation and benefited from this implementation. Before additional automation can be inserted into the composite wind blade manufacturing process, any proposed system will need to "buy" its way onto the blade with a good ROI. Thus, there is a need for a detailed investigation of the wind blade manufacturing process and potential automation technologies.

During the year, an extensive review of existing and past work in automation for composites manufacturing relevant to wind blades was performed to serve as the foundation for a larger investigation into the wind blade manufacturing process. Because the scope of a comprehensive project dedicated to identifying new opportunities to insert automation into the wind blade manufacturing process is larger than a typical WindSTAR project, the current study was pursued with the intent of laying the groundwork for an IACMI proposal. The IACMI project is focused on creating a simulation of a generic wind blade manufacturing facility and the development of a techno-economic model. These complimentary tools will provide insight into how automation can lead to manufacturing process improvements. The IACMI project proposal is in the late stages of submission and approval and several partnerships with members of industry have been made—including two members of WindSTAR.



Solution Approach to Challenge 1:
Surveys of members of blade and automation supply industries will be conducted to mine for information regarding opportunities for new automation. Site visits to blade manufacturing facilities will aid the development of the generalized blade manufacturing simulation and the identification of opportunities for process changes.

Solution Approach to Challenge 2:
The generalized blade manufacturing simulation and techno-economic model will be used in tandem to provide insight into potential benefits of proposed automation technologies and other process changes. Recommendations for further investigation of proposed technologies will be made based on indications of good ROI. The manufacturing simulation will have built-in flexibility to be easily applicable to various blade manufacturing processes.

PROJECT ID: A3-16

Evaluation of Nested Extremum Seeking Wind Farm Control with SWiFT Facility

Principal Investigator:
Yaoyu Li, University of Texas Dallas

Co-Principal Investigator:
Stefano Leonardi, University of Texas Dallas
Mario A. Rotea, University of Texas Dallas

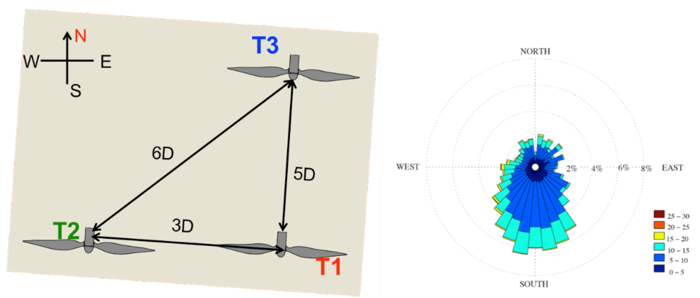
Student Researcher:
Umberto Ciri, Yan Xiao
University of Texas Dallas

IAB Mentors:
Veronica Hernandez, Bachmann
Ron Grife, Leeward

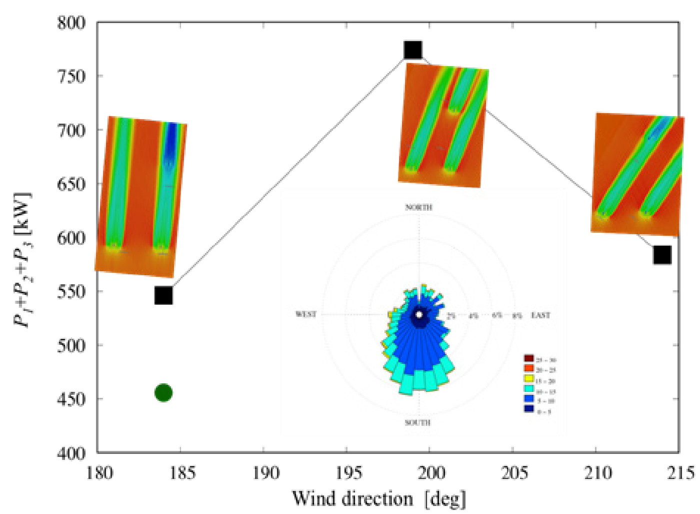
Control systems are critical for reducing the levelized cost of energy (LCOE) of wind energy. Axial-based and wake-steering controls using the generator torque, the pitch actuator and/or the yaw actuator can be deployed to maximize energy capture. Model-based control and optimization techniques have limited applicability due to the prohibitive cost for model calibration and wind field characterization. Therefore, model-free control and optimization strategies are highly desirable for wind power operators. From 2014 to 2016, WindSTAR IAB has supported two projects on model-free region-2 controls for wind turbine and wind farm based on extremum seeking control (ESC). In Project E2-14, ESC based region-2 controllers were tested on the CART3 facility at the National Renewable Energy Laboratory (NREL), and the testing results reveal a significant improvement of energy capture over NREL's baseline control strategy. In E3-14, large-eddy simulation (LES) study of the Nested ESC (NESC) reveals the effectiveness of NESC for model-free wind farm real-time optimization. The objective of Project D1-16 is to conduct initial stage work for experimental evaluation of NESC based wind farm control strategy on Sandia's Scaled Wind Farm Technology (SWiFT) facility.

During Project D1-16, the following research activities have been conducted: 1) acquisition of the FAST models of SWiFT wind turbines and wind resource information of SWiFT site; 2) ESC simulations using the SWiFT wind turbine FAST model; 3) development of NESC wind farm control testing plan based on SWiFT site wind source and IEC standard for performance evaluation; 3) development of LES simulation model of SWiFT wind farm on UTD-WF, with the capability of torque, blade pitch and yaw control; 4) LES based NESC simulations for UTD-WF model of SWiFT wind farm with both torque gain and yaw based controls.

A test plan that conforms to the IEC standard has been developed for torque-gain, blade-pitch and yaw based NESC, respectively, for the SWiFT facility. The LES based simulation studies of the SWiFT facility confirm the capability of NESC as model-free real-time optimization strategy for maximizing the energy capture of a cluster of turbines. Also, such study confirms the benefits of using high fidelity flow solvers like UTD-WF for evaluation of wind farm control strategies like NESC. The CFD model provides a virtual environment, in which a control solution can be reliably evaluated under realistic conditions with minimum impact of modeling uncertainties. In conclusion, the studies in Project D1-16 have laid a sound foundation for performing field tests for SWiFT facility.



Sketch of the SWiFT Facility wind farm (left), and wind rose at the site (right).



Total power of the SWiFT wind farm as a function of the wind direction: uniform inflow shown in black square symbols; realistic wind (with shear at inlet) shown in green circle symbol. The wind rose is included for reference.

PROJECT ID: D1-16

2014-2017 OUTCOMES

Through August 31, 2017

Deliverables:

1. Software: A matlab-based GUI that can predict the axial, transverse, and shear properties of composite laminates used in wind turbine blades based on CPFM advanced micromechanics model
2. Software: A Matlab based GUI for prediction of power production and wind turbine wakes for the Panhandle Phase II wind farm.
3. Software: Simulink code for Extremum Seeking Control of NREL CART3 (Controls Advanced Research Turbine, 3-bladed).

Journal Papers:

1. R. W. Martin, A. Sabato, A. Schoenberg, R. H. Giles, and C. Niezrecki, "Comparison of non-destructive testing techniques for the inspection of wind turbine blades spar caps," Wind Energy, under review.
2. Y. Xiao, Y. Li, and M. A. Rotea, "CART3 Field Tests for Wind Turbine Region-2 Operation with Extremum Seeking Controllers," IEEE Trans. on Control Systems Technology, under review.
3. Iungo G.V., V. Santhanagopalan, U. Ciri, F. Viola, L. Zhan, M. A. Rotea and S. Leonardi, "Parabolic RANS solver for low-computwational-cost simulations of wind turbine wakes," Wind Energy, to appear.
4. Santhanagopalan V., M.A. Rotea, G.V. Iungo, "Performance optimization of a wind turbine column for different incoming wind turbulence," Renewable Energy, Vol. 116, February 2018, pp. 232-243.
5. Ciri U., M.A. Rotea and S. Leonardi, "Model-free Control of Wind Farms. A comparative study between individual and coordinated extremum seeking," Renewable Energy, Vol. 113, December 2017, pp. 1033-45.
6. El-Asha S., L. Zhan, G.V. Iungo, "Quantification of power losses due to wind turbine wake interactions through SCADA, meteorological and wind LiDAR data," Wind Energy , Vol. 20, No. 11, November 2017, pp. 1823-1839.
7. Ciri U., M.A. Rotea, C. Santoni-Ortiz and S. Leonardi, "Large-Eddy Simulations with Extremum-Seeking Control for wind turbines array power optimization," Wind Energy, Vol. 20, No. 9, September 2017, pp. 1617-1634.

Master of Science Thesis:

1. Martin, R. W., "Analysis of polarimetric terahertz imaging for non-destructive detection of subsurface defects in wind turbine blades," Master of Science Thesis, University of Massachusetts Lowell, May, 2016.

Interns at Member Companies:

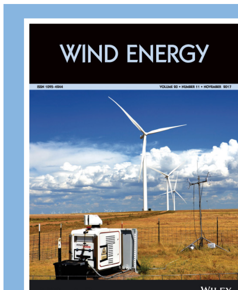
1. Said El-Asha, recipient of WindSTAR NSF REU at UT Dallas, Engineering Intern at Leeward Renewable Energy, LLC.

Conference Papers:

1. Ciri U., M.A. Rotea and S. Leonardi, "Nested Extremum Seeking Control for Wind Farm Power Optimization," 2017 American Control Conference, Seattle, WA, May 24-26 2017, pp. 25-30.
2. Xiao, Y., Y. Li, M.A. Rotea, "Multi-objective Extremum Seeking Control for Enhancement of Wind Turbine Power Capture with Load Reduction," Journal of Physics: Conference Series, Volume 753 (2016) 052025, The Science of Making Torque from Wind (TORQUE 2016), Munich, Germany, October 5-7, 2016.
3. Polcari M., and Sherwood J. 2016. "Simulation of the Automation of Composite Wind Turbine Blade Manufacture", Proceedings of the American Society for Composites 31st Technical Conference and ASTM Committee D30 Meeting. September 19-12, Williamsburg, VA.
4. Ciri U., M. Rotea, C. Santoni and S. Leonardi, "Large Eddy Simulation for an Array of Turbines with Extremum Seeking Control," 2016 American Control Conference, Boston, MA, July 6-8 2016, pp. 531-536.
5. DiPaola M., D. J. Willis, S. Leonardi, "A Fast Differential Deficit Control Volume Approach for Modeling Turbine-Turbine Interactions," 46th AIAA Fluid Dynamics Conference, 2016, (AIAA 2016-3962), Washington, DC, June 13-17, 2016.
6. Martin, R., Baird, C., Giles, R., Niezrecki, C., "Terahertz ISAR and x-ray imaging of wind turbine blade structures," Proceedings of the SPIE Symposium on Smart Structures & Materials/NDE, Las Vegas, NV, March 20-24, 2016.
7. Ashuri T., M.A. Rotea, Y. Xiao, Y. Li, and C.V. Ponnurangam, "Wind turbine aerodynamics performance degradation and its mitigation via Extremum seeking controls," AIAA 2016 Sci-Tech Wind Energy Symposium, Paper No. AIAA 2016-1738, San Diego, CA, January 4-8, 2016.
8. Iungo G.V., F. Viola, U. Ciri, S. Leonardi, M.A. Rotea, "Reduced order model for optimization of power production from a wind farm," 34th Wind Energy Symposium, AIAA SciTech Forum, (AIAA 2016-2200), San Diego, CA, January 9-13, 2016, pp. 1-9.
9. Xiao, Y., Y. Li, and M.A. Rotea, "Experimental Evaluation of Extremum Seeking Based Region-2 Controller for CART3 Wind Turbine," AIAA 2016 Sci-Tech Wind Energy Symposium, (AIAA 2016-1737), San Diego, CA, January 4-8, 2016.
10. S. Dev, C. Hansen. "Evaluation of self-healing performance in epoxy/glass fiber composites manufactured using VARTM. 20th International Conference on Composite Materials, July 19-24 2015, Copenhagen Denmark
11. Santoni C., U. Ciri, M.A. Rotea, and S. Leonardi, "Development of a high fidelity CFD code for wind farm control," 2015 American Control Conference, Chicago, IL, July 1-3, 2015, pp. 1715-1720.
12. S. Dev and C. Hansen, "Screening Barrier Properties for Robust Double Shell Walled Microcapsules," Fifth International Conference on Self Healing Materials, Durham, North Carolina, NC, USA, June 22-24, 2015.

Selected Presentations:

1. Ciri, U., M.A. Rotea, and S. Leonardi, "Evaluation of active wake steering using large-eddy simulations," North American Wind Energy Academy, 2017 Symposium, Ames, Iowa, September 26-29.
2. Iungo G.V., El-Asha S., Letizia S., Santhanagopalan V., Zhan L. "Proactive monitoring of an onshore wind farm through LiDAR, SCADA and RANS data," North American Wind Energy Academy 2017 Symposium, 26-29 September, Ames, Iowa, USA
3. Rotea M.A., S. Leonardi and Y. Li, "Extremum Seeking Control of Wind Turbines and Wind Farms," Invited presentation at the Mini Symposia "WindFarm2017," Wind Energy Science Conference 2017, June 26-29, 2017, Technical University of Denmark, Lyngby, Denmark.
4. Ciri U., Rotea M. and Leonardi S. (2016) G2.00005 Yaw control for power optimization of an array of turbines: large eddy simulations, Session G2: Wind Turbines: LES, the 69th Annual Meeting of the APS Division of Fluid Dynamics, Vol. 61, No. 20, November 20-22, 2016, Portland, Oregon, USA.
5. Rotea, M.A. "Modeling and Control of Wind Energy," Plenary, IEEE Multi-Conference on Systems and Control 2016, Buenos Aires, Argentina, September 19-22, 2016.



Wind Energy
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Photo of the deployment of the University of Texas Dallas mobile LiDAR station on the cover.

UPCOMING PROJECTS: 2017-2018

- Effects of Manufacturing Induced Defects
  Project ID: A4-16
  PI: James Sherwood (University of Massachusetts Lowell)
  Mentors: Nick Althoff (GE), Joyee Zhu (GE), Amir Riahi (GE), Steve Nolet (TPI)

- Curing of Thick Adhesive Joints
  Project ID: A1-17
  PI: Scott Stapleton (University of Massachusetts Lowell)
  Co PIs: Marianna Maiaru, Christopher Hansen
  IAB Mentors: Amir Riahi (GE), Chris Savio (GE), Nicholas Althoff (GE), Paul Ubrich (Hexion)

- Mechanical Properties Enhancement Prediction for Matrix Materials
  Project ID: A2-17
  PI: Marianna Maiaru (University of Massachusetts Lowell)
  Co PIs: Alireza Amirkhizi, Daniel Schmidt, Christopher Hansen
  Mentors: Stephen Nolet (TPI), Hui Zhou (Huntsman)

- Intelligent Damage Detection from Wind Turbine Blades Using Acoustic Excitation
  Project ID: B1-17
  PI: Murat Inalpolat (University of Massachusetts Lowell)
  Co PIs: Christopher Niezrecki, Yan Luo
  Mentors: Adam Johs (EDPR), Ben Rice (Pattern), Kathi Bentzel (GE)

- Low Cost Optical Fiber Strain Sensor Interrogator for Wind Turbine Blades
  Project ID: B3-17
  PI: Xingwei Wang (University of Massachusetts Lowell)
  Co PI: Christopher Niezrecki
  Mentor: Bernard Landa (GE)

- Proactive Monitoring of Wind Farm Performance Through Wind LiDAR Data and a Reduced Order Model
  Project ID: C1-17
  PI: G. Valerio Iungo (University of Texas Dallas)
  Co PI: Stefano Leonardi
  Mentors: Adam Johs (EDPR), Bernard Landa (GE), Ron Grife (Leeward)

- Evaluation of Nested Extremum Seeking Wind Farm Control with SWiFT Facility
  Project ID: D1-17
  PI: Yaoyu Li (University of Texas Dallas)
  Co PI: Mario Rotea
  Mentors: Ben Rice (Pattern), Ron Grife (Leeward)

- NREL FAST Modeling for Blade Load Control with Plasma Actuators
  Project ID: D2-17
  PI: Mario Rotea (University of Texas Dallas)
  Co PI: Yaoyu Li
  Mentors: Stephen Nolet (TPI), Neal Fine (Aquanis), Nicholas Althoff (GE)

- Wind Turbine Aerodynamics Modified Gurney Flaps
  Project ID: U1-17
  PI: David Willis
  Mentors: Neal Fine (Aquanis)

- Wind Turbine Foundation Monitoring Sensor Development
  Project ID: U2-17
  PI: Christopher Niezrecki
  Mentors: Ron Grife (Leeward), Adam Johs (EDPR), Diogo Silva (EDPR)

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