Structural Testing Technology Development

Cooperative Research and Development Final Report

CRADA Number: CRD-06-00200

NREL Technical Contact: David Snowberg

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5000-80822
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NOTICE

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Cooperative Research and Development Final Report

Report Date: August 26, 2021

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the final CRADA report, including a list of subject inventions, to be forwarded to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Diamond WTG Engineering & Services, Inc. (formerly: Mitsubishi Power Systems Americas, Inc., MHI Wind Power Americas)

CRADA Number: CRD-06-00200

CRADA Title: Structural testing technology development

Responsible Technical Contact at Alliance/National Renewable Energy Laboratory (NREL):

David Snowberg | David.Snowberg@nrel.gov

Name and Email Address of POC at Company:

Yasutaka Kimura | 木村 保貴 yasutaka1_kimura@mhi.co.jp

Note: Takao Kuroiwa was POC at the Company for all CRADA Mods but is no longer employed at the Company

Sponsoring DOE Program Office(s): Office of Energy Efficiency and Renewable Energy (EERE), Wind Energy Technologies Office (WETO)

Joint Work Statement Funding Table showing DOE commitment:

Note: the $5K of NREL shared resources (government in-kind funding) was used for the completion of Task 1 from Mod 0 (draft SOP copied into this CRADA report). All subsequent work was fully funded by the Company.

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
2009	$5000.00
2010, Modification #2	$.00
2012, Modification #3	$.00
2012, Modification #4	$.00
2012, Modification #5	$.00
2014, Modification #6	$.00
2015, Modification #7	$.00
2016, Modification #8	$.00
TOTALS	$5000.00

Executive Summary of CRADA Work:

NREL is the only organization in the US that is accredited to conduct tests of wind turbine systems and components in accordance with International Electrotechnical Commission (IEC) test standards. The National Wind Technology Center houses the only full-scale wind turbine blade drivetrain test facilities in the US. To maintain these facilities, accreditation, and the acceptance of the wind industry, NREL must strive continuously to maintain and improve staff capabilities, procedures, facility and equipment. In addition, as wind turbines continue to increase in size, NREL must improve its capability to test the larger components associated with these new turbines. NREL is currently investigating methods to increase blade and drivetrain testing capabilities.

Mitsubishi Power Systems (MPS) must also strive to meet the demands of the evolving wind energy industry by developing, proving and manufacturing new, cost-effective blades for its turbines. Mitsubishi has established a joint venture with TPI composites of Rhode Island for manufacturing blades to be installed on US wind turbines. There is an obvious advantage to test these prototype blades in a US facility. The NREL blade test facility is uniquely capable of fulfilling this need. In addition, NREL can provide other testing support to MPS through the use of its dynamometer facility for drivetrain testing and through the use of NREL's field-testing capabilities for testing wind turbine systems.

This CRADA provides the opportunity for both organizations to achieve critical goals in development of wind energy in the US. MPS obtains verification of its wind turbine components and system. NREL obtains improved test capabilities.

Summary of Research Results:

NREL completed all tasks from all CRADA modifications by the end of each POP. No deviations were noted from work described in the JWS from each CRADA modification. David Snowberg was not the original PI for this CRADA; he became the PI shortly after beginning at NREL in October 2009 and was responsible for work beginning with Mod2.

Note: National Wind Technology Center (NWTC) has been renamed after this project to Flatirons Campus.

The following summarizes the research results from each CRADA task:

CRADA Mod 0, Task 1: Cutting and disposing of tested wind turbine blades

The following is the draft SOP for composite cutting developed under Task 1 from Mod 0. The full amount of government in-kind funding ($5K) for this CRADA went towards the development of this SOP.

In addition, NREL received blades from MPS, performed the test cutting, and provided the samples to the participant. The picture below shows the MPS blade undergoing these cutting operations.

BLANK SAFE OPERATING PROCEDURE TEMPLATE

SOP #: ____________________

CENTER #: ____________________

SAFE OPERATING PROCEDURE
for
POWER TOOL CUTTING OF COMPOSITE STRUCTURES
at
THE NWTC

EMERGENCY SHUTDOWN PROCEDURE:

The tools used for power tool cutting of composite structures include hand-held portable electric devices, circular saws, reciprocating saws, etc. Tools are de-energized when the operator releases the on/off switch.

____

(Type Name), Principal Author Date:

____

EHS Office Director Date:

____

(Type Name), Center Director Date:

SAFE OPERATING PROCEDURE
FOR
POWER TOOL CUTTING OF COMPOSITE STRUCTURES

I. INTRODUCTION

A. Activity Description

Cutting of composite structures, notably wind turbine blades, is occasionally required in the structural testing facility at the NWTC. Cutting composites is necessary to perform post-mortem inspections of wind turbine blades, in-test blade modifications, and creating display articles. This document provides a safe operating procedure for cutting composite structures at the structural testing facility.

Prior to undertaking any blade cutting, staff should evaluate the following criteria to ensure the cutting operation falls within the scope of this Safe Operating Procedure. If any of the following items apply a Safe Work Permit, Confined Space Entry Permit, or other control document will be required. Contact the EHS point of contact (Mike Stewart x6909) for further guidance. It is always good practice to engage the EHS point of contact prior to initiating a cutting project.

Table 1 - Out of Scope Checklist - Contact EHS if any condition applies

1	☐	Cutting requires staff inside of blade
2	☐	NREL staff and subcontractors not performing the work
3	☐	Blade or structure not at ground level (worker above 6-ft)
4	☐	Adverse weather conditions (wet/icy, windy conditions)
5	☐	Exotic materials (fiberglass, carbon fiber, Kevlar are common materials)
6	☐	Other mechanical operations necessary (grinding, laminating)
7	☐	Non-standard tooling (circular and reciprocating electric saws, and grinder-based cutting disks are standard)

B. Location

This activity is conducted both inside facilities and in the field at the NWTC. Outdoor cutting is primarily performed near the IUF but may be performed at remote field locations.

C. Process

Power tool cutting involves using portable power tools such as circular saws and reciprocating saws held by a tool operator to cut a composite structure.

D. Organizations involved

The structural testing group at the NWTC (5000) is the usage group for this safe operating procedure.

II. DESCRIPTION OF SAFETY & HEALTH HAZARDS AND CONTROLS

A. Procedure Hazard and Control Information–

Responsibilities - The *tool operator* is responsible for the operation of the tool. The tool operator should ensure the tool is in proper working order, establish proper control over the tool for the intended cut, and ensure stable footing and positioning in the cut area.

A *spotter* is required to monitor the area and support the tool operator. The spotter should ensure the power cord does not become entangled or pinched while the tool operator is working. The spotter should avoid being in the plane of the cutting, maintaining as much distance from the cutting as possible. In certain cases the spotter may need to support a portion of the structure being cut (e.g. support a piece which could cause the saw to bind, or support a panel from falling upon cut completion), in which case the tool operator and spotter shall agree on the position of the spotter and the spotters appendages prior to cutting. The spotter is responsible for keeping staff and visitors away from the working area.

Engineer support is required for indicating where cuts are to be made and provide analysis for properly supporting blade sections and identifying areas where lightning protection systems or other metallic components are located.

Personal Protective Equipment - A Tyvek suit is required for the tool operator. A PAPR is required for this work [3]. Non-fogging eye protection is required, use of the PAPR aids in the non-fogging ability of glasses. Gloves are required, leather work gloves for the spotter, and latex or Nitrile gloves for the tool operator. The PAPR, including filters, should be tested prior to use according to the manual to ensure proper airflow is present.

The spotter should be equipped with safety glasses and work gloves at a minimum. A dust mask is recommended. Typically the spotter will maintain a safe working distance from the tool, preferably upwind from the cutting area.

Equipment - The existing inventory of hand power saws used to cut composites are electric. 120AC power is typically required to run the saw. For outdoor cutting this typically requires running AC power to the tool using a GFCI circuit located on the exterior of any one of the facility buildings or using an inline GFCI connector. Care should be taken that the length of cord is suitable for the current draw of the tool being used. Work should not be performed with electric power tools when wet conditions exist.

The most typical tool used for cutting is an electric circular saw. Different types of saw blades can be used for cutting. Toothed blades (preferably smaller pitch) to carbide-grit blades have been employed. Grit blades are typically preferred in that the probability of kickback is less than for toothed blades. The composite fines generated by the grit-type blade are typically smaller. The tool operator must ensure the tool rest is firmly positioned against the work piece to minimize any potential for kickback.

Reciprocating saws are also employed for cutting. These saws work well for cutting thin laminate areas (shear webs, leading and trailing edges, etc). The tool operator should ensure that the tool base is firmly resting against the work piece while operating the tool. The tool operator should ensure the blade is long enough to cut through the section, and free to travel in the cutting plane (blade tip will not impact backing surface).

All power tools shall be in good condition and thoroughly inspected prior to use. Blade guards shall be in place and functional where required (e.g. circular saw).

While blades are primarily constructed of composite materials (glass, carbon, resins), blades often contain lightning protection systems which are typically metallic. Blades can also contain ballast weights which are typically composed of steel shot. Care must be exercised if cutting through the lightning protection system or ballast weights. Grit-style blades have been demonstrated to effectively cut through metallic components. The Engineering support staff should verify the location of these items and indicate before cutting operations.

A HEPA vacuum should be used to collect dust between cutting operations for outdoor cutting. At the end of the cutting operation the area should be vacuumed with the HEPA vacuum with waste disposed of in plastic bags or other containers, which prevent fiber and/or dust emission, and disposed of in accordance with the requirements of the local waste disposal authority.

Occasionally power drills are used to transfer a surface location for referencing while inside the blade. Carbide drill bits are recommended along with slow surface speeds.

Lift equipment where necessary should be inspected prior to use with operators following all applicable safe operating procedures including fall protection.

Work Area Staging - The work piece should be positioned such that translation and rolling of the specimen is restrained. In many cases this can be accomplished by blocking the work piece with cribbing. If high winds are expected the blade should be tethered to suitable restraints such as concrete ballast blocks. It is preferable that the work piece is elevated such that the tool operator is performing tool operations at waist or chest level. During cuts where parts of the work piece will be fully detached from the main article, the tool operator should ensure the cut piece will not fall and contact staff, contact electrical cords. Care should be taken such that a cut section will not cause undue binding on the saw.

The cutting station should be located in a location which has a minimal impact on other NWTC operations. The cutting station should not be near main entrances to buildings, preferably down wind of entrances, and not in a location which exposes power cords to damage from vehicles or other traffic. The location should be situated such that ground impediments (plants, equipment) do not interfere with the cutting. Ideal locations include proximity close to the Quonset hut and at the east end of the IUF. The spotter should keep staff at least 10-ft away from the active cutting area. This work perimeter does not need to be barricaded provided the spotter is in the working area. If the spotter is engaged in supporting sectioned panels, barricades will be deployed keeping staff a minimum of 10-ft from the cutting area.

Use of hand power tools to cut composites requires that the tool operator be in a stable position without chance of falling or sliding. Many times the tool operator will be on the top surface of a blade, provisions are necessary to ensure the tool operator will not slip during the cut and are typically addressed by adding tread.

Elevated cutting - It is sometimes required that composite structures are cut while the structure is attached to the test stand. The most common occurrence is when a tip of a blade needs to be removed to allow ground clearance or change the properties of a resonant test. These procedures involve the use of manlifts, fall-protection equipment, and overhead cranes. Additional safety implements are employed to protect staff inside of the building, both highbay and office areas, from dust fines and crushing.

For operations where the tip of the blade is to be cut a detailed engineering plan is required which accounts for the weight and CG of the cut section and safe lift plan to secure the section by the overhead crane once the section is cut from the main structure.

In situations where the tool operator is repositioning between cuts on the top of the blade, it is recommended that the spotter disconnect the power cord when the tool operator is moving and reconnect when the tool operator is ready to cut. Recommended commands to use in these situations are as follows

a. Tool operator - Power Off
b. Spotter - Confirm Power Off
c. *Tool operator repositions*
d. Tool operator - Power On
e. Spotter - Confirm Energized

Indoor Cutting - Additional controls through more aggressive vacuuming or confinement of the area through temporary enclosures may be necessary. Air flow through the facility should be examined to ensure any excess fines are routed out of the highbay and away from the intake to the office area. This can be accomplished through use of integrated facility exhaust fans or portable fans and ventilators.

For indoor cutting, the HEPA vacuum for dust collection during cutting is required. This can be accomplished by employing a remote enabler to the end of the vacuum hose operated by the spotter. Care should be exercised to not allow the vacuum hose to come in contact with the cutting tool and not impede the tool operator. At the end of the cutting operation the area should be vacuumed with the HEPA vacuum with waste disposed of in plastic bags or other containers, which prevent fiber and/or dust emission, and disposed of in accordance with the requirements of the local waste disposal authority.

Confined Space Procedures - **This section is provided for informative information only; cutting composites from inside of the structure necessitates an EHS issued Confined Space Entry Permit**. For cutting inside of a blade a confined space entry permit is required. The methods and procedures are similar to external cuts but additional precautions are necessary for safe work. Typically internal cuts are necessary to cut the shear web of a blade. Due to the construction of the shear web (thin composite with foam or wood) reciprocating saws are preferred. Additional cribbing may be required to ensure the blade shell does not distort during the cutting or prevent shifting of the cut sections. Engineering analysis is necessary to determine proper cribbing. It is preferred that internal cuts are performed prior to external cuts as this minimizes the potential for panel movement while the tool operator is cutting. A confined space ventilator fan is employed to provide fresh air into the cavity of the blade, typically a free flow of air is required (both ends of blade open). An ankle tether is attached to the tool operator for extraction from the blade should the entrant become unresponsive.

B. Hazard and Control Itemization -

Table 2 provides a summary of the hazards and controls associated with portable power tool cutting.

Table 2 - Hazards and Controls - Hand Power Tool Cutting

Category	Hazard	Control
Crushing	Unexpected Blade Movement	Crib blade and tether to ballast weight or handling equipment as needed to secure structure
Crushing	Crushing hazard - sections of structure may be cut free from supported body	Ensure area beneath cut section is clear, and the tool operator and spotter are clear of drop area
Hazardous Materials	Fiberglass Dust and Fiber Hazards - Inhalation (short term irritation of mouth, nose and throat and stomach), skin and eye (mechanical irritant)	1. Minimize contact with dust through PAPR (operator), dust mask (spotter). 2. Tyvek suit mandatory for tool operator, gloves for spotter and tool operator 3. HEPA Vacuum area and bag fines after procedure 4. Eye protection required for operator and spotter 5. Wash skin and clothing after procedure
Hazardous Materials	Indoor cutting	Use HEPA vacuum with remote enabler close to cutting area. Deploy containment tarps if required. Examine airflow through facility, deploy exhaust or portable fans
Machinery/ Equipment	Cutting blade binding	Ensure blade is cribbed such that blade deformation during cutting will not bind blade. Ensure cutting plane allows for travel of reciprocating saw blade.
Machinery/ Equipment	Kickback	Ensure tool rest is firmly against work surface. Ensure operator grip on tool
Machinery/ Equipment	Tool operator Stability	Ensure tool operator has stable base to work from along the length of cut. Add tread tape if working on top of blade as needed.
Noise	Noise Emission from electric tools	Ear plugs are recommended but not required
Natural Environmental Conditions	Wet/Icy Conditions	Cutting operations will not be conducted when test articles are wet or icy or surface water is present
Natural Environmental Conditions	High Wind	Position staff up wind of cut area to minimize particulate exposure
Temperature Extremes	High Temperatures, UV exposure	Monitor staff for high temperature and UV exposure

III. DESCRIPTION OF ENVIRONMENTAL HAZARDS AND CONTROLS

A. Air and Water Emissions –

Containment of composite fines through vacuuming

B. Hazardous Waste –

Waste generated during this process is composed of composite particulates. Particulates collected are placed in hazardous waste bags for disposal.

C. Waste Minimization –

Not applicable

D. Decommissioning -

Not applicable

IV. ASSEMBLY/OPERATIONAL PROCEDURES

1. Ensure work falls under this Safe Operating Procedure by examining Table 1
2. Designate responsibilities
    a. Engineering Support: ____________________
    b. Tool Operator: ____________________
    c. Spotter: ____________________
3. Engineering assessment
    a. Mark locations for cuts
    b. Identify lightning protection systems or other metallic structures in blade
    c. For elevated cutting draft and review with crew the detailed engineering plan
4. Assemble Personal Protective Equipment
    a. PAPR for tool operator (charge battery prior to use)
    b. Dust masks for spotter
    c. Safety glasses
    d. Tyvek Suit for tool operator
    e. Nitrile (N-DEX) gloves for tool operator
    f. Leather Gloves for spotter
5. Assemble Tools
    a. Insure operator familiar with tool, reference manual
    b. Circular saw
    c. Reciprocating saw
    d. Ensure operation of saw and check that blade is in proper working condition (bent or dull blade, power chord is good condition)
    e. Power cords
    f. GFCI (if wall receptacle not GFCI)
    g. HEPA Vacuum
    h. Lift equipment (elevated cutting operations)
6. Position Blade
    a. Move blade to designated cutting area
    b. Tether blade to concrete blocks or heavy items, or crib blade as needed to prevent blade from rolling or translating
    c. Ensure extricated sections from main work piece can fall without binding blade, falling on worker, or contacting power cord
    d. If working on top of blade add tread tape as necessary to prevent tool operator from slipping
    e. Position lift equipment (elevated cutting operations)
    f. Position and secure rigging support (on-stand cutting)
    g. Position tarps or plastic if required (indoor cutting)
    h. Position or energize fans as required (indoor cutting)
7. Perform Cutting
    a. Mark cut lines on blade with sharpie or other writing instrument
    b. Inspect blade for presence of metallic structures
    c. Check operation of tool
    d. Apply PPE
        i. Tool operator - Tyvek, PAPR, eye protection, N-DEX gloves
        ii. Spotter - Eye protection, dust mask, leather gloves
    e. Clear work area, deploy barricades as necessary.

f. Tool operator in stable position for length of cut
g. Spotter in stable position
h. Perform Cut(s)
    i. Tool operator - Power Off
    ii. Spotter - Confirm Power Off
    iii. *Tool operator positions or repositions*
    iv. Tool operator - Power On
    v. Spotter - Confirm Energized
i. Clean working area with HEPA vacuum, optional active use of vacuum

8. Cleanup
    a. Secure any cut sections
    b. Clean tools with brush or compressed air tools used
    c. HEPA vacuum work area and cut pieces
    d. Dispose excess fines in yellow hazardous material bags
    e. Discard Tyvek and fines
    f. Wash hands, clothes as necessary
    g. Store tools and equipment
9. Administrative
    a. Record activity in Blade Cutting and Modification Log [5]

V. PERSONNEL TRAINING

A 'Blade Cutting and Modification Log' [5] spreadsheet is maintained for all on-site operations involving blade cutting and modifications. This log provides documentation for determining authorized personnel.

Qualifications for obtaining Authorized status for 'Hand Power Tool Cutting Operator' include:

- Observation of cutting procedure conducted by authorized personnel
- (2) apprentice cutting operations
- Written approval by Authorized Engineering Support Staff.

VI. EMERGENCY INFORMATION

Emergency Reporting - Emergency procedures follow from the site-wide and structural testing SOP. Emergency phone number(s): Dial 9-911, ask for Boulder County, address is NWTC or National Wind Technology Center. Then, activate the NREL Emergency Notification System by calling 1-2-3-4 from an NREL phone or 303.384.6811 using an outside line or cellular phone. Emergency services are provided by RMFD.

Stop Work Authority - All workers have the authority to stop work in the event that potentially hazardous conditions are observed. All work shall immediately cease in the event that a stop work determination is made. Work shall not resume until the potential hazard is thoroughly evaluated and appropriate mitigate or compensatory measures are identified and implemented to achieve and maintain an acceptable level of risk.

VII. AUTHORIZED PERSONNEL

Authorized workers are required to read, understand, and abide by the SOP and supporting and control documents. The Center 5000 staff and subcontractors listed in Table 3 are authorized to perform cutting of composite structures according to this SOP. Engineering support is authorized only by staff indicated in Table 3.

Table 3 - Authorized Personnel

Hand Power Tool Cutting Operators	Engineering Support
Scott Wilde	Scott Hughes
Troy Boro	Darren Rahn
Bill Gage	
Scott Hughes	
Darren Rahn (spotter only)	
Jeroen van Dam (spotter only)	
Mike Jenks (spotter only)	

VIII. REFERENCES

1. NWTC SOP - [internal link omitted]
2. Structural Testing SOP - [internal link omitted]
3. PAPR Instructions - [internal link omitted]
4. Job-specific hand tool manuals - varies
5. Blade Cutting and Modification Log - [internal link omitted]

IX. APPENDICES

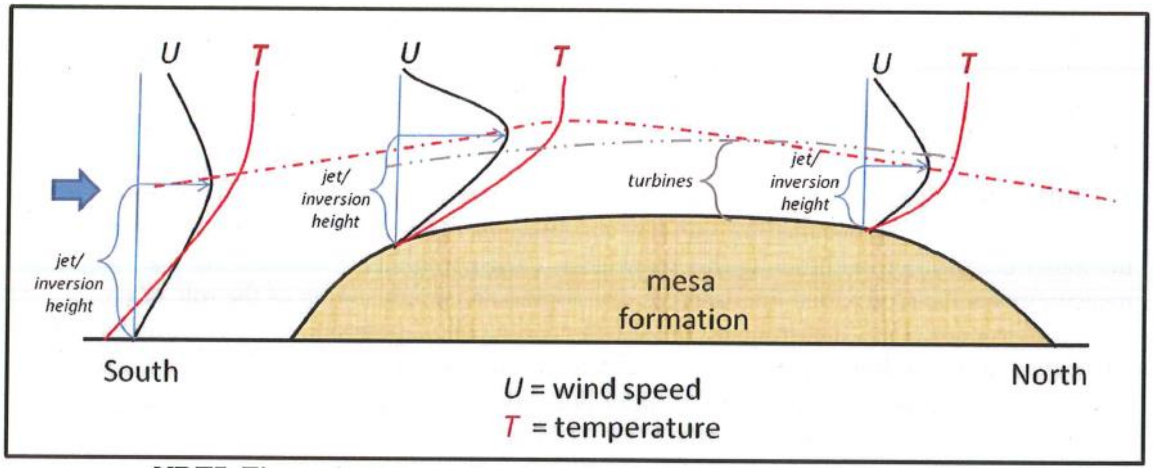
none

X. ADDENDUMS

none

CRADA Mod 1, Task 2: Field test data technical assessment

This task completed by Neil Kelley was an evaluation of LIDAR data at a wind farm site. LIDAR instruments were used to measure wind profile data based on scattered light from particulates contained in the wind stream. This work concluded there are nocturnal low-level jets that occur at this wind farm site. The following figure shows a depiction of the wind speed and temperature distributions across the mesa at this wind farm site.



CRADA Mod 2, Task 1: Static blade testing (50m)

This task was successfully completed by the testing of a 50m wind turbine blade between June 24, 2011 through August 4, 2011 at NREL's National Wind Technology Center (NWTC) near Boulder, Colorado. Testing was performed with the blade test article mounted to the 20-degree static test stand (16.3MN-m rated) located to the northwest of the Structural Testing Laboratory (STL) highbay at the NWTC. Loads were successfully applied to the test article in the maximum edge, minimum edge, minimum flap, and maximum flap orientation.

All testing was successfully completed according to requirements in the IEC 61400-23 standard (Wind turbines – Part 23: Full-scale structural testing of rotor blades). NREL's 1239.01:Accoustics and Vibration Field of Testing accreditation by A2LA covered the NREL scope to complete this test according to the IEC 61400-23 standard.

CRADA Mod 2, Task 2: Fatigue blade test (50m)

This task was initially completed by the successful edge fatigue testing of a 50m wind turbine blade between August 23, 2011 through September 20, 2011 at the NREL's NWTC near Boulder, Colorado. Testing was performed with the blade test article mounted to the 3.5-degree fatigue test stand located to the northwest of the STL highbay at the NWTC. The test article was mounted to the test stand with a 2-degree adapter plate assembly resulting in a 1.5 degree test article angle with respect to ground. A UREX resonant test system was used to input edge fatigue loads to the test article.

This task was ultimately completed by the successful flap fatigue testing of a 50m wind turbine blade between November 23, 2011 through February 28, 2012 at the NREL's NWTC near Boulder, Colorado. Testing was performed with the blade test article mounted to the 3.5-degree fatigue test stand located to the northwest of the STL highbay at the NWTC. The test article was mounted to the test stand with a 2-degree adapter plate assembly resulting in a 1.5 degree test article angle with respect to ground. A UREX resonant test system was used to input flap fatigue loads to the test article.

All testing was successfully completed according to requirements in the IEC 61400-23 standard (Wind turbines – Part 23: Full-scale structural testing of rotor blades). NREL's 1239.01:Accoustics and Vibration Field of Testing accreditation by A2LA covered the NREL scope to complete this test according to the IEC 61400-23 standard.

CRADA Mod 3, Task 4: No cost extension

This task was a 6-month no cost extension (NCE) that added 6-months to the CRADA period of performance (POP). No new work was added to the CRADA for this NCE task.

CRADA Mod 4, Task 4: Additional flap fatigue cycles

This task was successfully completed by the flap fatigue testing of a 50m wind turbine blade between June 20, 2012 through September 20, 2012 at the NREL's NWTC near Boulder, Colorado. Testing was performed with the blade test article mounted to the 3.5-degree fatigue test stand located to the northwest of the STL highbay at the NWTC. The test article was mounted to the test stand with a 2-degree adapter plate assembly resulting in a 1.5 degree test article angle with respect to ground. A UREX resonant test system was used to input flap fatigue loads to the test article.

All testing was successfully completed according to requirements in the IEC 61400-23 standard (Wind turbines – Part 23: Full-scale structural testing of rotor blades). NREL's 1239.01:Accoustics and Vibration Field of Testing accreditation by A2LA covered the NREL scope to complete this test according to the IEC 61400-23 standard.

CRADA Mod 5, Task 5: Dual-axis blade fatigue test

This task was successfully completed by the biaxial fatigue testing of a 50m wind turbine blade between November 16, 2012 and August 15, 2013 at the NREL's NWTC near Boulder, CO. Testing was performed with the blade test article mounted to the 3.5-degree fatigue test stand located to the northwest of the STL highbay at the NWTC. The test article was mounted to the test stand with a 2-degree adapter plate assembly resulting in a 1.5 degree test article angle with respect to ground. A UREX resonant test system was used to input flap fatigue loads, and separate UREX resonant test system was used to input the edge fatigue test loads to the test article, which resulted in the biaxial loading of the test article.

A report titled, *Implementation of a Biaxial Resonant Fatigue Test Method on a Large Wind Turbine Blade*, was published as a result of this CRADA research.

All testing was successfully completed according to requirements in the IEC 61400-23 standard (Wind turbines – Part 23: Full-scale structural testing of rotor blades). NREL's 1239.01:Accoustics and Vibration Field of Testing accreditation by A2LA covered the NREL scope to complete this test according to the IEC 61400-23 standard.

CRADA Mod 6, Task 6: Fatigue blade test

Performance of Task 6 from Mod 6 was removed in Mod 7.

CRADA Mod 7, Task 6: Fatigue blade test (1st test in truncated test series)

This task was successfully completed by the flap fatigue testing of a 46m wind turbine blade between January 24, 2015 through August 5, 2015 at the NREL's NWTC near Boulder, Colorado. Testing was performed with the blade test article mounted to the 3.5-degree fatigue test stand located to the northwest of the STL highbay at the NWTC. The test article was mounted to the test stand with a 2-degree adapter plate assembly resulting in a 1.5 degree test article angle with respect to ground. A UREX resonant test system was used to input flap fatigue loads to the test article.

All testing was successfully completed according to requirements in the IEC 61400-23 standard (Wind turbines – Part 23: Full-scale structural testing of rotor blades). NREL's 1239.01:Accoustics and Vibration Field of Testing accreditation by A2LA covered the NREL scope to complete this test according to the IEC 61400-23 standard.

CRADA Mod 7, Task 7: Fatigue blade test (2nd test in truncated test series)

This task was successfully completed by the flap and lead-lag fatigue testing of a 46m wind turbine blade between May 2, 2015 through April 12, 2016 at the NREL's NWTC near Boulder, Colorado. Testing was performed with the blade test article mounted to the 3.5-degree fatigue test stand located to the northwest of the STL highbay at the NWTC. The test article was mounted to the test stand with a 2-degree adapter plate assembly resulting in a 1.5 degree test article angle with respect to ground. A UREX resonant test system was used to input flap fatigue loads to the test article. The UREX system was reconfigured for the lead-lag loading of the test article.

All testing was successfully completed according to requirements in the IEC 61400-23 standard (Wind turbines – Part 23: Full-scale structural testing of rotor blades). NREL's 1239.01:Accoustics and Vibration Field of Testing accreditation by A2LA covered the NREL scope to complete this test according to the IEC 61400-23 standard.

CRADA Mod 7, Task 8: Fatigue blade test (3rd test in truncated test series)

This task was successfully completed by the flap and lead-lag fatigue testing of a 46m wind turbine blade between August 5, 2015 through February 22, 2016 at the NREL's NWTC near Boulder, Colorado. Testing was performed with the blade test article mounted to the 3.5-degree fatigue test stand located to the northwest of the STL highbay at the NWTC. The test article was mounted to the test stand with a 2-degree adapter plate assembly resulting in a 1.5 degree test article angle with respect to ground. A [UREX resonant test system] was used to input flap fatigue loads to the test article. The UREX system was reconfigured for the lead-lag loading of the test article.

All testing was successfully completed according to requirements in the IEC 61400-23 standard (Wind turbines – Part 23: Full-scale structural testing of rotor blades). NREL's 1239.01:Accoustics and Vibration Field of Testing accreditation by A2LA covered the NREL scope to complete this test according to the IEC 61400-23 standard.

CRADA Mod 8, Task 9: Fatigue blade test (4th test in truncated test series)

This task was successfully completed by the flap and lead-lag fatigue testing of a 46m wind turbine blade between August 2, 2016 through February 22, 2017 at the NREL's NWTC near Boulder, Colorado. Testing was performed with the blade test article mounted to the 3.5-degree fatigue test stand located to the northwest of the STL highbay at the NWTC. The test article was mounted to the test stand with a 2-degree adapter plate assembly resulting in a 1.5 degree test article angle with respect to ground. A UREX resonant test system was used to input flap fatigue loads to the test article. The UREX system was reconfigured for the lead-lag loading of the test article.

All testing was successfully completed according to requirements in the IEC 61400-23 standard (Wind turbines – Part 23: Full-scale structural testing of rotor blades). NREL's 1239.01:Accoustics and Vibration Field of Testing accreditation by A2LA covered the NREL scope to complete this test according to the IEC 61400-23 standard.

Subject Inventions Listing:

None

ROI #:

None