WIND ENERGY RESEARCH & DEVELOPMENT
Advanced Manufacturing and Materials

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Advanced Manufacturing and Materials

Exploring the use of innovative materials and manufacturing processes to develop lighter, stronger, more cost-effective wind turbine blades and components that are easier to recycle.

Materials Research and Applications

Exploring materials and techniques that reduce costs and enable advanced designs for renewable power generation and transportation

Manufacturing Processes at Scale

Helping manufacturers find the most energy-efficient and sustainable solutions for their products and processes

Manufacturing Optimization, Onsite and Modular Manufacturing

Enabling onsite manufacturing and lighter blade structures to achieve lower levelized cost of energy (LCOE)

Recycling and Reuse

Developing novel materials that are manufacturable and recyclable by design—and enabling recycling of existing composite structures

Materials Research and Applications

Larger wind turbine blades require stronger composite materials that effectively retain their shape and strength when subjected to varying wind conditions—as well as other physical and environmental stressors.

- Currently, blades are manufactured from a combination of glass and/or carbon fiber composite materials with a thermoset resin that requires energy-intensive and expensive heating processes to cure. NREL's research on fusion joining of thermoplastic composites uses energy-efficient processes.
- NREL's additive manufacturing research for electric machines taps into performance advantages associated with design and discovery of new, low-cost, 3D-printable magnet materials.

Areas of Expertise

- Identify and develop advanced composite materials
- Accelerate commercialization of additive manufacturing and next-generation technologies and processes.

Current Projects

Lightning Protection System for Wind Turbine Blades

MATERIALS RESEARCH AND APPLICATIONS

CHALLENGE

Protect thermally welded wind turbine blades from lightning strikes.

APPROACH

- NREL researchers designed a 5-meter blade-tip section and determined the optimum joining methodology to accelerate learning (to ‘mock weld' the blade) and designed a lightning-protection system that is infused into the blade skin.
- Additional evaluations will accelerate learning in the National Technical Systems Pittsburgh Lightning Test Center during the blade-tip strike trial.

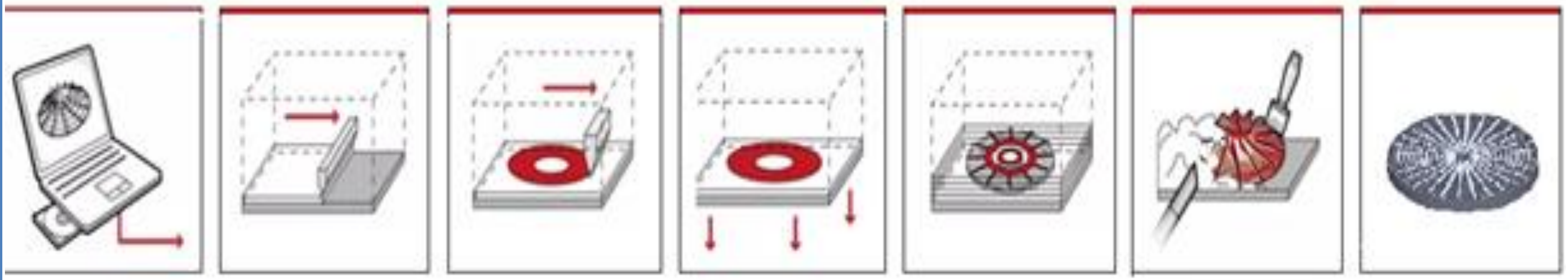
IMPACT

- Having designed the lightning protection system component and created the mock welding method with materials at NREL’s Flatirons Campus, NREL researchers can move toward manufacturing the blade-tip section.
- Once manufactured, researchers can validate the new section at National Technical Systems, with the goal of protecting wind turbines from lightning strikes in the field.

Current Projects

MADE3D: Manufacturing and Additive Design of Electric Machines Enabled by 3D Printing

MATERIALS RESEARCH AND APPLICATIONS



From computer design to 3D-printed generator rotor mold, printed using binder jetting.

CHALLENGE

Traditional approaches to designing and manufacturing direct-drive electric generators result in prohibitively expensive and heavy powertrains that are no longer cost-effective for large wind turbines.

APPROACH

NREL researchers and partners are leading the design, fabrication, and validation of the world's first fully additively manufactured direct-drive electric generator. Using a new topology-optimization software, the team is exploring opportunities for using innovative materials and manufacturing for lightweight electric machines that use high-performance, low-cost materials and multimaterial printing technologies.

IMPACT

The MADE3D project is identifying risks, opportunities, and challenges with the integration of 3D-printing processes for high-torque, dense, electric machines. This knowledge will help instill more confidence to accelerate the adoption of *in situ* 3D printing for electric machines.

Manufacturing Processes at Scale

- NREL is performing foundational research to enable next-generation wind turbine components through advanced manufacturing processes that will support the factories of the future.
- Our Composites Manufacturing Education and Technology (CoMET) facility contains the equipment and materials to transform design concepts into prototypes, and from prototypes to products.

Areas of Expertise

- 3D-printed, large-scale, composite blade structures and electromagnetic wind turbine generators
- Recyclable materials and thermoplastic resin systems
- Thermal welded/fusion-composite joining technologies
- Automated blade manufacturing processes
- Technoeconomic modeling and LCOE impact analyses.

Current Projects

3D-Printed, Large-Scale, Composite Blade Structures

MANUFACTURING PROCESSES AT SCALE

CHALLENGE

Use 3D-printing technologies to print large-scale, structural components for wind turbine blades.

APPROACH

NREL and Oak Ridge National Laboratory (ORNL) researchers will design novel sandwich composite solutions that utilize the latest software and optimization techniques to produce lightweight, topology-optimized, blade core structures. The structural cores required to support a 13-meter technology demonstrator blade will be 3D printed using large-scale 3D-printing technologies at ORNL, and the full-scale blade will be manufactured and validated at NREL.

IMPACT

Automated 3D printing of large-scale structural blade components, through disruptions in labor, capital, and supply chain costs, can enable competitive domestic onsite and modular manufacturing processes, leading to potentially lower LCOE through highly optimized, supersized blade designs that bypass transportation and logistical constraints.

Manufacturing Optimization/Onsite and Modular Manufacturing

- NREL is researching how new and emerging Industry 4.0 technologies in material science, high-performance computing, automation, and 3D printing can impact large-scale wind turbine blade manufacturing to enable advanced manufacturing solutions.
- Our multipronged approach leads to lower LCOE as high stiffness-to-weight ratio and high strength-to-weight ratio sandwich composite structures enable onsite manufacturing and lighter blade structures.

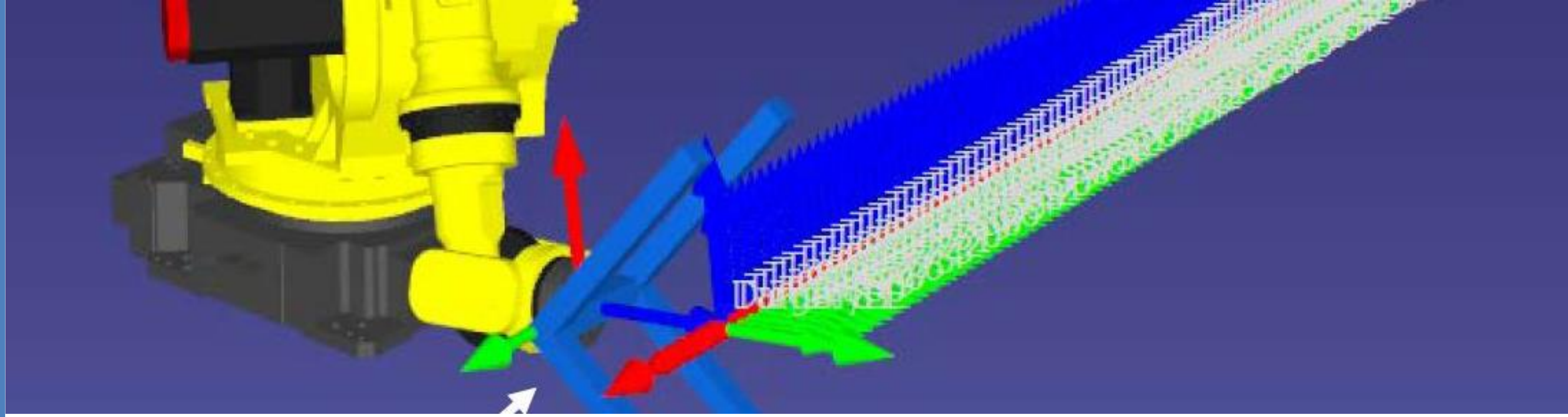
Areas of Expertise

- Wind turbine market and technoeconomic analyses
- Topology optimization, large-scale 3D printing, additive materials properties, and additive design guidelines
- High-tolerance, repeatable, low-cost production technologies suitable for onsite and modular manufacturing.

Current Projects

Automation for Wind Turbine Blade Manufacturing

MANUFACTURING OPTIMIZATION/ONSITE AND MODULAR MANUFACTURING



CHALLENGE

Wind turbine blade production has been an historically labor-intensive operation. Efforts to automate certain aspects of wind turbine blade production have had limited degrees of success.

APPROACH

This project designs and prototypes an automation system for wind turbine blade-finishing operations, including trimming, composite surface finishing, and nondestructive evaluation. The research designs a ‘cell-based’ approach to automation, reducing the need to move large wind turbine blades around the factory floor.

IMPACT

Automated blade finishing will reduce labor hours and labor costs, reduce factory floor space requirements, reduce the cost of blades, and increase quality of wind turbine blades—all leading to increased reliability, better performance, increased annual energy production, and ultimately lower LCOE for wind power.

Recycling and Reuse

- NREL is researching innovative recycling solutions for composite materials, including for both existing thermoset and future thermoplastic wind turbine blades.
- Employing a thermoplastic resin system, including the use of thermal welding to bond blade components, will enable longer, lower- cost, recyclable wind turbine blades.

Areas of Expertise

- Thermoplastic material system characterization and processing for wind turbine blades at scale
- Industry collaborations across supply chains
- High-impact, circular-economy research initiatives
- Composite processing and structural validation
- Polymer chemistry for composite materials.

Current Projects

Recyclable-by-Design Materials for Wind Turbine Composite Structures

CHALLENGE

Wind turbine blades are constructed primarily of thermoset composite materials, such as epoxies, polyesters, and vinyl esters. Because no economically viable options exist for recycling these materials, most of these blade materials end up in landfills.

APPROACH

NREL is researching and demonstrating the scale-up of new polymer chemistries that are recyclable by design.

IMPACT

The development of new chemistries for recyclable resin materials can fundamentally enable a circular economy of composite materials for wind turbine blades.

RECYCLING AND REUSE

Accomplishments & Impacts

NREL maintains a collaborative research environment that enables researchers to push industry frontiers in advanced manufacturing and materials, including:

- Exploring materials and techniques that reduce costs and enable advanced designs for renewable power generation and transportation of wind turbine blades.
- Integrating new and emerging technologies to produce novel manufacturing processes that increase local and domestic production capacity, reduce dependence on foreign supply chains, increase product reliability, lower product costs, increase recyclability, and overcome barriers, such as transportation of large-scale wind turbine blade structures.
- Manufacturing and validating a 13-meter composite wind turbine blade produced with thermoplastic resins, which has more viable recycling options than traditional composite wind blades made with thermoset resin.
- Using NREL's advanced additive design software to develop novel, high-performance, 3D-printable electric machine designs.
- Enabling onsite manufacturing and lighter blade structures to achieve a lower levelized cost of energy.