# Electric Motor Thermal Management

Project ID: ELT214

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## OVERVIEW

### Timeline

- Project start date: October 1, 2018
- Project end date: September 30, 2024
- Percent complete: 80%

### Budget

- Total project funding: $1,240,000
- U.S. Department of Energy (DOE) share: $1,240,000
- Funding for FY 2022: $250,000
- Funding for FY 2023: $240,000

### Barriers Addressed

- Cost, power density, and lifetime

## RELEVANCE

This project is part of the Electric Drive Technologies (EDT) Consortium and focuses on NREL's role under Keystone 2. The research enables compact, reliable, and efficient electric machines.

- Motor 10x power density increase (2025 versus 2015 targets) [1]
- Motor 2x increase in lifetime [1]
- Motor 53% cost reduction (2025 versus 2015 targets) [1]

[1] U.S. DRIVE. 2017. *Electrical and Electronics Technical Team Roadmap*. https://www.energy.gov/sites/default/files/2017/11/f39/EETT%20Roadmap%2010-27-17.pdf

## SUMMARY

### Approach/Strategy

- Supports research enabling compact, reliable, low-cost, and efficient electric machines aligned with roadmap research areas [1]
- Collaborate with ORNL, Ames, and SNL to provide motor thermal analysis support, reliability evaluation, and material measurements on related motor research at national laboratories
- Collaborate with university partners including Georgia Institute of Technology and University of Wisconsin Madison to support university-led motor thermal management research efforts.

### Technical Accomplishments

- NREL collaborating with SNL to support mechanical and thermal measurements of new motor materials
- NREL providing thermal design support for electric machine design process led by ORNL.

## ACKNOWLEDGMENTS

Susan Rogers, U.S. Department of Energy

## APPROACH

**Electric Drive Technologies Consortium Team Members**

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**NREL-Led Thermal Management Research**

| Material and interface thermal and mechanical characterization | Motor system thermal analysis support |
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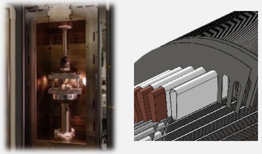
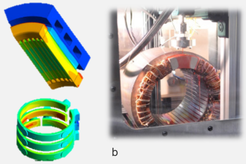
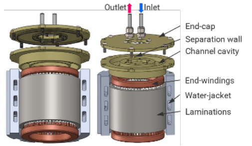
|  a |  b |

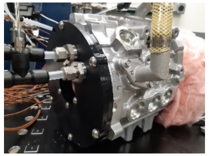
Photo credits:
a: Doug DeVoto, NREL
b: Kevin Bennion, NREL

## ACCOMPLISHMENTS AND PROGRESS

### Collaboration with Georgia Institute of Technology (ELT251)

- Electric motor cooling concept developed collaboratively between NREL and Georgia Tech to directly cool electric motor end windings, which addresses a common hot spot within motor end windings.
- The cooling concept demonstrated a 30%–45% decrease in motor end-winding temperatures relative to the commercial baseline.
- Concept can be retrofitted to existing electric motor designs.



**Section view of end-winding motor cooling concept (left). Assembled motor end-winding cooler at NREL. Photo by Sebastien Sequeira, Georgia Tech/NREL**

## ACCOMPLISHMENTS AND PROGRESS

### Collaboration with Sandia National Laboratories (ELT216)

- Completed mechanical characterization of new motor materials showing reduced strength and increased stiffness of the material in correlation with the volume percent iron nitride loading, indicating the loading embrittles the epoxy.

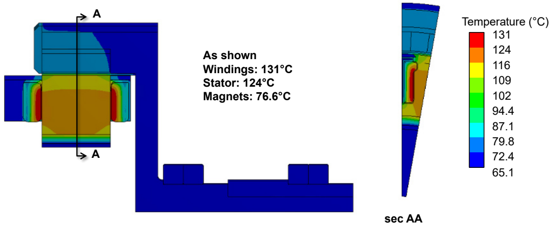
**Mechanical Characterization Results of New Motor Materials**

| vol % loading | Elongation at Yield | Tensile Strength | Tensile Modulus |
|---|---|---|---|
| | | (MPa) | (GPa) |
| 0% | 9.7% | 51.7 | 3.8 |
| 30% | 6.2% | 35.7 | 10.3 |
| 40% | 5.4% | 32.7 | 15.4 |
| 65% | 3.5% | 33.0 | 33.0 |

**Sample from SNL undergoing tensile testing. Photo by Emily Cousineau, NREL (left). Comparison of samples with different loading showing the change in mechanical properties. Each entry is the average of three samples (right).**

### Collaboration with Oak Ridge National Laboratory (ELT212)

- Thermal design of electric machine design shown to meet magnet temperature requirement.
- Cantilever design enables incorporation of power electronics and its associated cooling system into stator cavity and improved in-slot cooling manifolding using off-the-shelf, high-speed bearings.




**Steady-state temperatures at 6,667 RPM and 50 kW showing magnets below 80ºC magnet temperature limit.**

## FUTURE WORK

- In collaboration with ORNL, build prototype heat exchanger to verify expected cooling performance in relation to the non-heavy-rare-Earth, high-speed motors research effort led by ORNL
- In support of SNL, prepare for thermal property tests of additional SNL material samples
- Support Georgia Institute of Technology in efforts to model motor thermal management concepts, conduct experiments, and publish motor thermal management research results
- Continue meetings and discussions with University of Wisconsin – Madison to provide technical support, thermal data, and material information to support integrated cooling of motor and power electronics.

*Any proposed future work is subject to change based on funding levels.*

## COLLABORATIONS

### Oak Ridge National Laboratory (ORNL)

- NREL collaborating on electric motor design efforts led by ORNL
- NREL supporting thermal modeling and simulation analysis for motor and material performance trade-off studies.

### Sandia National Laboratories (SNL)

- NREL supporting material thermal and mechanical property measurements for material research efforts led by SNL.

### Ames Laboratory

- NREL continuing discussions with Ames to support material characterization efforts led by Ames.

### Georgia Institute of Technology

- NREL providing technical support, geometry data, thermal modeling data, and experimental data to support evaluations of advanced cooling impacts
- NREL and Georgia Tech completing experiments of motor subcomponent (motorette) thermal characterization.

### University of Wisconsin

- NREL providing technical support, thermal data, and material information to support integrated cooling of motor and power electronics.

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