# NONDESTRUCTIVE FATIGUE DAMAGE EVALUATION FOR SCRAP METAL REMANUFACTURING

*A proposed methodology for characterizing and predicting the condition of used materials could help facilitate their reuse.*

Remanufacturing is a comprehensive and rigorous industrial process by which a product which has reached its end-of-life is returned to a like-new condition from both a quality and performance perspective. For components that have experienced high stresses during their initial lifetime it is difficult to determine if they can be successfully remanufactured. As a result, currently the components are not remanufactured.

Accurately predicting fatigue damage in end-of-life materials will not only enable effective screening to determine whether a component can be reused, but will also provide valuable information for process optimization and control in downstream remanufacturing. However, critical challenges exist in the development of nondestructive evaluation (NDE) technology to assess the functional condition of recycled metals.

A project led by the University of Illinois at Urbana-Champaign, partnering with Pennsylvania State University, has developed an innovative NDE methodology for the quantification and prediction of accumulated fatigue damage in recycled metal materials using multi-sensor fusion approaches.

## PROJECT DESCRIPTION

High-resolution measurements of accumulated mechanical damage, or fatigue, before crack initiation are essential to determining a component's remaining useful life and optimizing remanufacturing process parameters. Moreover, analytics methods are lacking for quantitatively measuring accumulated mechanical damage and conducting prognostics to determine the remaining useful life.

The team on this 20-month project developed machine-learning based NDE technology that combines the strengths of linear ultrasonic and nonlinear ultrasonic methods to predict loading conditions and fatigue levels. First, the researchers established a testbed design for fatigue testing and obtained a database for fatigue development under cyclic loading. They measured all samples using both linear and nonlinear ultrasonic techniques. They then developed a new NDE technology based on sensor fusion and data analytics. Finally, they performed industry outreach to maximize the impact of the proposed work.

The project resulted in a framework to identify fatigue damage levels and infer remaining useful life. The researchers also built regression models to nondestructively estimate residual stress and estimated remaining life based on ultrasonic measurements. They demonstrated the proposed methods' effectiveness on life cycle fatigue testing data for a 5052-H32 aluminum alloy,

Industry participation in the project was promoted through different channels. John Deere worked with the team by providing input on materials of interest. The methodology and results were also presented in two REMADE-hosted webinars and multiple technology summit and peer review events.

## PROJECT IMPACT

Existing NDE methods in the literature rely on continuous



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measurements over the entire use life, which are sometimes not available in industrial applications. As such, the developed NDE technology addresses a critical gap, improving the prediction accuracy of a fatigue state in secondary materials to gauge remaining useful life. This insight can enhance the efficiency in reusing materials by maximizing their value and reducing the embodied energy in product processing.

The methodology was shown to distinguish new and fatigue specimens with nearly 98% accuracy. The added capability of predicting residual stress, which was not included in the original project goals, is expected to be very helpful for determining important material properties in remanufacturing applications.

## NEXT STEPS

The team plans to share its technology with prospective industry users through REMADE, relevant conferences, and publication in industry and academic journals. They will continue to acquire samples from John Deere and other companies to test and improve the technology, including plans to extend the methodology to factory floor applications.

PROJECT PARTNERS

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PUBLICATIONS

Shao, C. *Quantitative Non-Destructive Evaluation of Fatigue Damage Based on Multi-Sensor Fusion: Final Report for REMADE Project 18-01-RM-12*. June 2021.

## FOR MORE INFORMATION

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