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ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN NDT

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It is my pleasure to share with you this technical focus issue on the subject of artificial intelligence and machine learning (AI/ML) in nondestructive testing (NDT).

I have had the great opportunity in my career to work actively on this subject over the past 25 years, going all the way back to my graduate work at Northwestern University. That work, performed in collaboration with so many important mentors of mine and others in the NDT community (Professor Jan Achenbach, Glenn Andrew, Charlie P'an, Bob Grills, Tommy Mullis, Floyd Spencer, and Matt Golis) resulted in the successful demonstration of making calls on complex ultrasonic data through a probability of detection study of a neural network–based approach.

There exists great potential with the application of AI/ML in NDT. Such tools can excel at repetitive tasks, performing complex data review faster than inspectors. The vision of AI/ML has been to reduce the burden of laborious data review and ideally eliminate missed calls, ensuring greater reliability. However, the widespread application of AI/ML in NDT has not yet been adopted for a number of reasons. Training deep learning neural networks requires very large, well-understood datasets, which are not typically available for many NDT applications. Also, many promising research demonstrations have run into issues with overtraining or robustness to variability found outside of the laboratory. In addition, while human factors are frequently cited as being sources for error in NDT applications, humans are inherently more flexible in handling unexpected inspection scenarios and are better at making judgement calls.

The vision of AI/ML has been to reduce the burden of laborious data review and ideally eliminate missed calls, ensuring greater reliability.

AI/ML clearly has provided us with so many advances to our daily lives in recent years. For example, Google Translate can translate text well between English and more than 100 other languages, enabling broader communication throughout the world. Apps like Shazam can detect a song being played in seconds. Computers using deep learning routines can beat the best human chess players. How can the NDT community make better use of AI/ML, while ensuring we are doing what is best for our customers and members of ASNT? My goal with this technical focus issue is to highlight progress and success stories and share best practices for AI/ML use, but also discuss concerns and the value of having humans in the loop.

In the first feature article, I write about emerging AI chatbots and explore the benefits and concerns with using them as part of our work in NDT. As well, in the NDE Outlook column, Singh and Garg highlight the importance of balancing innovation and responsibility with these generative AI tools, ensuring a safer world.

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The second feature article by Lindgren highlights several successful applications of AI/ML for the Department of the Air Force, introducing best practices for development and validation, and highlighting the critical role for human inspectors to ensure NDT data quality and address outlier indications. The NDT Tutorial article by Harley and Zafar provides a number of helpful tips for effective training and testing of AI/ML for NDT applications. A Review Paper by Taheri and Zafar provides a survey of different AI/ML architectures that are used today and reviews ML progress for interpreting acoustic data acquired as part of additive manufacturing process monitoring.

Two technical papers included in this special issue highlight promising AI/ML research and applications. The first paper by Scott, Stocco, Chertov, and Maev presents progress on the development and performance evaluation of a real-time AI-driven weld process characterization routine reviewing ultrasonic NDT data. In the second paper, Huang, Elshafiey, Farzia, Udpa, Han, and Deng present a promising demonstration of using deep transfer learning with a finite element modeling-based knowledge transfer for an improved acoustic emission source localization demonstration.

I hope you enjoy this technical focus issue and learn something new about AI/ML in NDT. Please feel free to send comments or feedback. ME

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MACHINE LEARNING APPROACH HELPS HIT 100% PREDICTION RATE

A research team led by Tao Sun, associate professor of materials science and engineering at the University of Virginia, has made new discoveries that can expand additive manufacturing in aerospace and other industries that rely on strong metal parts.

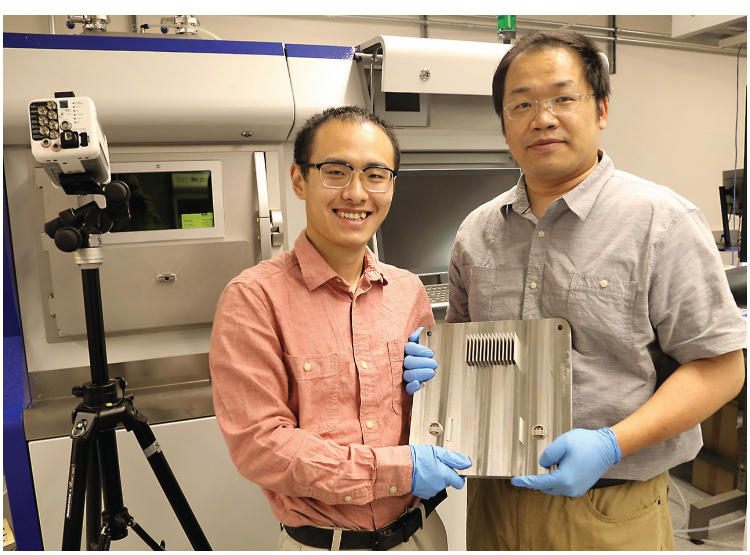
Their peer-reviewed paper, "Machine Learning Aided Real-Time Detection of Keyhole Pore Generation in Laser Powder Bed Fusion," was published 6 January 2023 in *Science Magazine* and addresses the issue of detecting the formation of keyhole pores, one of the major defects in a common additive manufacturing technique called laser powder bed fusion, or LPBF.

Introduced in the 1990s, LPBF uses metal powder and lasers to 3D print metal parts. But porosity defects remain a challenge for fatigue-sensitive applications like aircraft wings. Some porosity is associated with deep and narrow vapor depressions, called keyholes.

The formation and size of the keyhole is a function of laser power and scanning velocity, as well as the material's capacity to absorb laser energy. If the keyhole walls are stable, it enhances the surrounding material's laser absorption and improves laser manufacturing efficiency. If, however, the walls are wobbly or collapse, the material solidifies around the keyhole, trapping the air pocket inside the newly formed layer of material. This makes the material more brittle and more likely to crack under environmental stress.

Zhongshu Ren (left) and Tao Sun display the results of their research. Ren is the first author of the *Science* journal article.

PHOTO CREDIT: TOM COGILL FOR UVA ENGINEERING



Sun and his team, including materials science and engineering professor Anthony Rollett from Carnegie Mellon University and mechanical engineering professor Lianyi Chen from the University of Wisconsin-Madison, developed an approach to detect the exact moment when a keyhole pore forms during the printing process.

"By integrating operando synchrotron X-ray imaging, near-infrared imaging, and machine learning, our approach can capture the unique thermal signature associated with keyhole pore generation with sub-millisecond temporal resolution and 100% prediction rate," Sun said.

In developing their real-time keyhole detection method, the researchers also advanced the way a state-of-the-art tool—operando synchrotron X-ray imaging—can be used. Utilizing machine learning, they additionally discovered two modes of keyhole oscillation.

"Our findings not only advance additive manufacturing research, but they can also practically serve to expand the commercial use of LPBF for metal parts manufacturing," said Rollett, who is also the co-director of the Next Manufacturing Center at CMU.

"Porosity in metal parts remains a major hurdle for wider adoption of the LPBF technique in some industries. Keyhole porosity is the most challenging defect type when it comes to real-time detection using lab-scale sensors because it occurs stochastically beneath the surface," Sun said. "Our approach provides a viable solution for high-fidelity, high-resolution detection of keyhole pore generation that can be readily applied in many additive manufacturing scenarios."

The team's research is funded by the Department of Energy's Kansas City National Security Campus managed by Honeywell FM&T.

NDT SOLUTIONS AND NDE LABS ANNOUNCE PARTNERSHIP

NDT Solutions (New Richmond, WI) and NDE Labs (Benbrook, TX) have announced a strategic partnership to deliver a single point of contact for all nondestructive engineering and testing services. With over 50 years of combined experience in nondestructive inspection, this alliance positions the two companies at the forefront of Industry 4.0.