



DEC 2 – 3, 2020

Diffuse field ultrasonics for in situ material property monitoring during additive manufacturing using the SMART Platform

Award Number: 20-20021

Award Dates: 10/2020 to 09/2023

PI: Chris Kube

Team Members: Haifeng Zhang, Abdalla Nassar, Ted Reutzler, Anthony Rollett, and Clint Armstrong



Project Team

- Haifeng Zhang, Associate Professor in Mechanical and Energy Engineering at North Texas
- Abdalla Nassar, Associate Research Professor and head of Process Physics, Analytics, and Engineering Department at Penn State's Applied Research Laboratory
- Ted Reutzler, Director of Center for Innovative Material Processing thru Direct Digital Deposition (CIMP-3D) and Associate Research Professor at Penn State's Applied Research Laboratory
- Anthony Rollett, Professor of Materials Science & Engineering at Carnegie Mellon University and co-director of NextManufacturing Center
- Clint Armstrong, Advanced Manufacturing & Materials Subject Matter Expert at Westinghouse Electric Company
- Chris Kube, Assistant Professor in Department of Engineering Science and Mechanics at Penn State University

Contact e-mail: [kub@psu.edu](mailto:kube@psu.edu)



PennState

PennSUL
Penn State Ultrasonics Lab



CIMP-3D

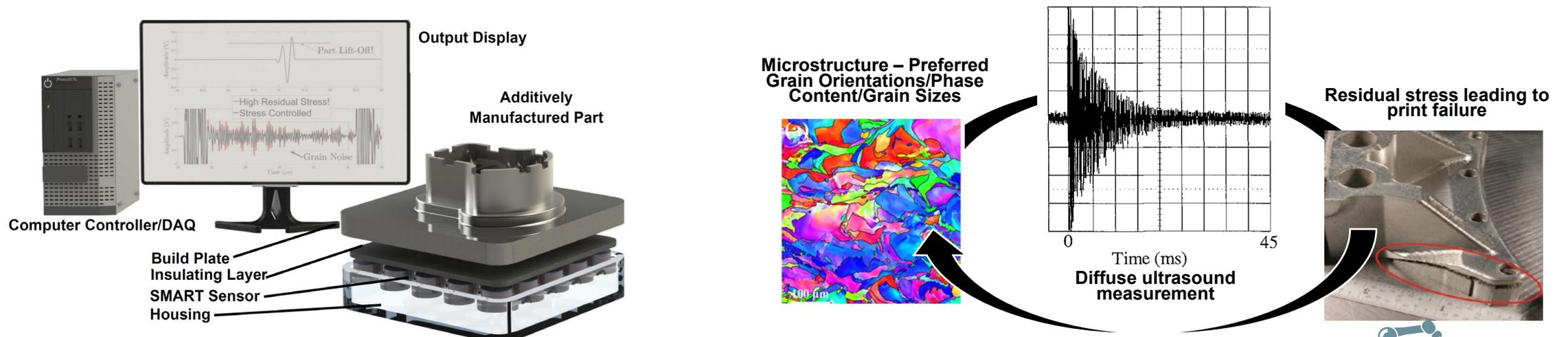
**Carnegie
Mellon
University**

 **Westinghouse**



Project Objectives

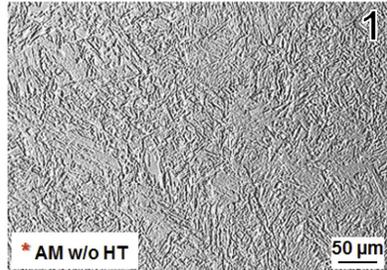
- Develop, test, and implement a diffuse-field sensitive ultrasonic sensor to be used in powder bed fusion additive manufacturing
- Integrate plurality of sensors to provide in situ monitoring of additive manufacturing using ultrasonic diffuse field measurements to sense:
 - subtle microstructure variations during printing of Gr91 steel parts toward ascertaining desired properties are present via structure-property relationships and
 - time-dependent changes in residual stress



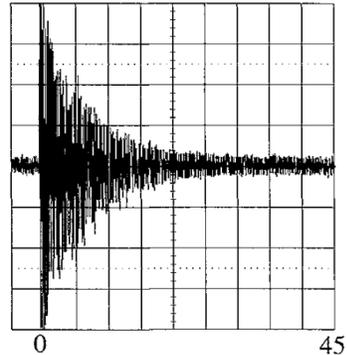
Broader Impact

Goal: leverage in situ ultrasound to advance additive manufacturing science

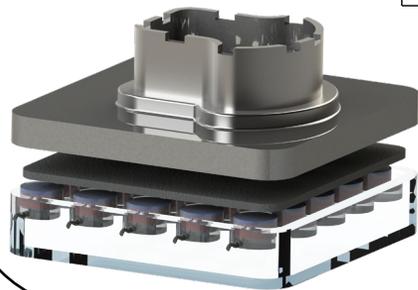
Ultrasound for in situ microstructure-sensitive part qualification (Current NEET)



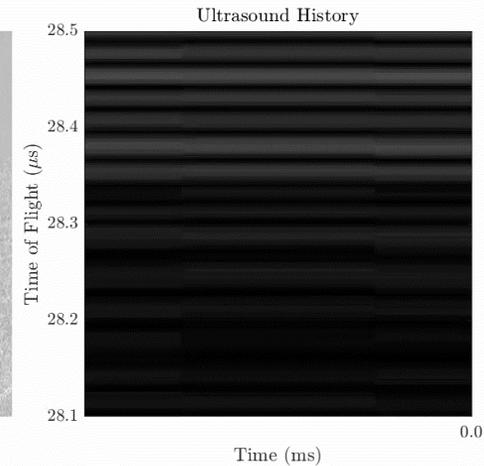
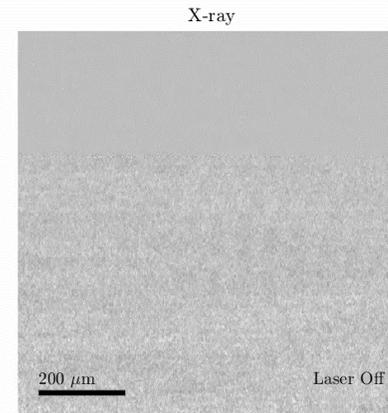
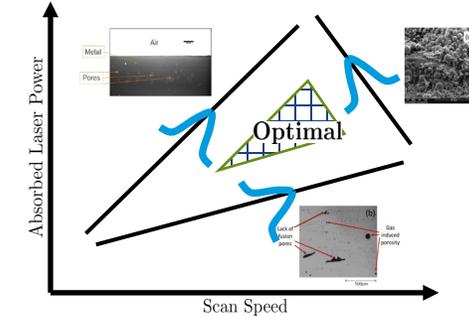
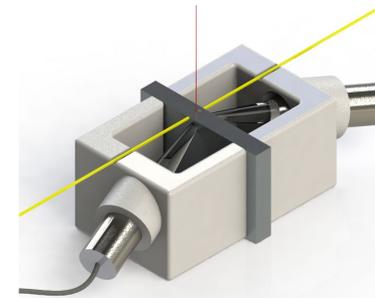
Martensitic microstructure desired for Gr91 F/M steel components in reactor service.



Diffuse ultrasound measurement



Ultrasound for in situ melt pool monitoring/process window determination (Other ongoing research)



¹S. Maloy et al, "Laser additive manufacturing of F/M steels for radiation tolerant nuclear components," LANL Technical Report, LA-UR-17-30052 (2017).



Project Impacts

- Invited to give virtual seminar at Rutgers on 12/02/2020
- Patent disclosure (in discussion)



Issues and Concerns

- Covid-19 had no direct influence – lab remained accessible
- Covid-19 has indirect influences related to migration to online teaching (time sink), postponement of recruiting events, etc.
- Include identified risks and mitigation strategies



Milestones and Deliverables for FY-21

- Design and development of multi-modal piezoelectric sensors for diffuse field measurement (Report/Paper, Zhang, 01/01/2021 - 09/30/2021)
- Initial purchases, testing, and validation of ultrasound sensors and equipment on pre-built parts/build plate. Also, development of ultrasound control software/user interface (PPT Overview, Kube, 01/01/2021 – 09/30/2021)
- Design, printer modifications, and integration of sensors into EOS printer (Kube, Nassar, Reutzel, 08/01/2021 – 09/30/2021)
- All activity documented in annual report



Possible Areas/Industries/Programs (and Readiness) for Adoption

- Very early stages – Clint Armstrong of Westinghouse to help guide/advise potential future transition toward nuclear industry adoption
- Focus on flexibility. Agnostic to printer/manufacturing process (as long as a part is being built on a build plate)



Contact Information and Questions

- Any questions can be sent to: kube@psu.edu