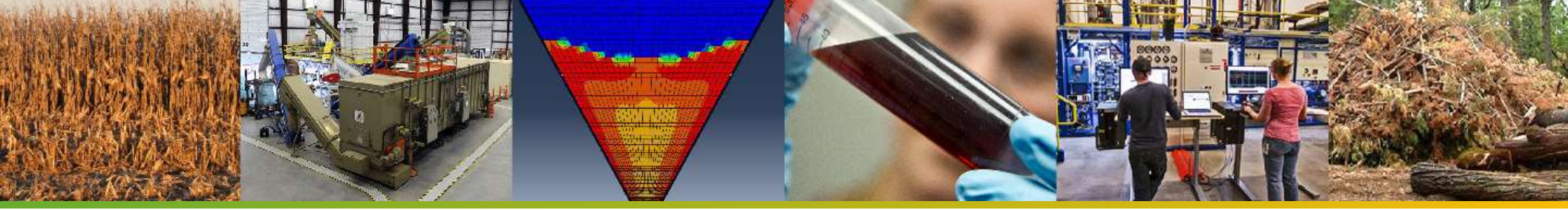

DOE Bioenergy Technologies Office (BETO) 2021 Project Peer Review

"Smart" Transfer Chutes with In-line Acoustic Sensors for Bulk-Solids Handling Solutions

16 March 2021
Feedstock Conversion Interface Consortium

Troy A. Semelsberger
Los Alamos National Laboratory

This presentation does not contain any proprietary, confidential, or otherwise restricted information

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FEEDSTOCK-CONVERSION INTERFACE CONSORTIUM

The Team

Los Alamos NATIONAL LABORATORY EST.1943

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John Greenhall, Ph.D.
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JENIKE & JOHANSON SCIENCE ENGINEERING DESIGN

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NREL NATIONAL RENEWABLE ENERGY LABORATORY

Mike Resch, Ph.D.

FCIC Task Organization

Task 2: Feedstock Variability

Task 5: Preprocessing

Task 6: Conversion High-Temp

Task 1: Materials of Construction

Task 7: Conversion Low-Temp

Task 3: Materials Handling

Task X: Project Management

Task 4: Data Integration

Task 8: TEA/LCA

Task X: Project Management: Provide scientific leadership and organizational project management

Task 1: Materials of Construction: Specify materials that do not corrode, wear, or break at unacceptable rates

Task 2: Feedstock Variability: Quantify & understand the sources of biomass resource and feedstock variability

Task 3: Materials Handling: Develop tools that enable continuous, steady, trouble free feed into reactors

Task 4: Data Integration: Ensure the data generated in the FCIC are curated and stored – FAIR guidelines

Task 5: Preprocessing: Enable well-defined and homogeneous feedstock from variable biomass resources

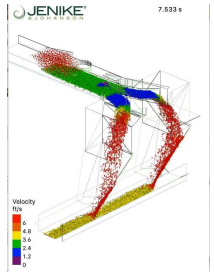
Task 6 & 7: Conversion (High- & Low-Temp Pathways): Produce homogeneous intermediates to convert into market-ready products

Task 8:Crosscutting Analyses TEA/LCA: Valuation of intermediate streams & quantify variability impact

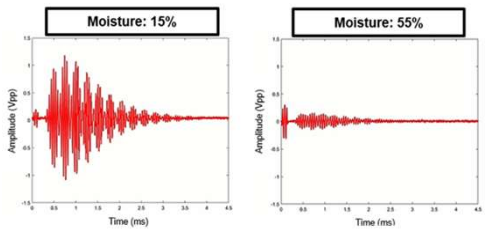
Project Overview

- **Objective:** Develop innovative solids handling equipment (1) and unique in-line acoustic measurement sensors (2, 3) that improve operational reliability, safety, throughput, and yield of biorefineries.
- **Current limitations:** The current limitations for moisture sensing is cost, durability, complexity, reliability, sampling volume, and continuous monitoring. There are no known commercial sensors for real-time monitoring of plug-screw feeder wear or commercial chutes with the ability to change configuration to discard problematic feedstock.
- **Relevance:** This project directly aligns with the long-term goal of FCIC, and the challenges identified in the ADO and Biorefinery Optimization Workshops by developing novel bulk solids handling equipment specifically designed for biomass material, and developing novel acoustic sensors addressing the long-standing, well-known IBR bulk solids handling challenges
- **Risks:** 1) Timely adaptation of "smart" chute and acoustic sensors to maximize impact and TRL level; 2) the failure to ensure funding after project completion that addresses additional IBR bulk solids handling challenges

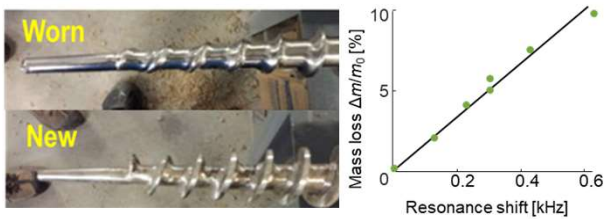
1. "Smart" Chute



2. Moisture Sensor (corn stover)



3. Wear Sensor



1 – Management

Subtask	Lead(s)	Major Responsibilities
Moisture Sensor	LANL	Develop *in operando* moisture sensor
Wear Sensor	LANL	Develop *in operando* plug-screw feeder wear sensor
“Smart” Chute	J&J	Design “SMART” chute
Material Supply	INL	Provide corn stover material & IBR resource
Plug-screw feeder	NREL	Provide plug-screw feeder & IBR resource

- **Risks:** project scheduling, communication, and contractor delays. Project risks and challenges are identified and mitigated through open and honest communication with the expectation that they are disclosed as soon as they come up. Challenges are addressed both inter-and intra-team.
- **Communication strategy:** Communication and coordination are critical to the success of this project. Strategies implemented include:
  - Face-to-Face meetings
  - Site visits
  - Quarterly Reports (BETO)
  - Quarterly Telecons (BETO)
  - Collaboration with INL & NREL
  - Biweekly teleconferences (J&J, LANL)
  - Weekly LANL team meetings
  - FCIC Webinars

2 – Approach

- **Technical Approach:**
  - **Innovation 1:** Design, build, and demonstrate in-line acoustic sensor for continuous monitoring of plug screw feeder wear and erosion
  - **Innovation 2:** Design, build, and demonstrate in-line acoustic sensor for continuous monitoring of corn stover feedstock moisture content
  - **Innovation 3:** Design, build, and demonstrate "smart" chute technology capable of discarding unacceptable material (based on moisture content) prior to further processing; thus, improving overall operational reliability, throughput, yield, and conversion

Challenges:

- **Moisture Sensor:** 1) performance at full-scale flow rate and 2) homogeneity and uniformity of feed flow
- **Wear Sensor**: 1) standardized add-on to existing commercial vendors of plug-screw feeders, and 2) coupling source and receiver for reliable measurements

Metrics:

- Demonstrate five consecutive discarding actions of "smart" transfer chute (Jenike & Johanson) discriminating high (>40%) and low moisture (<20%) content corn stover with coupled in-line moisture sensor (LANL)
- Demonstrate the ability to measure plug-screw wear to within ±10% of measured mass in simulated industrial operating environment

3 – Impact

Impact: The three innovative technologies developed in this project will have a profound impact on integrated biorefineries by:

- ✓Increasing IBR time-on-stream
- ✓Offering advanced process control strategies
- ✓Increasing product selectivity, conversion, and yields
- ✓Increasing IBR plant operational safety
- ✓Decreasing maintenance downtime & costs (i.e., failures)
- ✓Active control of incoming feedstock quality

Target Industry: *Integrated Biorefineries (IBR)*

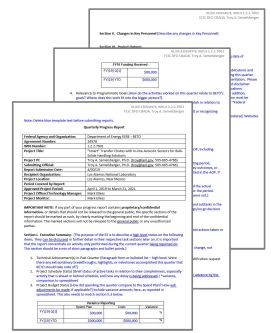
Relevant Industries: *Pharmaceutical*, *Mining*, *Coatings*, *Lumber*, *Additive Manufacturing,….*

Dissemination:

ABLC2020
ABLC 2020
24 June 2020
Virtual Conference

Michael Berube : Acting Deputy Assistant Secretary for Transportation in the Office of Energy Efficiency and Renewable Energy

R&D 100

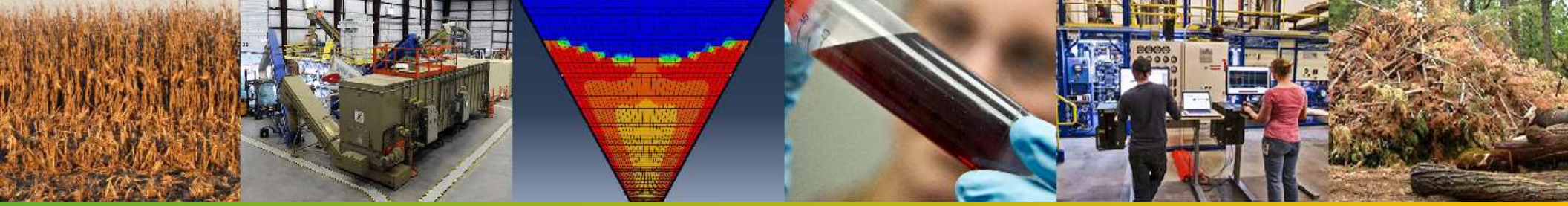


BiofuelsDigest
The world's most widely read biofuels daily

Latest Hot Tech for Bulk-Solids Handling: The Digest's 2020 Multi-Slide Guide to Feedstock Conference Interface Consortium
October 8, 2020 | Jim Lane

PATENT PENDING

INTELLECTUAL PROPERTY



4 – Progress and Outcomes

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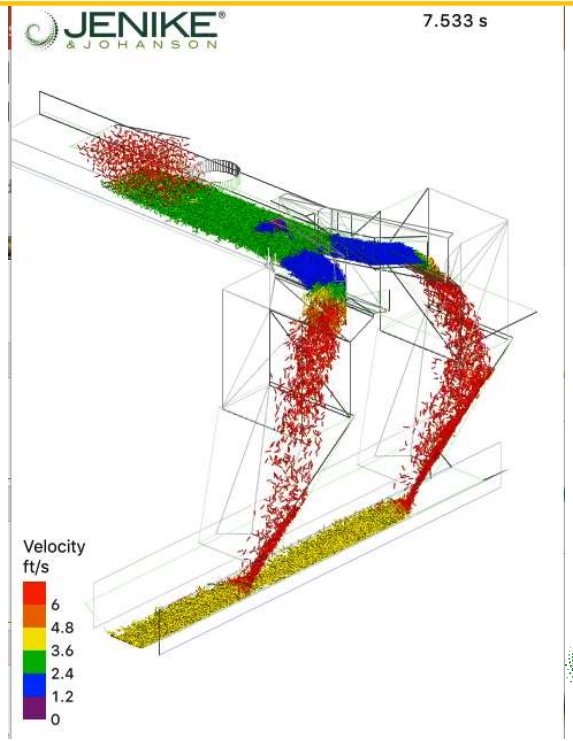
"Smart" chute technology with moisture sensor

Tools

"Smart" chute capable of discarding problematic material using moisture sensor



JENIKE & JOHANSON Science Engineering Design

Description

- Continuous real-time active control of incoming feedstock quality for reliable bulk-solids handling

Value of new tool

- Increases IBR time-on-stream
- Offers advanced process control strategies
- Increases product selectivity, conversion, and yields
- Increases IBR plant operational safety
- Decreases maintenance downtime & costs (i.e., failures)
- Active control of incoming feedstock quality

Potential Customers & Outreach Plan

- IBR plants, additive manufacturing, mining, wood products
- Tech transfer and commercialization

Measuring moisture content in corn stover

Knowledge

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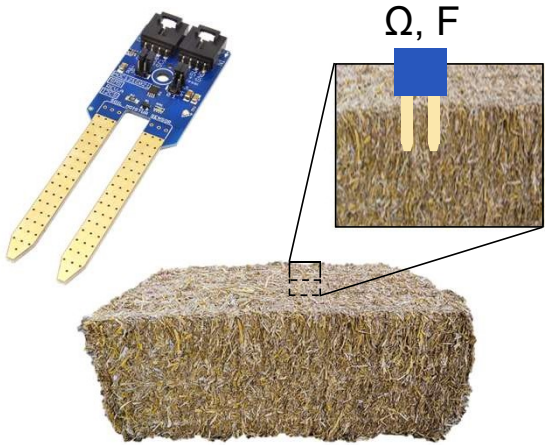
Dielectric

Conductivity & capacitance

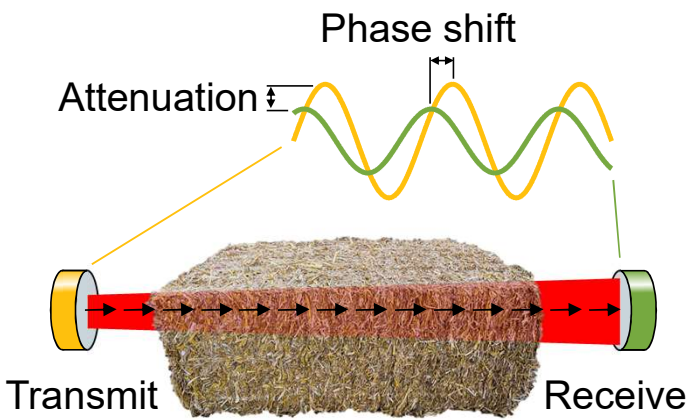
Complexity: **simple**
Moisture range: **5 - 70 %**
Limits: **10% of bale**
Cost: **~$3,500**
Measurement: **discrete**



Microwave

Attenuation & phase shift

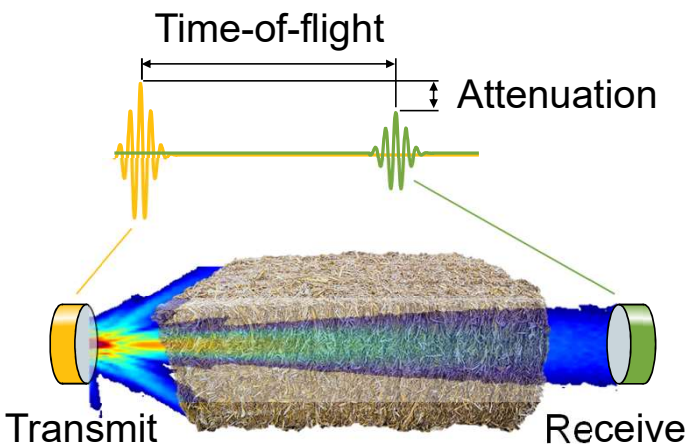
Complexity: **moderate**
Moisture range: **0 - 25 %**
Limits: **25% of bale**
Cost: **~$8,000**
Measurement: **discrete**



Acoustic

Attenuation & time-of-flight

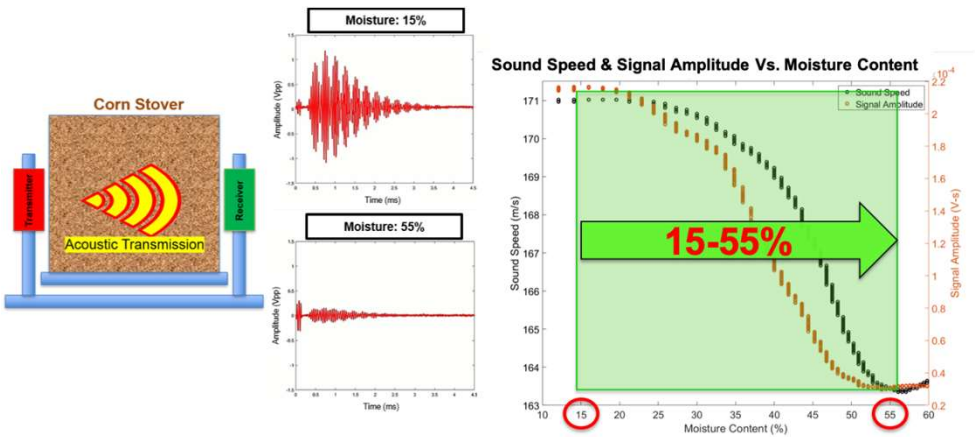
Complexity: **simple**
Moisture range: **15 – 55 %**
Limits: **100% of sample**
Cost: **~$3,000**
Measurement: **continuous**



Acoustic moisture sensor

Tools

Sensing moisture content of corn stover using acoustic technology (static measurement)



Technology	Electrical Conductivity	NIRS Analysis	Microwave	Acoustics
Moisture range	5-70% ✓	5-60% ✓	0-25% ✗	15-55%* ✓
Sensing location	Surface ✗	Surface ✗	Bulk ✓	Bulk ✓

* Current demonstrated range

Description

- Novel acoustic sensors to quantify bulk moisture content of corn stover using sound speed and acoustic signal amplitude analysis.

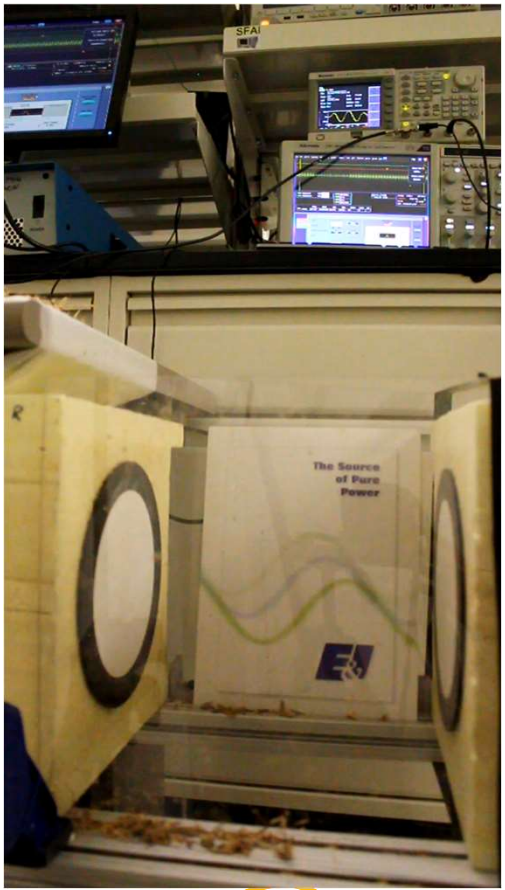
Value of new tool

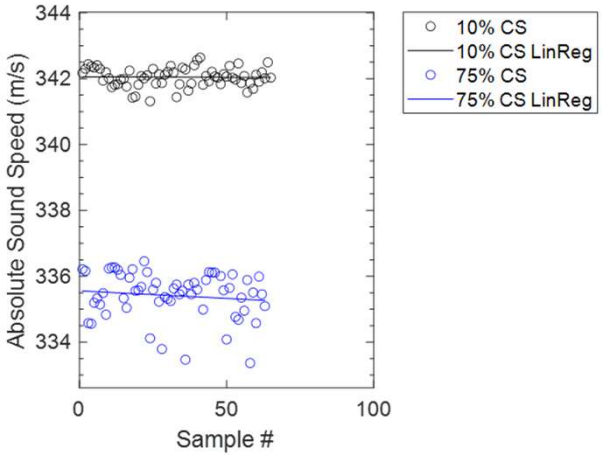
- *In operando*, continuous real-time monitoring of bulk moisture
- Simple, cheap, and reliable setup delivering high accuracy, resolution and fast moisture measurements (millisecond sampling rates)
- Flexible installation–installed at multiple locations in IBR processing trains
- Applicable for a wide range of biomass feedstocks
- Active control of incoming feedstock quality
- Offers advanced process control strategies

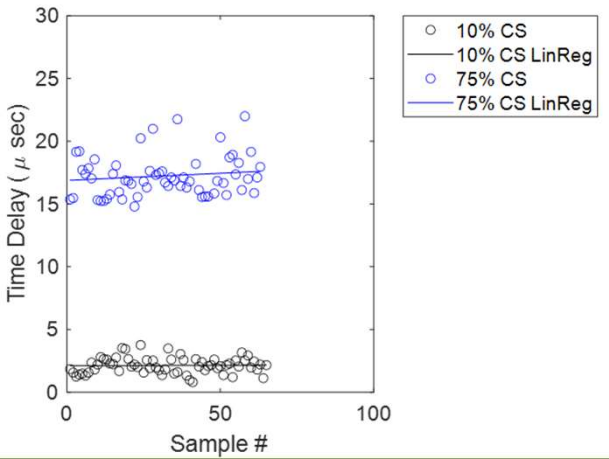
Potential Customers & Outreach Plan

- IBR process engineers, additive manufacturing, wood/lumber, pharmaceutical
- Tech Transfer and Commercialization

Acoustic moisture sensor (dynamic)







Material characterization for "Smart" chute design

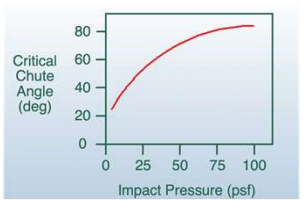
Knowledge

Flow property testing and characterization of corn stover for equipment design

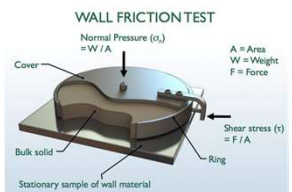
1. Cohesive Strength: RESULTS

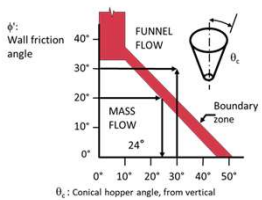
3. Angle of Repose: RESULTS

2. Flowability: RESULTS



4. Wall Friction: RESULTS





Description

- Material and flow property testing for designing and optimizing transfer chutes and hoppers for corn stover

Achievement

- Completed flow property testing of corn stover by Jenike & Johanson: the world leader in bulk solids handling

Relevance

- Hopper and chute designs specifically for industrially relevant material properties of corn stover

Flow Properties Test Results
Corn Stover

Los Alamos National Laboratories
Los Alamos, NM

71103-1

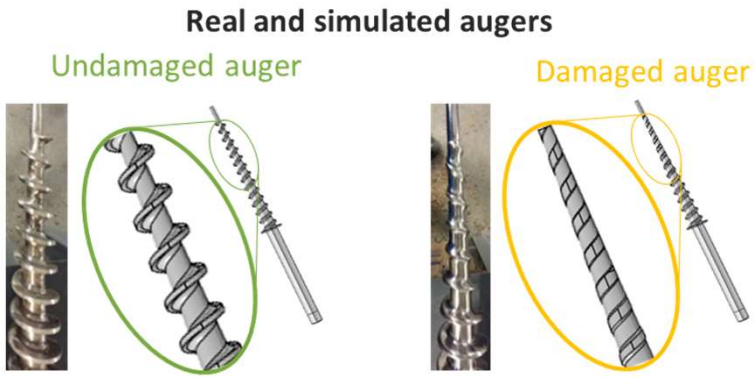
Contains Confidential Information

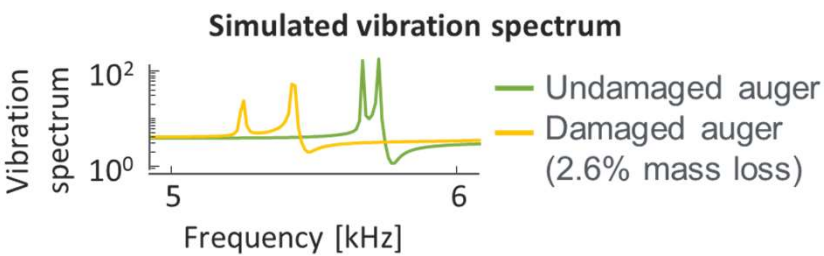
October 23, 2019

Acoustic wear sensor for plug-screw feeder

Tools

In operando monitoring of plug-screw feeder wear state





Description

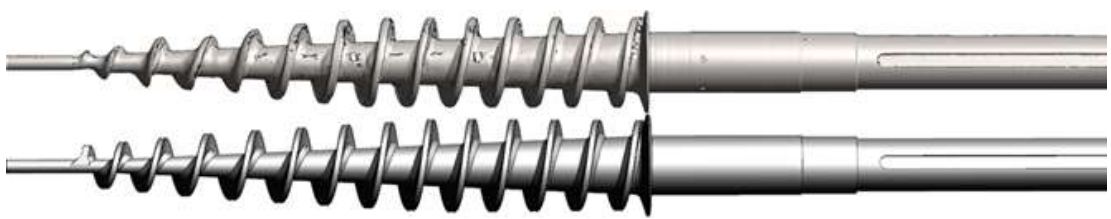
- Continuous real-time wear monitoring of plug-screw feeder

Value of new tool

- Offers advanced process control strategies
- Increases IBR plant operational safety
- Increases IBR time-on-stream
  - Decreases maintenance downtime & costs (i.e., failures)

Potential Customers & Outreach Plan

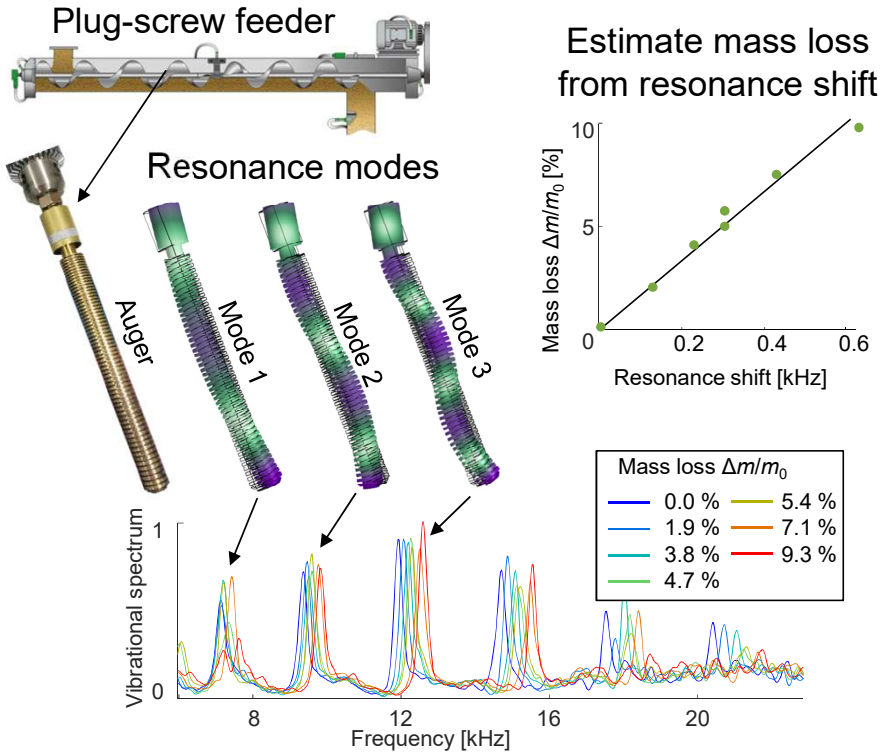
- IBR plants, additive manufacturing, mining,
- Tech transfer and commercialization



Acoustic monitoring for wear in plug-screw feeder augers

Tools

- **Track shifting vibrational resonances to noninvasively measure auger wear**



Description

During operation, augers are subjected to wear that shifts the frequencies of the auger natural vibration modes. We employ an acoustic transducer to excite the auger and a Laser Doppler Vibrometer to measure the resulting vibration spectrum. We track the resonance shifts to estimate the amount of damage. This enables noninvasive damage detection while the auger is in operation.

Value of new tool

Current damage detection requires halting operation, removing the plug-screw auger, and visually inspecting for damage. This leads to significant down time, and is unable to detect sudden damage that frequently leads to auger failure. Noninvasive measurement will greatly reduce the machine downtime.

Potential Customers & Outreach Plan

- IBR plants, additive manufacturing, mining,
- Tech transfer and commercialization

Summary

Management: Our team is a high performing, agile team that has 1) met project milestones & deliverables, 2) maintained research excellence, 3), successfully demonstrated proof-of-concept for each innovation, and 4) strengthened our collaboration with relevant industries, via management strategies including: 1) timely communication (between labs and industries), 2) adaptive market identification, and 3) through risk identification and mitigation

Technical Approach: Our approach is to leverage Jenike & Johanson's expertise as the world leader in bulk solids handling in the development of a novel "smart" chute capable of actively discarding problematic biomass material resulting in IBR downtime; and LANL's expertise in applied acoustic technologies to develop novel acoustic sensors for the continuous real time monitoring of moisture content and plug-screw feeder wear.

Impact: The impacts of our innovative technologies on biorefineries would usher in a new era of novel equipment (i.e., "smart" transfer chutes), novel in-line measurement techniques and novel process-control strategies for not only the next generation of biorefineries, but for broader industries such as mining, pharmaceuticals, wood composite, and additive manufacturing, to name a few.

Progress: This task has delivered all the milestones & technical achievement to date, published articles & proceedings, presented at conferences, developed IP, and attained growing market impact in the biomass industry by being highlighted as the "Latest Hot Tech" by Biofuels Digest.

Quad Chart Overview (Competitive Project)

Timeline

- Project start date (04/2019) – end date (10/2021)

	FY20 Costed	Total Award
DOE Funding	(10/01/2019 – 9/30/2020)	$1,000 K
Project Cost Share	$429 K	$429 K

Project Partners

- Jenike & Johanson

Project Goal

The **long-term goal** is the development of novel solids handling equipment and novel in-line sensors that increase the overall IBR operational reliability beyond 40-50% time on-stream—meeting our three objectives, we expect IBR operational reliability to improve to 68%. Our team, consisting of Jenike & Johanson and Los Alamos National laboratory, will leverage the many decades of experience, expertise and prior successes to achieve our project-specific objectives.

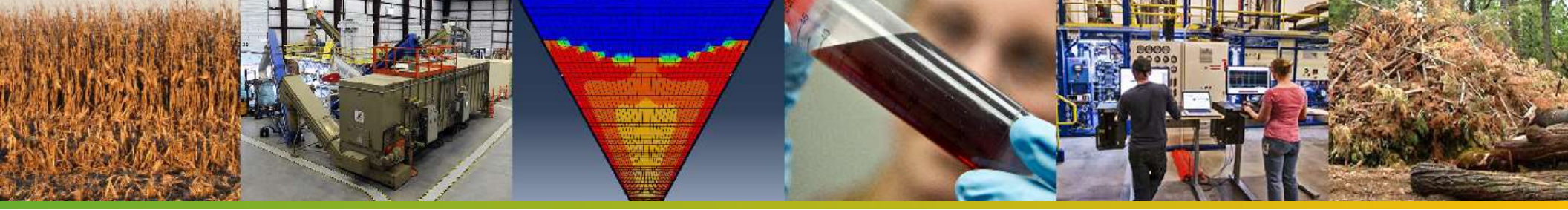
- **Objective 1**. Design, build, and demonstrate "smart" chutes for biomass solids handling of corn stover,
- **Objective 2**. Design, build, and demonstrate in-line moisture sensors for corn stover feedstock,
- **Objective 3**. Design, build, and demonstrate in-line sensor for real-time monitoring of plug-screw feeder wear/erosion.

End of Project Milestone

Demonstrate five consecutive discarding actions of "smart" transfer chute (Jenike & Johanson) discriminating high (> 40%) and low moisture (< 20%) content corn stover with coupled in-line moisture sensor (LANL)

Funding Mechanism

BETO FCIC-DFO



Thank you

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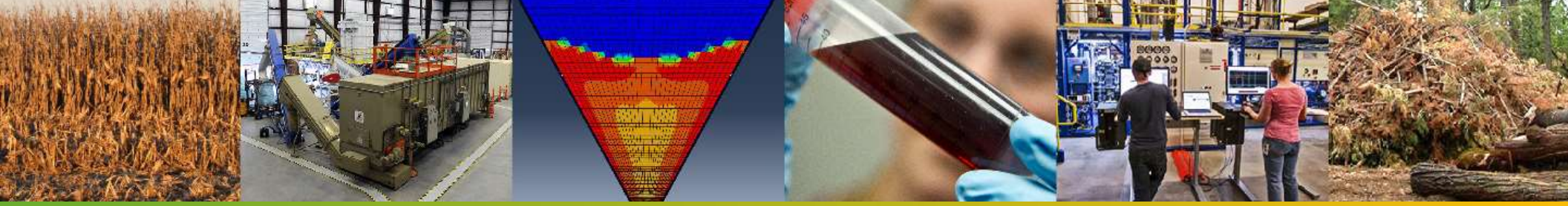

Additional Slides

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Responses to Previous Reviewers' Comments

- Project was not previously peer reviewed

Publications, Patents, Presentations, Awards, and Commercialization

- Greenhall, J., Doan, H., Semelsberger, T. A. & Pantea, C. In situ damage monitoring of plug-screw feeder via acoustic spectroscopy. in SBFC 2020 Conference.
- Doan, H., Greenhall, J., Semelsberger, T. A. & Pantea, C. Acoustics Characteristic of Biomass Feedstock - Corn Stover. in SBFC2020 Conference.
- Semelsberger, T. A. & Hartford, C. FCIC-DFO " Smart " Transfer Chutes with In-Line Acoustic Sensors for Bulk-Solids Handling Solutions. in ABLC 2020 Conference.
- Doan, H., Hakoda, C., Greenhall, J., Pantea, C. & Semelsberger, T. A. The Effect of Moisture Content on the Acoustic Characteristics of Bioenergy Feedstocks –Corn Stover. Bioresour. Technol. Submitted, (2021).
- Semelsberger, T. A., Pantea, C., Hartford, C. & Craig, D. ***Invention Disclosure (S133620)***: In-Line Acoustic Sensors for Monitoring Bulk Solids Handling Operations: Physical Properties and Equipment Reliablity. (2018).
- Pantea, C., Semelsberger, T. A., Greenhall, J., Hakoda, C. & Doan, H. ***Invention Disclosure (S3730)***: Data Acquisition for Moisture Determination of Bulk Solids. (2020).

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Latest Hot Tech for Bulk-Solids Handling: The Digest's 2020 Multi-Slide Guide to Feedstock Conversion Interface Consortium
October 8, 2020 | Jim Lane