Wireless Valve Position Indication Sensor System

Advanced Sensors and Instrumentation Annual Webinar

October 23, 2019

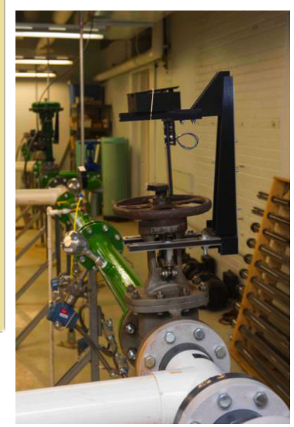
Vivek Agarwal
Idaho National Laboratory

Wireless Valve Position Indication Sensor System

Idaho National Laboratory
70 YEARS OF SCIENCE & INNOVATION

Wireless Valve Position Indication Technology


Experimental flow loop


Rising stem valve


Rising handle valve


Quarter turn valve

Enable online monitoring to manual valve position and calibration to enhance efficiency and reduce cost

Project Overview

- Project Goal
  - Advancement and commercialization of the wireless valve position indication (VPI) sensor system

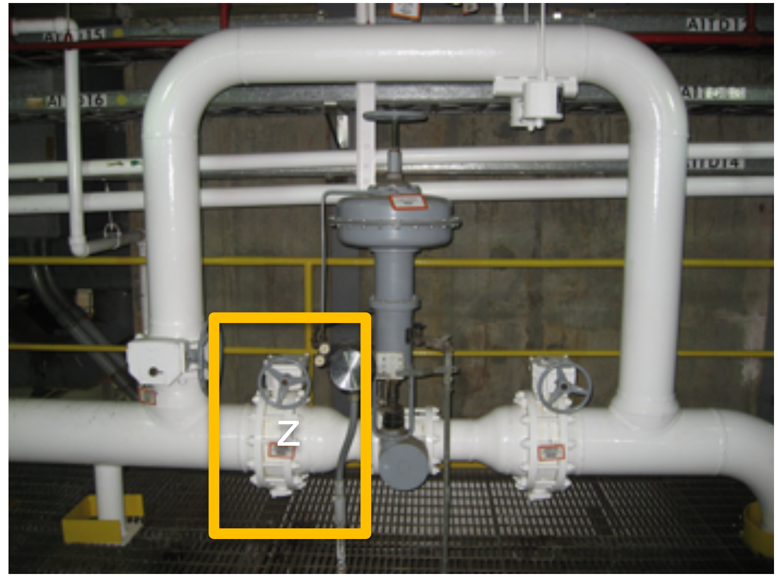
- Project Objectives
  - Advance the INL-developed wireless VPI prototype to include an interoperable, modular, and reconfigurable sensor system to enable reliable wireless communication at multiple nuclear sites (specific focus on 900 MHz Distributed Antenna System)
  - Evaluate any potential concerns associated with cybersecurity, seismic qualification, and radiation- based life expectancy of the sensor system
  - Implement techniques for reducing power consumption and evaluate embedding power harvesting capabilities to the sensor system.

Project Team and Timeline

- Idaho National Laboratory
  - Vivek Agarwal – Project lead
  - John W. Buttles
  - Sasa Kovacevic
- Exelon Generation Company
  - William Ansley – Exelon Innovation
  - Timothy Baugher – Calvert Cliff Nuclear Power Station
  - Nicholas A. Tryt – Nine Mile Point Generating Station
- Project Schedule
  - December 01, 2018 to November 30, 2020

Target Valves at Plant Sites

Rising Stem Valve Loop

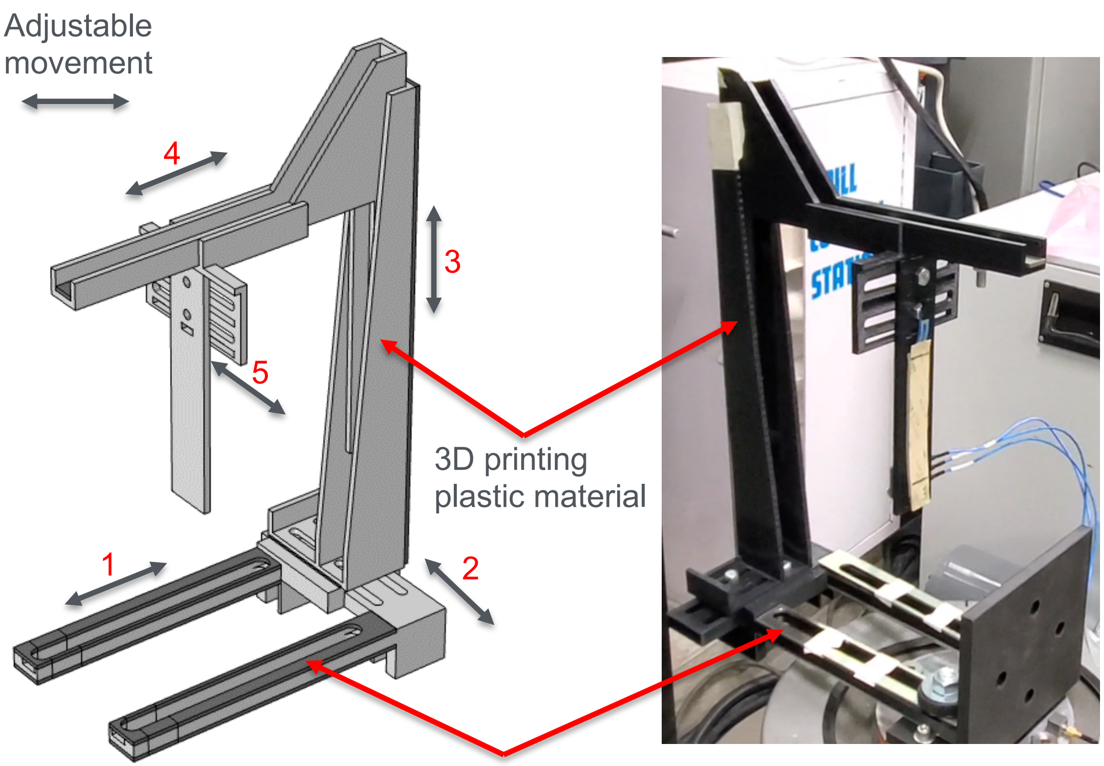


Butterfly Valve Loop

Butterfly Valve

Accomplishments: Initial Bracket Design

Initial Design: 3D printing plastic material (Ultem 9085) with steel plates



CAD model

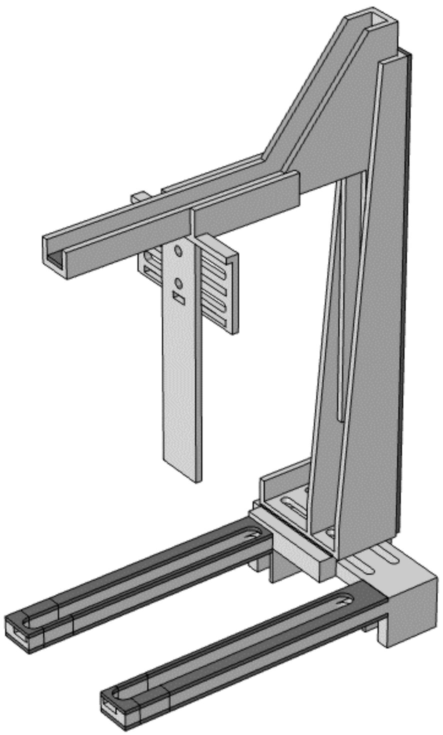
steel plates

3D printed bracket

Characteristics	Ultem 9085	Steel
Density (lb/in^3)	0.05	0.28
Stiffness (ksi)	290	29000
Total weight: 3.8 lb		

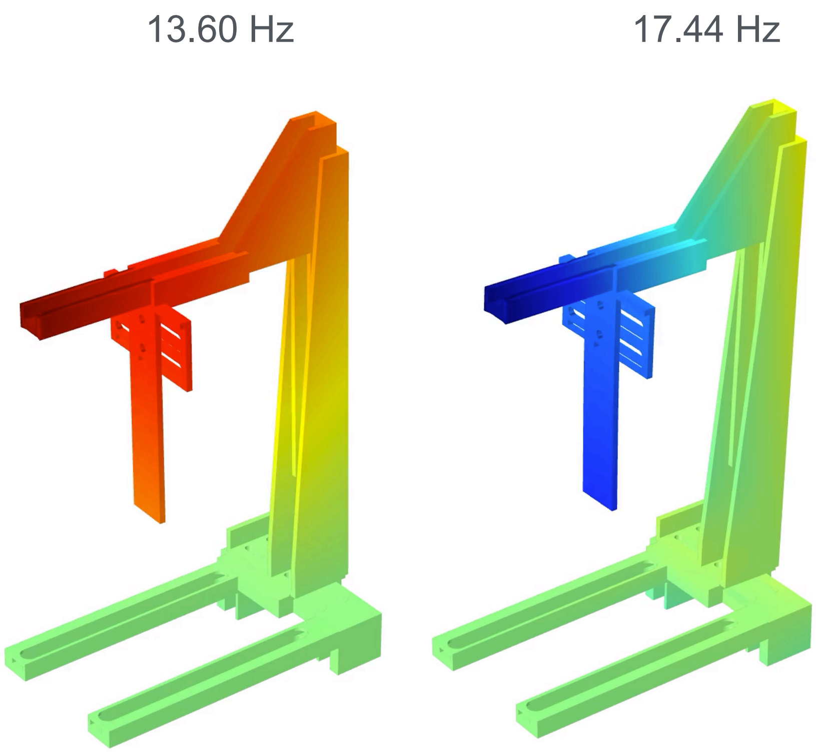
Accomplishments: Initial Bracket Design

- Numerical simulation performed using the COMSOL software
- According to Generation 3 nuclear plant design requirements, valve assemblies must have a minimum specified natural frequency of 33 Hz.
- Further improvements of the bracket.



CAD model

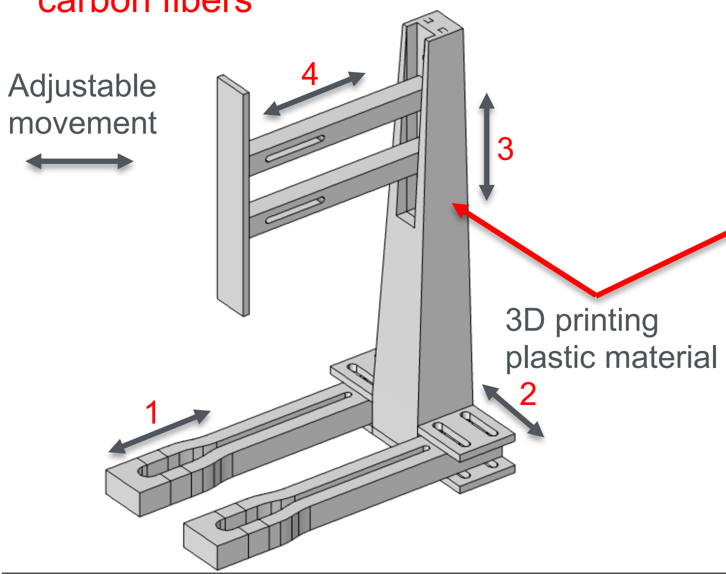
Numerical modeling:
Eigenfrequency analysis

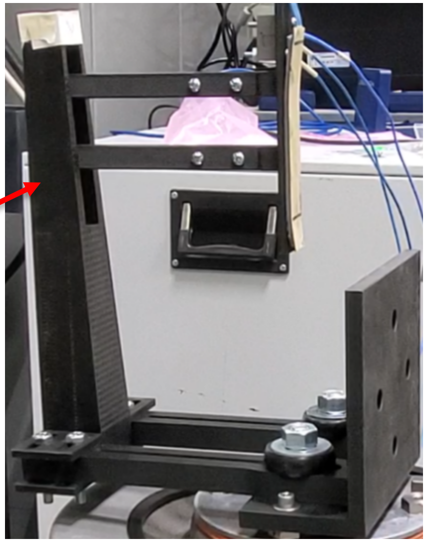


Accomplishments: Advancing Bracket Design

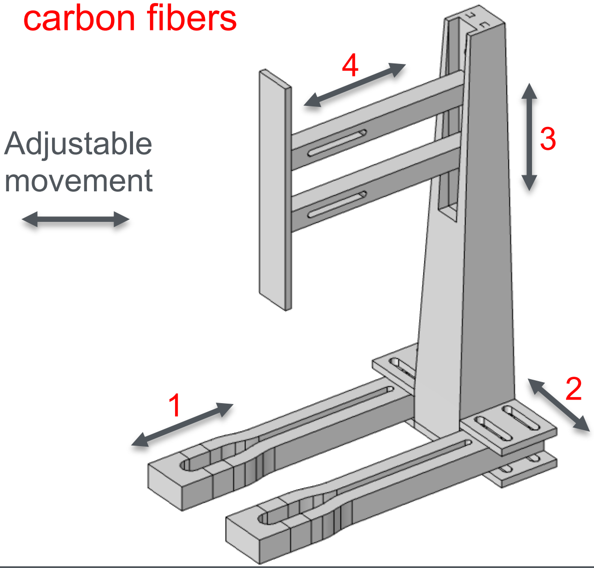
Advanced Design: 3D printing plastic material reinforced by carbon fibers

3D printing plastic material reinforced by chopped carbon fibers





3D printing plastic material reinforced by continuous carbon fibers



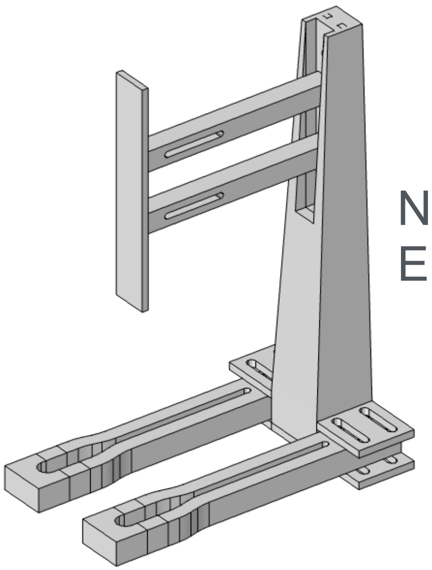
Characteristics	Chopped carbon
Density (lb/in^3)	0.04
Stiffness (ksi)	522

Total weight: 1.5 lb

Characteristics	Continuous carbon
Density (lb/in^3)	0.05
Stiffness (ksi)	7250

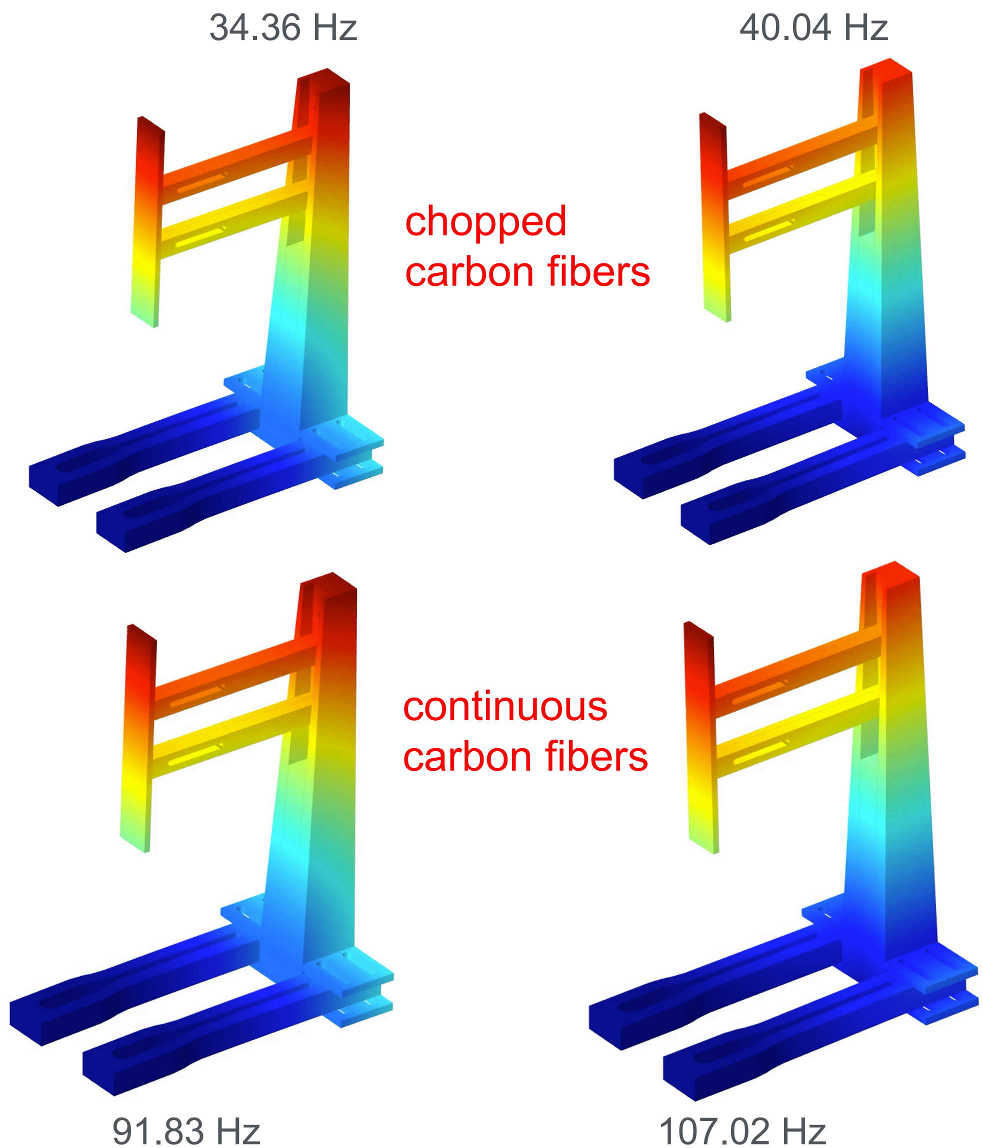
Total weight: 1.7 lb

Accomplishments: Numerical Simulation Results



CAD model

Numerical modeling:
Eigenfrequency analysis



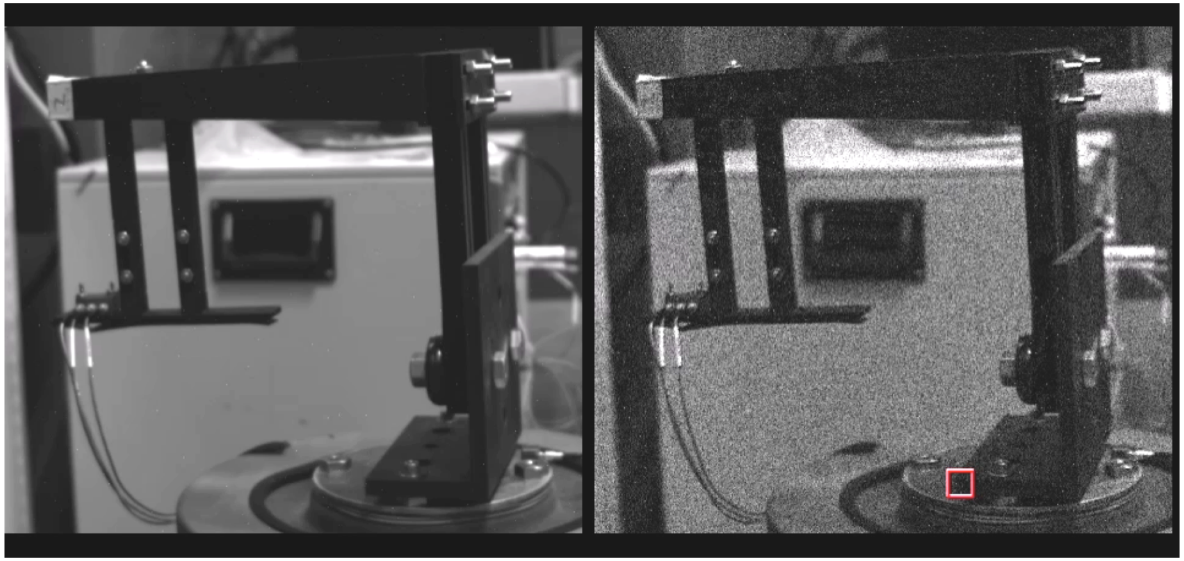
Accomplishments: Experimental Testing

- All three brackets are experimentally tested performing sine dwell tests at several frequencies
- This type of testing is recommended by ASME QME-1-2017: Qualification of Active Mechanical Equipment Used in Nuclear Facilities
- The amplitude for the sine tests is determined using an allowable vibration velocity of 0.5 in/s defined by ASME OM-2012: Operation and Maintenance of Nuclear Power Plants
- The tests consisted of three test sets for each bracket (X, Y, Z directions)
- Each test set consisted of performing the test five times.

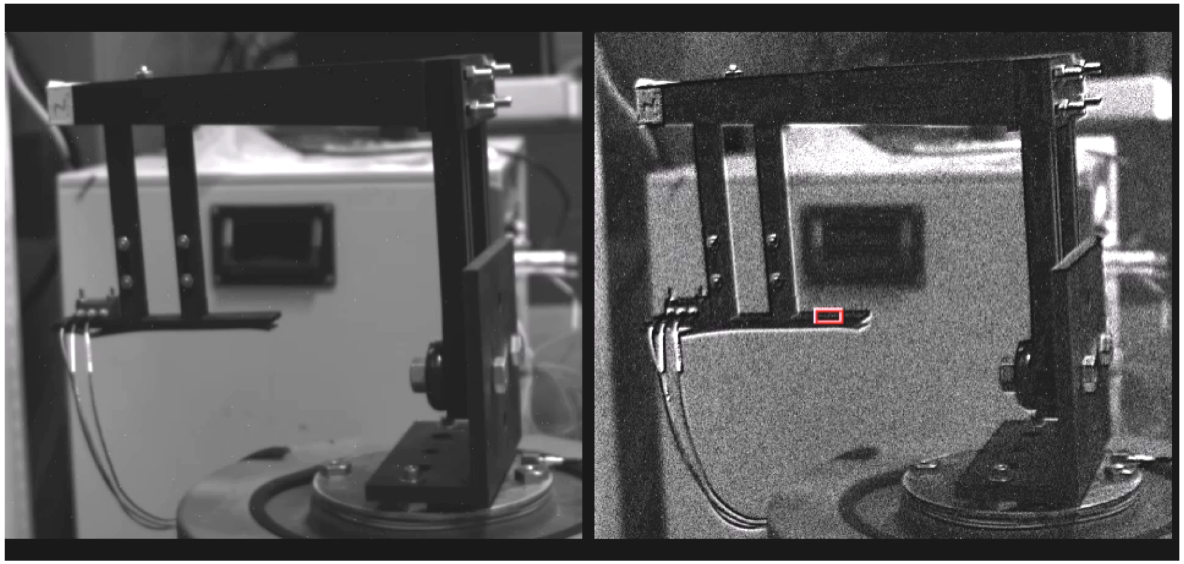
Accomplishments: Experimental Set-up

- The tests are conducted at the Materials and Fuels Complex at INL
- To perform the tests a Labworks ET-127 shaker table has been used
- Time history of the magnitude of acceleration for each frequency is recorded

Accomplishments



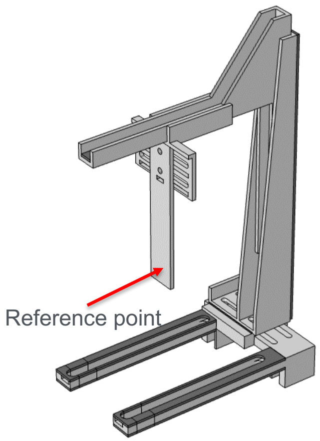
Frequency 18 Hz

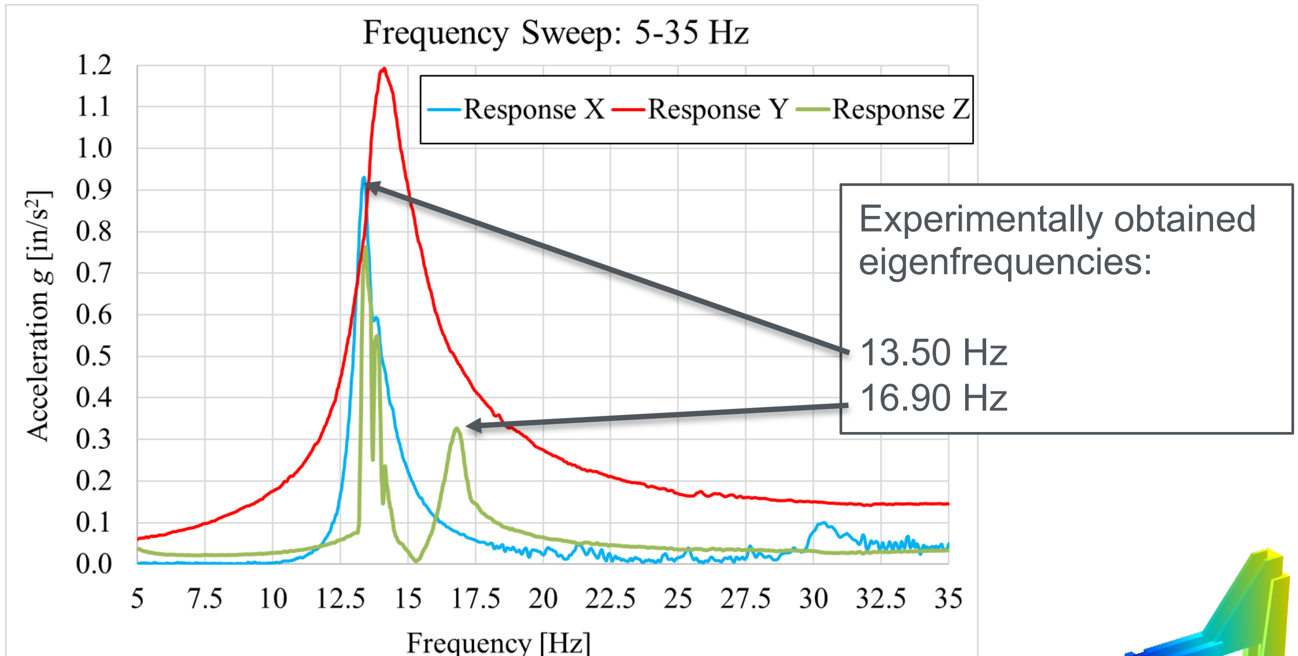


Frequency 34 Hz

Accomplishments: Experimental Results

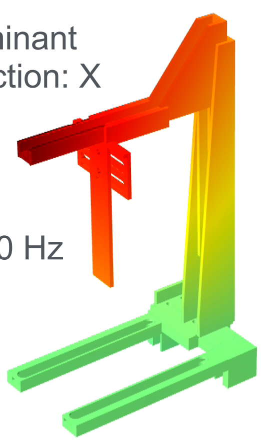
- Initial Design: 3D printing plastic material (Ultem 9085) with steel plates





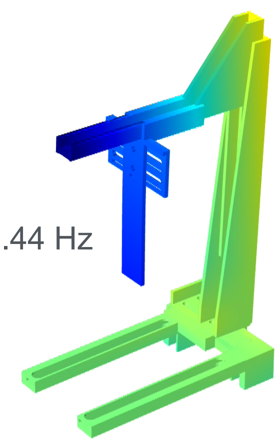
Dominant direction: X

13.60 Hz



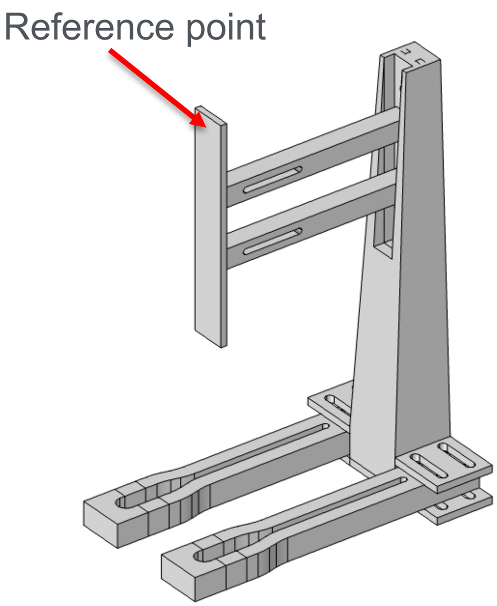
Dominant direction: Z

17.44 Hz



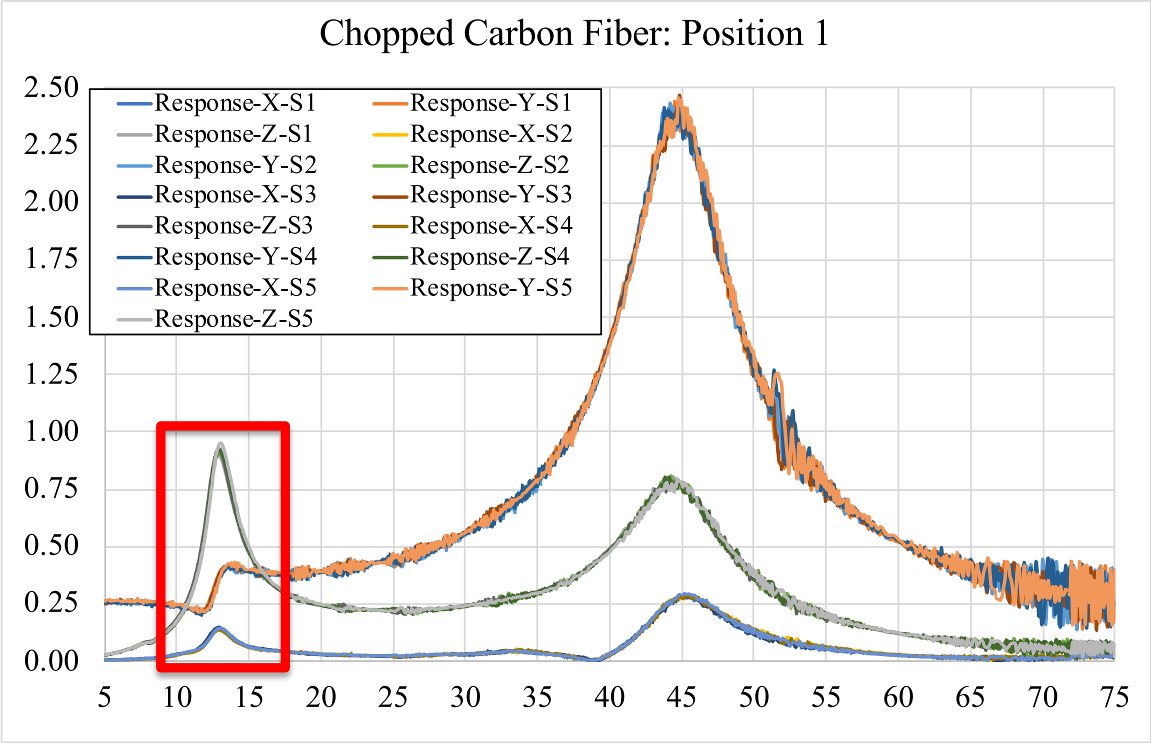
Accomplishments: 3D Brackets with Chopped Carbon Fibers

Advanced Design: 3D printing plastic material reinforced by chopped carbon fibers



3D printing plastic material reinforced by chopped carbon fibers

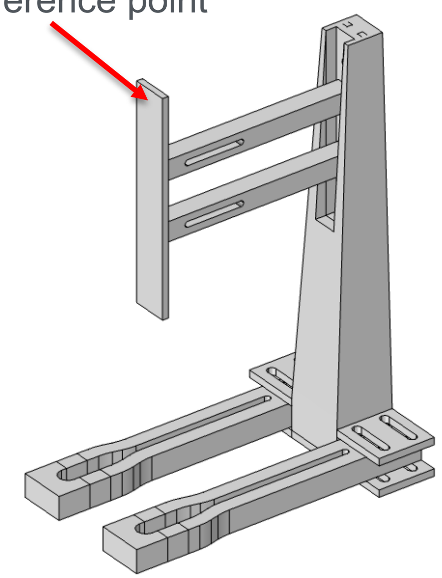
Frequency sweep from 5 Hz to 75 Hz



Accomplishments: 3D Brackets with Continuous Carbon Fibers

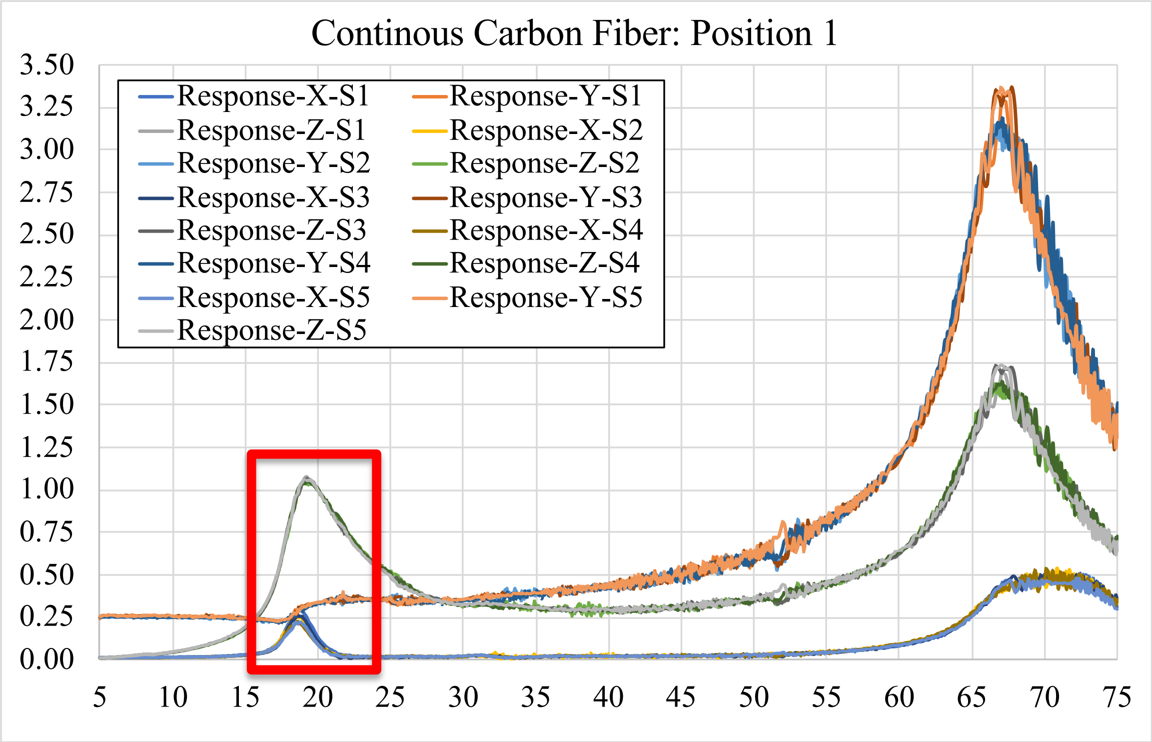
Advanced Design: 3D printing plastic material reinforced by continuous carbon fibers

Reference point

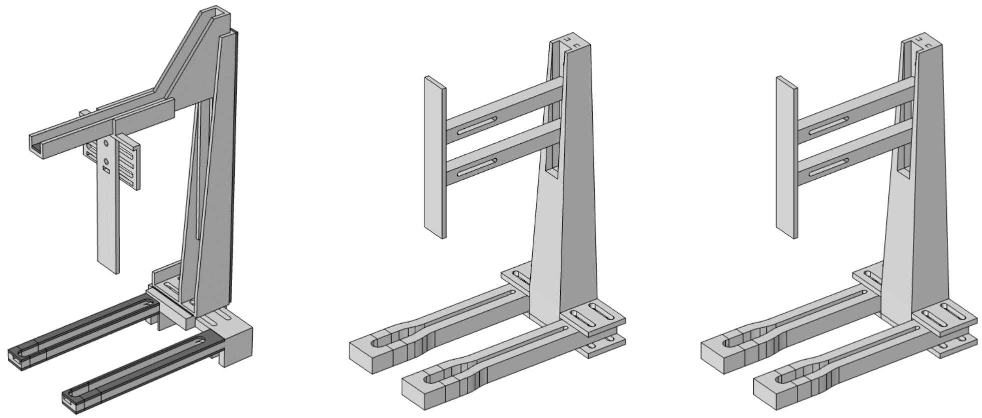


3D printing plastic material reinforced by continuous carbon fibers

Frequency sweep from 5 Hz to 75 Hz



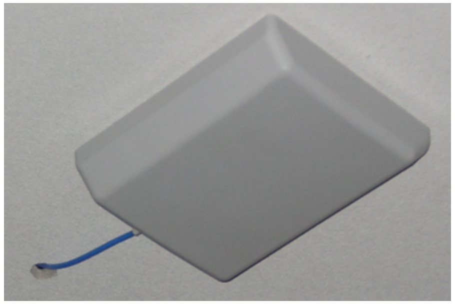
Accomplishments: Bracket Comparison



Characteristics	Initial Design Ultem 9085+Steel	Chopped carbon	Continuous carbon
Density (lb/in^3)	0.05 (Ultem 9085)	0.04	0.05
Stiffness (ksi)	290 (Ultem 9085)	522	7250
Weight (lb)	3.8	1.5	1.7
Natural frequency (Hz): Numerical	13.60	34.36	91.83
Natural frequency (Hz): Experimental	13.50	10 to 15	~20

Higher frequencies are obtained numerically than experimentally. Possible reason: 3D printing infill percentage and infill geometry.

Distributed Antenna System



Antenna

Distributed Antenna System is set-up in the Human System Simulation Laboratory to support transmission of information at 900 MHz

Technology Impact

- *Advances the state of the art for nuclear application*

Analog Technologies

Limit Switches

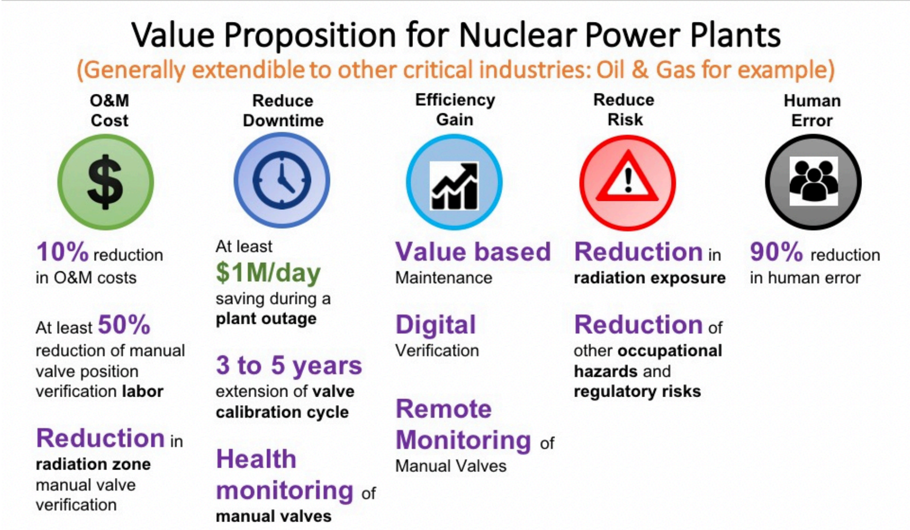
Shaft Encoder

Proximity Readers

Digital Technologies	Recertification & Valve Disassembly	All Manual Valve Types	Radiation Tolerant	Communication Protocol	Continuous VPI	EMI/RFI Certification
INL Wireless VPI	No (Not Required)	Yes	Yes*	Securely Supports Most Wireless Communication	Yes	Yes
Emerson	Yes	No	No	Wireless HART	No	No
ELTAV	Yes	No	No	IEEE 802.15.4	No	No
Honeywell	Yes	No	No	Proprietary	No	No
Westlock	Yes	No	No	IEEE 802.15.4	No	No

Technology Impact

- *Impacts the nuclear industry*
  - *Value-based maintenance*
  - *Reduction of human errors*
  - *Efficiency gain and cost reduction*
  - *Minimize risk and downtime*



- *Supports the DOE-NE research mission*
  - *Long-term economical operation of existing fleets*
  - *Automation of manually performed operations*
  - *Availability of online data that otherwise won't have been available or would have be difficult to collect*
- *Will be commercialized*
  - *INL team is working with Exelon on identifying potential vendors to support commercialization of the wireless VPI sensor system*

Conclusion

- Based on inputs from plant sites engineering, INL advanced the design of the brackets
- INL have established a DAS at Human System Simulation Laboratory
- Tested the transmission of valve position over 900 MHz

- Going forward, INL will complete the bracket design for butterfly valves
- Install, test, and validate the design in nuclear plant sites

- *Vivek.Agarwal@inl.gov for any additional questions on the project.*

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