Sound Speed in 3D Printed Material

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Mission

Our team was commissioned by Los Alamos National Laboratory (LANL) to investigate the speed of sound in carbon doped additive manufacturing materials.

- Embed controlled concentrations of carbon fillers into 3D-printed materials with fixed geometry.
- Analyze and characterize sound speed in carbon-doped samples, emphasizing stringent quality control..
- Develop predictive models to estimate:
  - Carbon filler levels from measured sound speed.
  - Sound speed based on known carbon filler percentages.
- Insights will support design optimization for materials requiring precise acoustic properties.

Methodology and Process Development

- Perform multiple through-transmission ultrasonic tests on 1-inch cube specimens to ensure accuracy in developing a calibration curve.
- Establish a repeatable, controlled process for printing and testing to minimize potential errors.
- Use an enclosed 3D printer to enhance print quality and consistency.
- Calculate speed sound with time of flight in a peak-to-peak method and the the dimensions of the testing specimen.
- Develop a calibration curve to analytically represent the relationship between sound speed and carbon content in the doped filament.
- Leverage the established calibration curve to assess carbon content in future, unknown filament samples through ultrasonic testing.

Figure 1. Printed Test Specimens

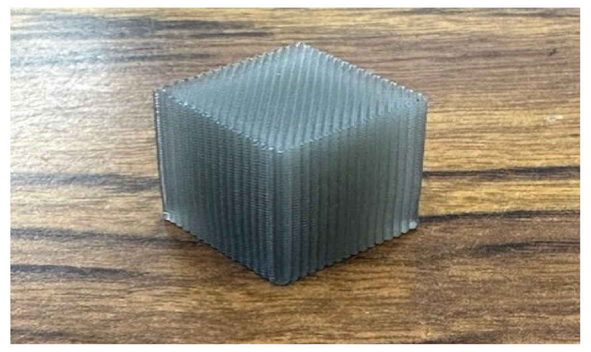

Figure 2. 0% Clear PLA Test Specimen

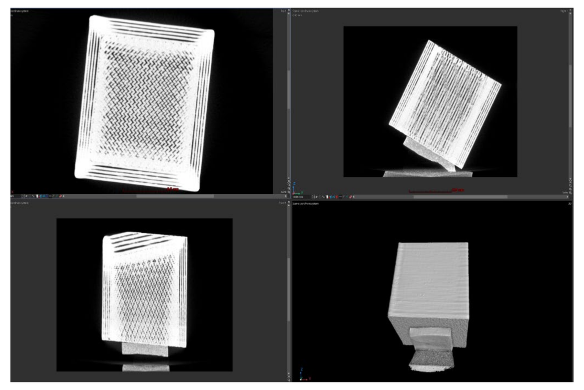

Figure 3. Porous CT Scan

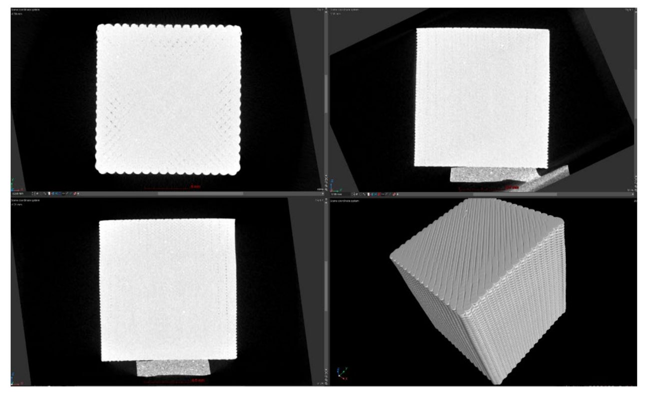

Figure 4. Non-Porous CT Scan

Final Results

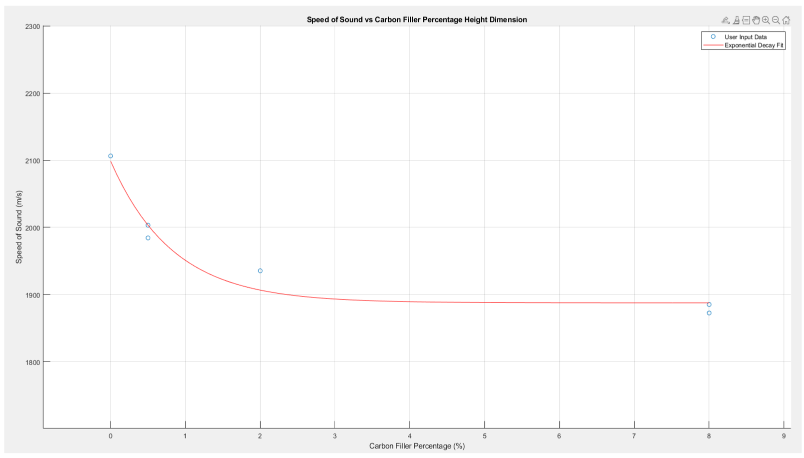

Figure 5. Speed of sound vs. Carbon % Height

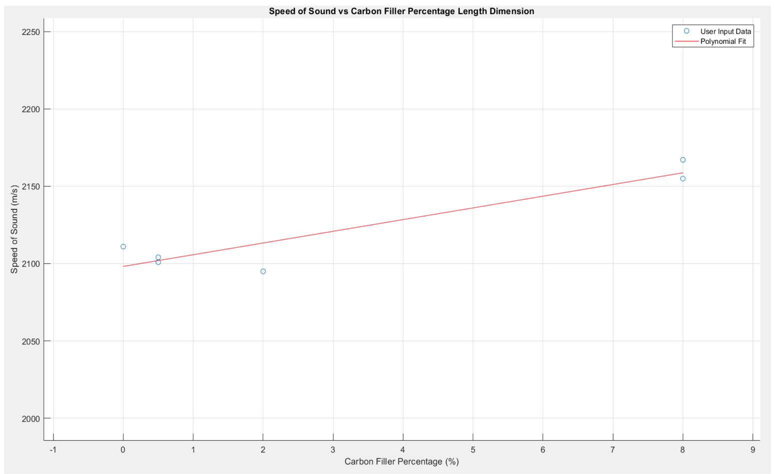

Figure 6. Speed of sound vs. Carbon % Length

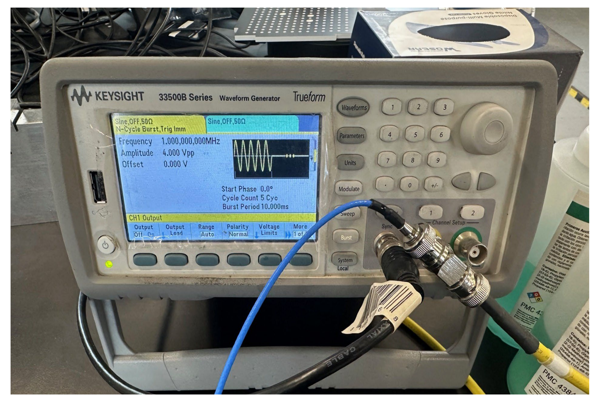

Figure 7. Keysight 33520B - Trueform Waveform

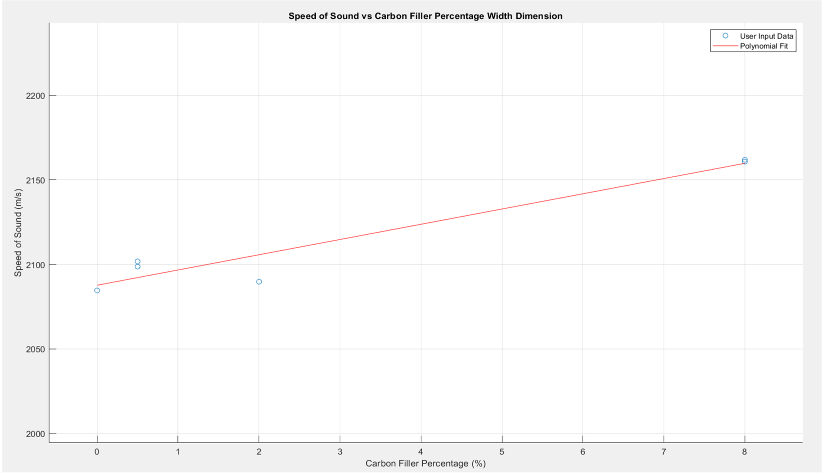

Figure 8. Speed of sound vs. Carbon % Width

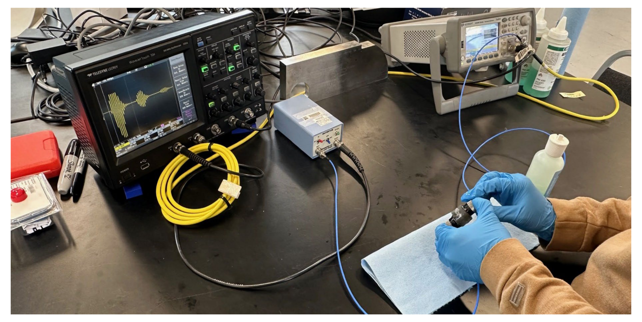

Figure 9. Acoustics Testing Configuration

Figure 10. Phoenix V|tome|x S 240 CT Scanning

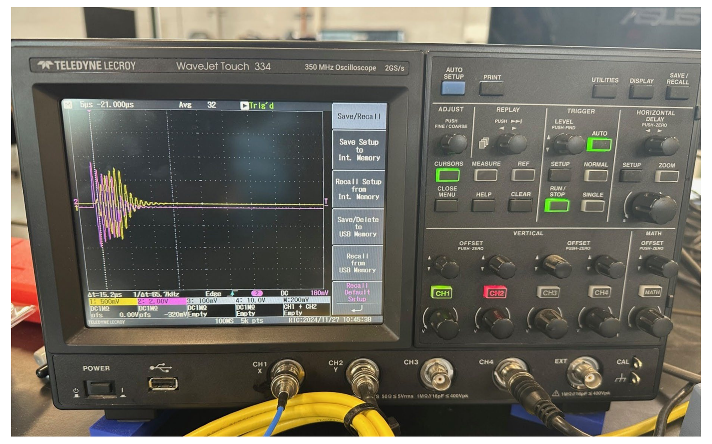

Figure 11. Teledyne Oscilloscope

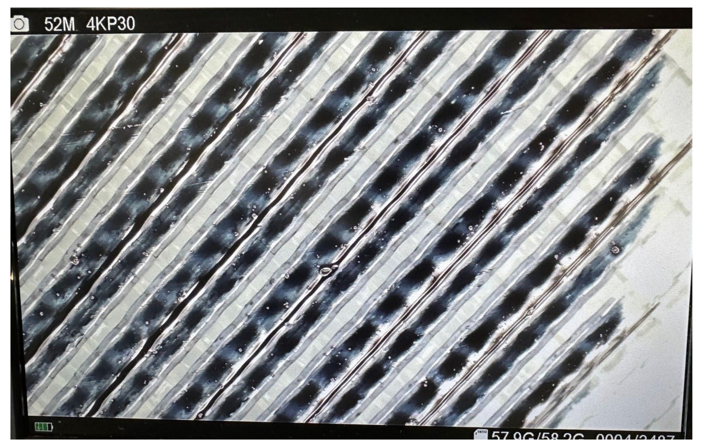

Figure 12. Microscope View Under Extrusion

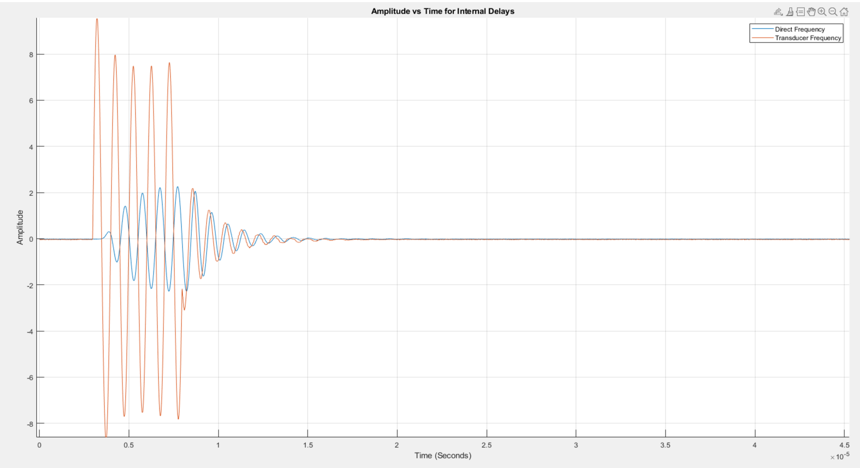

Figure 13. Internal Equipment Delays

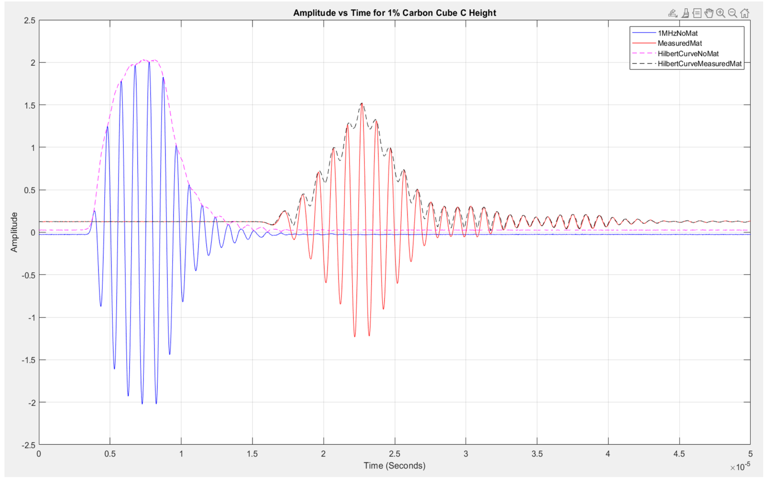

Figure 16. 1% Carbon Height Measurement

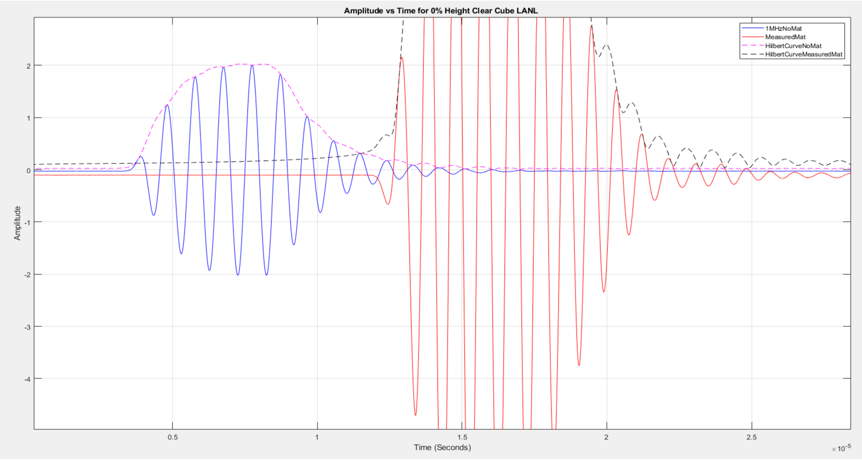

Figure 14. 0% Carbon (PLA) Height Measurement

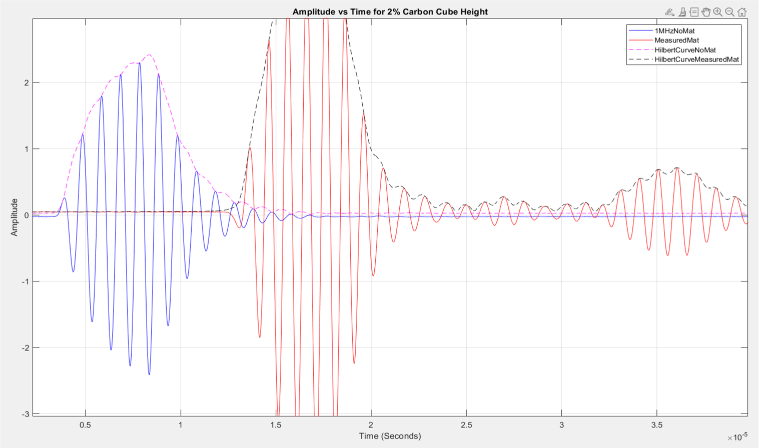

Figure 17. 2% Carbon Height Measurement

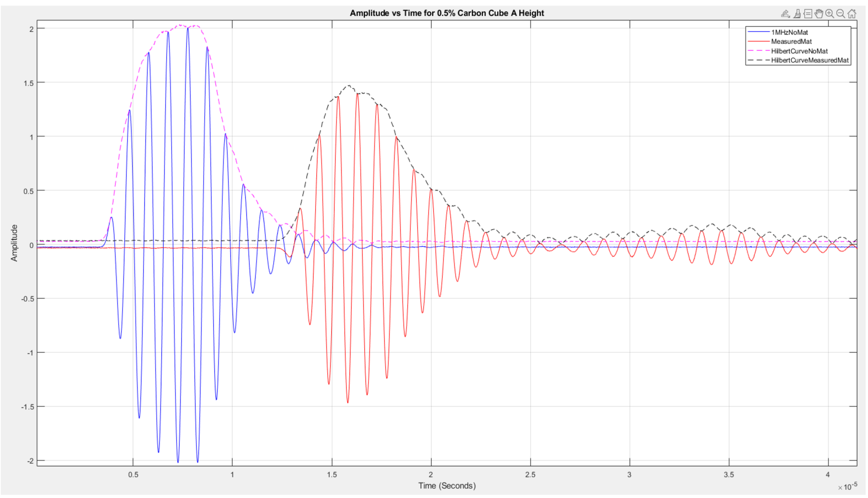

Figure 15. 0.5% Carbon Height Measurement

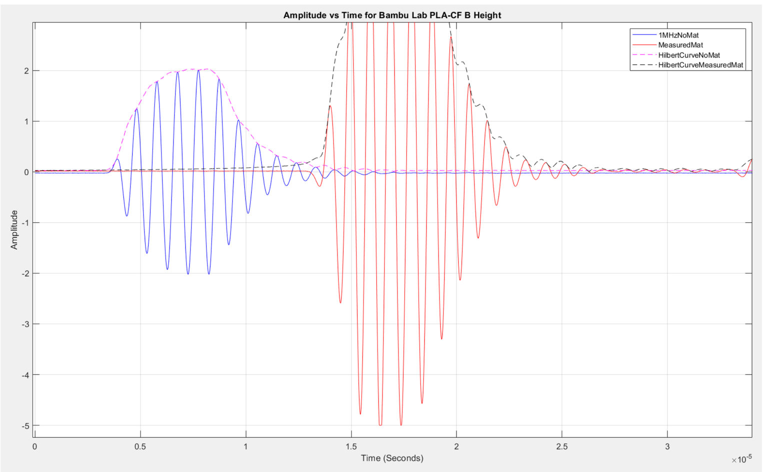

Figure 18. Bambu Lab PLA-CF Height Measurement

Technical Background and Experimental Setup

- Nondestructive Evaluation (NDE) / Nondestructive Testing (NDT): Techniques for detecting material defects and assessing additional properties without causing damage to any testing specimens.
- Ultrasonic Testing (UT): High-frequency sound waves (0.5-15 MHz) are used in methods such as pulse-echo, through-transmission, and phased array (PAUT) to ensure high precision and reliability.
- Equipment Utilized:
  - Teledyne LeCroy WAVEJET TOUCH 334T Oscilloscope
  - Keysight 33520B - Trueform Waveform / Function Generator
  - Olympus longitudinal transducers (0.5-5 MHz)
  - D12-Gel coupling agent
  - Olympus Preamplifier 5660C Preamp
  - Bambu Lab X1C 3D Printer
  - Tomlov Microscope
  - Phoenix V|tome|x S 240 CT Scanning
- Data Analysis: Conducted using advanced MATLAB data processing for ultrasonic test data and calibrating material properties.

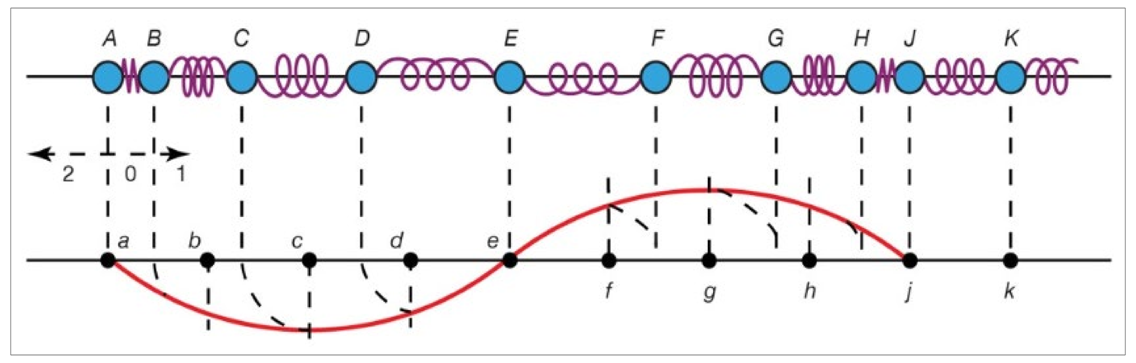

Figure 19. Through Transmission Wave

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