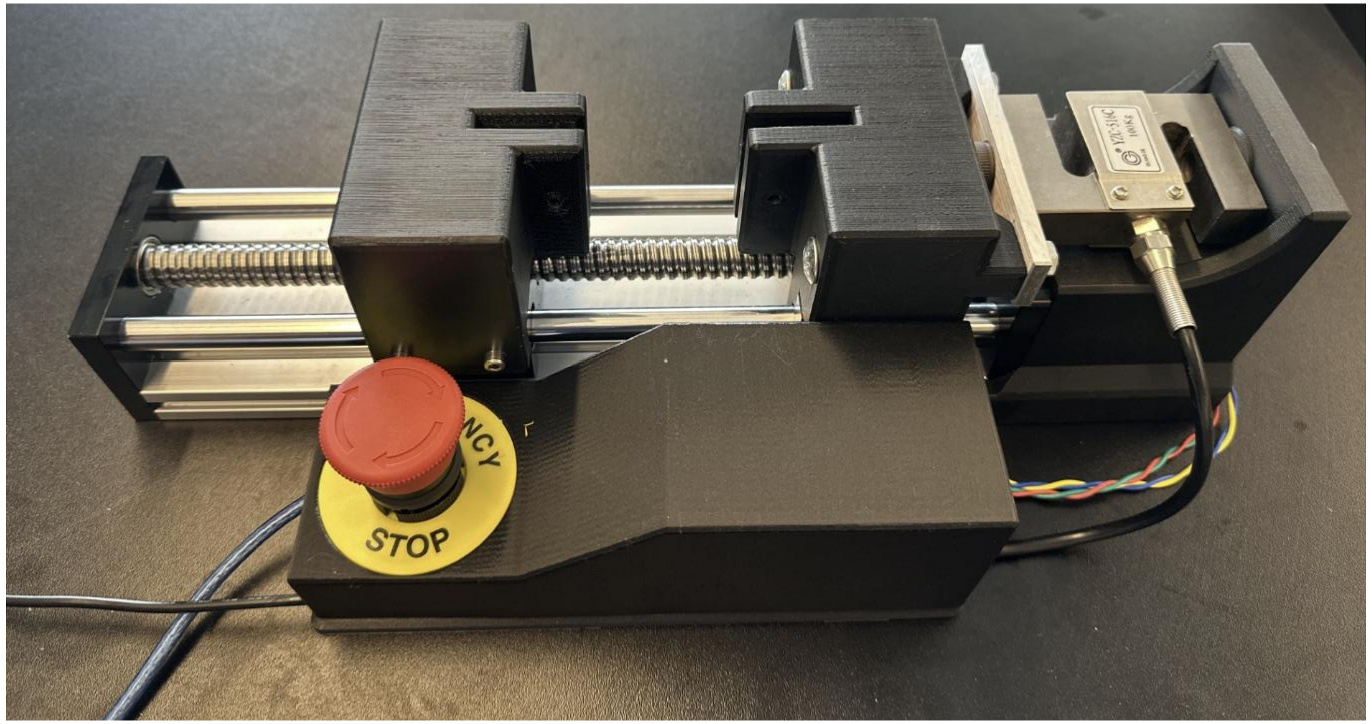


Tensile Tester Design, Implementation, and Calibration

A comprehensive overview of the custom tensile tester design, implementation challenges, and performance results for material testing applications. This details the development process, technical specifications, and testing data from prototype to calibrated system.

Project Overview

Current Status

All hardware features are implemented with the mechanical setup fully assembled. The system is capable of running the stepper motor and gathering readings from the load cell.

Several firmware bugs remain that require resolution before full functionality is achieved. These primarily affect consistent operation and calibration.

Work

- Complete firmware debugging and calibration
- Finalize frontend software (expected completion next week)
- Implement Kalman filtering for improved signal quality
- Conduct final validation testing on standardized samples

Design Goals Achieved

The tensile tester successfully measures force over time (blue line) and position over time (red line) during material testing, providing the core data needed for mechanical property analysis.

Resolution of approximately 50 μm has been achieved for position measurements, allowing for precise strain calculations.

Hardware Challenges & Solutions

Power Supply Limitations

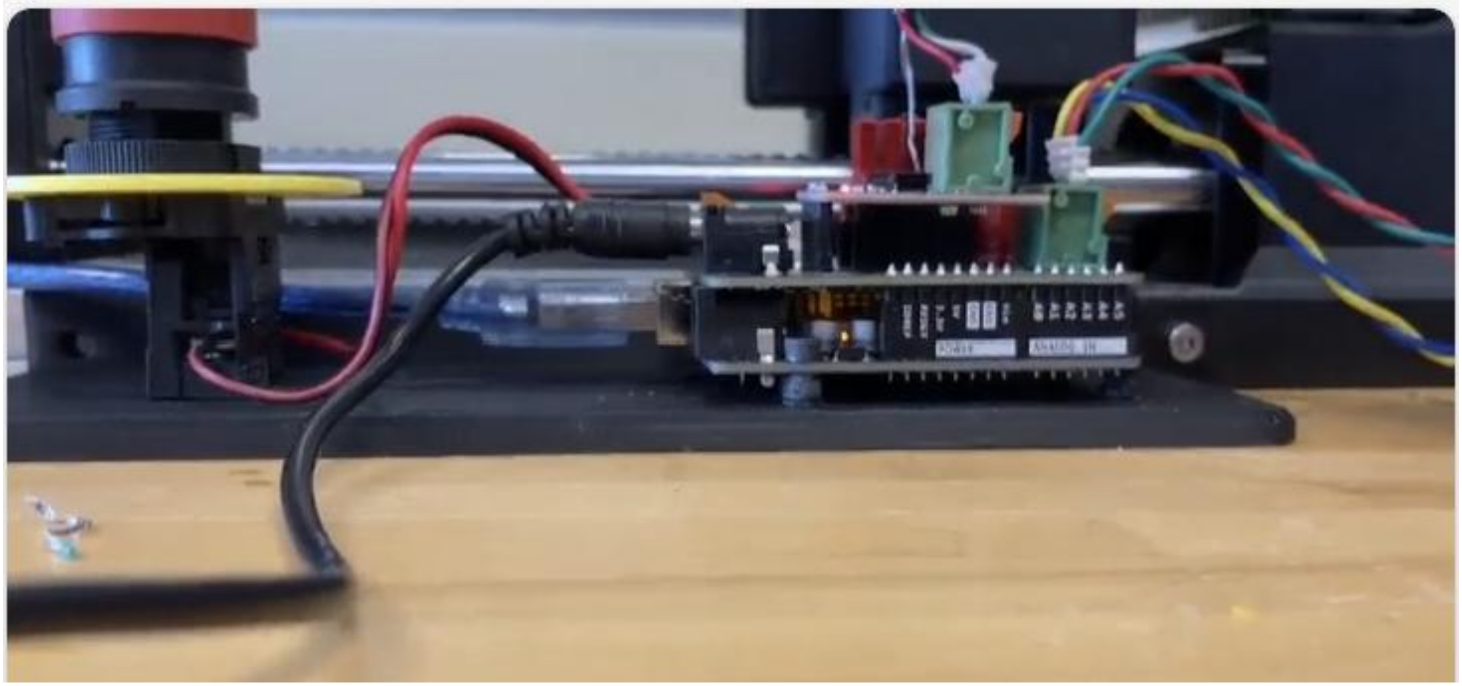
Testing revealed that the current power supply, rated for 3A RMS, cuts out during peak loads:

- Motor current had to be limited to 2.7A RMS to prevent cutouts
- Even at reduced current, occasional cutouts still occur
- When cutouts happen, the driver is completely disabled and requires a full device reset

Recommendations

Replacing the current power supplies with units rated for 5-6A would:

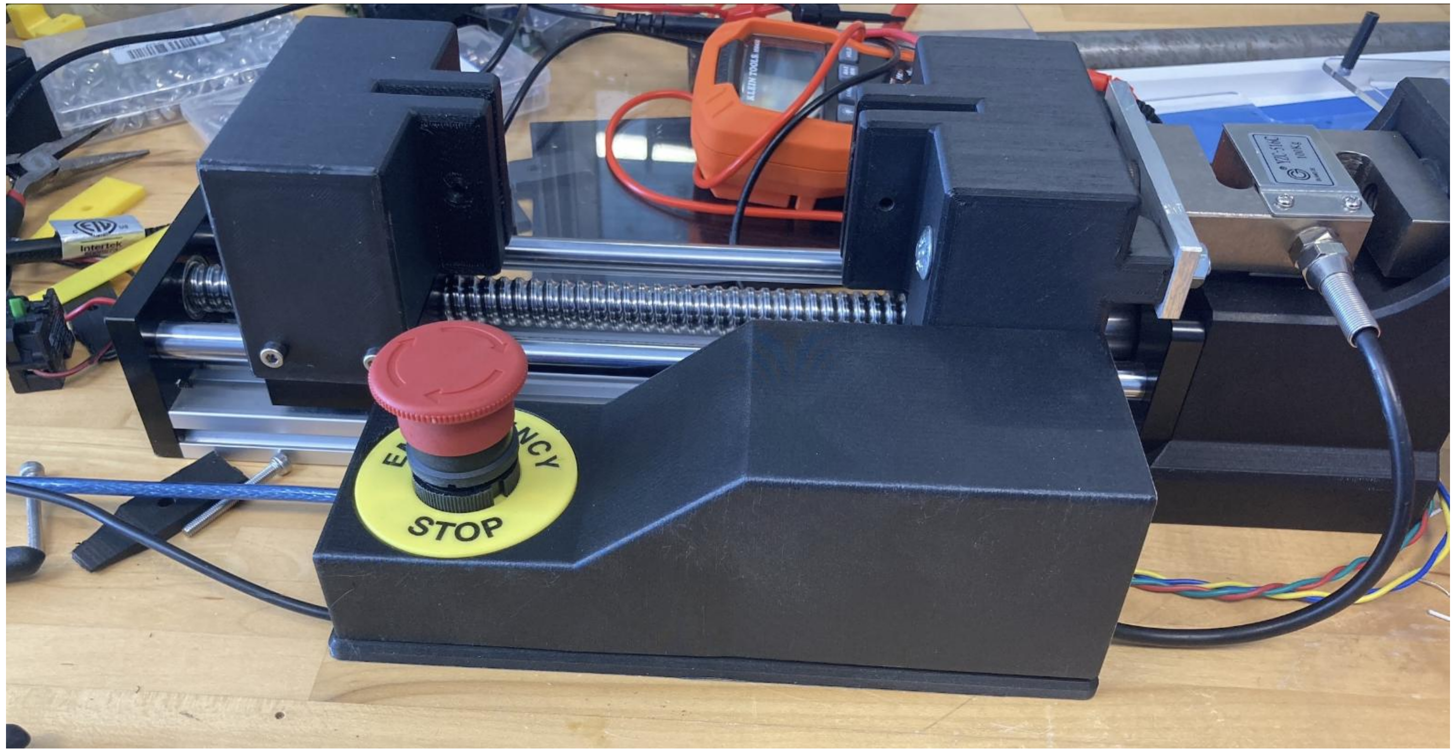
- Provide necessary headroom for current spikes
- Enable testing of materials requiring higher forces
- Extend device lifespan by reducing continuous load percentage
- Eliminate frustrating mid-test failures requiring full system restarts



Safety Enhancements

An enclosure has been designed and 3D printed to prevent students from contacting electronic components during operation. The design:

- Covers all high-voltage components
- Maintains accessibility for maintenance
- Left side intentionally open for easier printing, but positioned to prevent accidental contact
- Can be easily modified if full enclosure is deemed necessary



Key Observations from Material Testing

Material Quality Impact

Mosaic PLA exhibited unexpected ductility compared to typical PLA behavior, requiring only 350N to break rather than the calculated 930N based on Granta values.

This significant deviation suggests that additives used to create the matte finish substantially affect mechanical properties, making it a poor representative sample of typical PLA behavior.

Environmental Effects

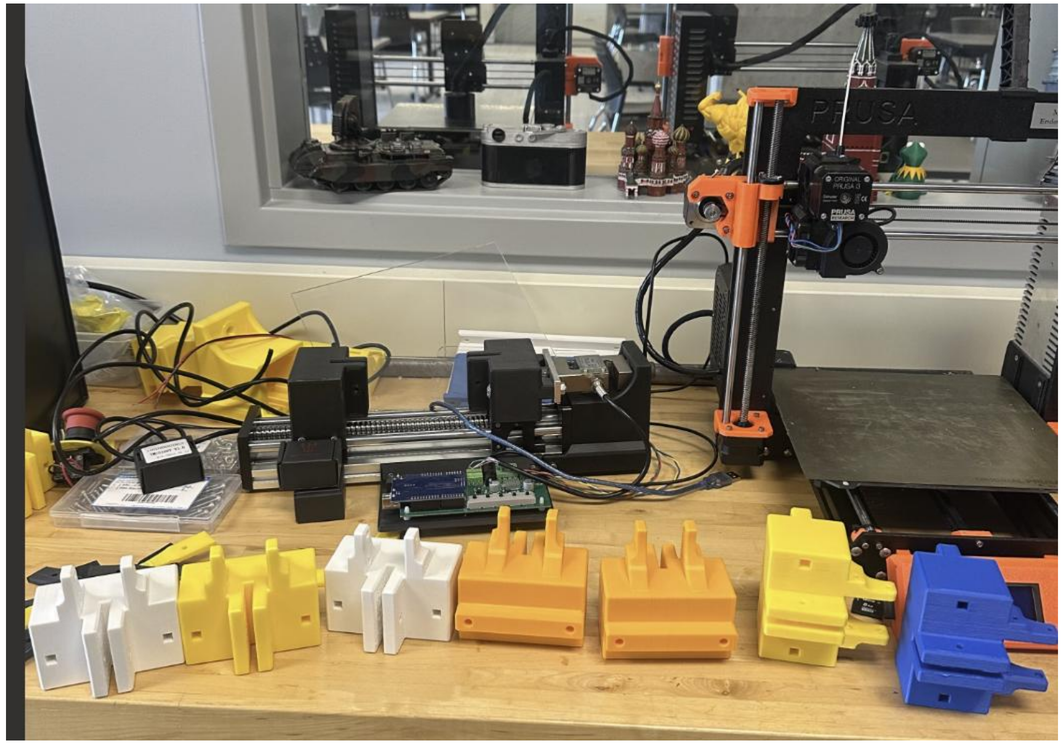
Despite moisture exposure in the Mosaic ABS (evidenced by bubbles), it performed relatively well at nearly 88% of theoretical strength (500N vs. 570N).

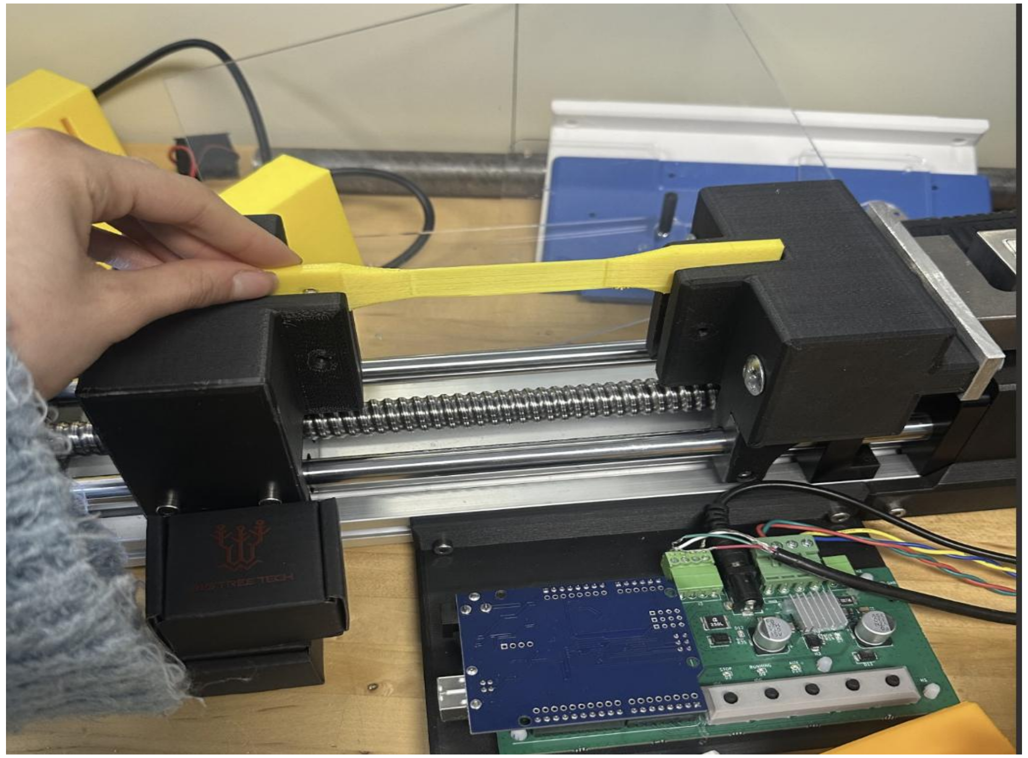
The ABS exhibited a surprisingly brittle fracture pattern with some white stretch marks at the fracture point, indicating a mixed failure mode.

System Performance

The 900N software limit prevents damage to the tester when testing stronger materials.

Signal noise remains low (~1N typical, 6N peak) without Kalman filtering, indicating good baseline sensor performance.





Software Interface Development

1

User Controls

The software interface includes both jog buttons and a precise GoTo function:

- Jog buttons move the test head in small increments but are currently limited by MATLAB's serial communication speed
- GoTo function allows direct positioning with ~50 µm resolution by entering position in millimeters
- Adaptive design accommodates future physical changes as long as hole positioning remains consistent

2

Data Handling

Recent software enhancements focus on usability and flexibility:

- Implemented save dialog allowing users to choose file location and name
- Prevents data from being saved to restricted Program Files directory
- Reduced test stop threshold from -200N to -100N to accommodate more ductile materials
- Added automatic stop at 900N to prevent device wear

3

Installation Requirements

Software distribution considerations:

- Packaged as installer with MATLAB Runtime included for standalone operation
- Windows version complete; Mac version in development
- Recommending installation during Week 1 alongside Granta to prevent lab time delays
- Designed to function independently of institutional MATLAB licenses

Materials Testing: Uncalibrated Results

Initial testing was conducted before full calibration to validate system operation. These results should be viewed as preliminary.

Material	Property	Test Result	Granta Reference
PLA (Mosaic)	Yield Strength (σy)	125.79 MPa	45-72 MPa
	Ultimate Tensile Strength	137.26 MPa	45-72 MPa
	Young's Modulus (E)	3.46 GPa	2.4-3.6 GPa
ABS (Mosaic)	Yield Strength (σy)	172.83 MPa	20.6-44.1 MPa
	Ultimate Tensile Strength	194.58 MPa	30-50 MPa
	Young's Modulus (E)	3.48 GPa	2-2.9 GPa
PLA (Value)	Yield Strength (σy)	261.05 MPa	45-72 MPa
	Ultimate Tensile Strength	292.12 MPa	45-72 MPa
	Young's Modulus (E)	4.28 GPa	2.4-3.6 GPa

The uncalibrated results showed significant discrepancies from expected values. Young's Modulus measurements were reasonably close to reference ranges, but strength values were considerably higher than expected. This validated the need for proper calibration before the system could be used for accurate materials characterization.

Technical Implementation Details

Hardware Specifications

- Stepper motor with maximum 3A RMS current rating (currently limited to 2.7A)
- Load cell with force measurement capability up to 900N
- Position resolution of approximately 50 μm
- Custom 3D printed enclosure for electronics protection
- Full mechanical setup designed for educational laboratory use

Firmware Features

- Precise stepper motor control with adjustable current settings
- Real-time load cell measurement and processing
- Auto-stop functionality at 900N to prevent system damage
- Reduced test stop threshold (-100N) for testing ductile materials
- Automatic resetting of device when test completes

Software Capabilities

- Cross-platform support (Windows complete, Mac in development)
- Bundled with MATLAB Runtime for standalone operation
- Real-time graphing of force and position data
- File save dialog for custom data storage locations
- Position control via jog buttons and direct GoTo commands
- Automatic calculation of material properties (σy, UTS, E)

Documentation

- Materials Research Report completed
- Operating manual in development (includes troubleshooting, schematics)
- Assembly documentation planned for next batch of testers

Tasks Done

Power Supply Upgrade

Replace current 3A power supplies with 5-6A rated units to:

- Eliminate mid-test cutouts that require full system restart
- Enable testing at full motor capacity (3A RMS)
- Support testing of materials requiring higher forces
- Reduce continuous load percentage for extended component life

Signal Processing

Optional Kalman filtering implementation if noise reduction is needed:

- Current noise levels are acceptable (typically <1N, peak ~6N)
- Filter algorithm is developed but not yet implemented
- Can be added if instructors require smoother data for student analysis

Interface Optimization

Potential improvements to jog button responsiveness:

- Current limitations due to MATLAB serial communication speed
- Possible optimization of communication protocol
- Consider alternative to jog buttons if optimization is insufficient
- GoTo function remains efficient regardless of jog button improvements

Material Testing

Expanded testing with additional materials:

- Test newly acquired Elegoo and ESun PLA brands
- Validate tester performance with standardized samples
- Create comparative database of material properties for student reference
- Develop standardized testing protocols for laboratory use

Results

Immediate Action Items

- Resolved firmware bugs for consistent operation
- Completed the Mac version of the software interface
- Finalized operating manual with troubleshooting steps
- Documented assembly process with photos during next batch construction
- Tested additional material brands (Elegoo, ESun) to validate system performance

Integration

- Coordinated with course instructors for software installation
- Scheduled demonstration session with Bryan Lee
- Developed laboratory protocols for student use
- Upgraded power supply for full deployment

Key Achievements

1 Functional Prototype

Successfully developed a working tensile tester capable of measuring force and position with high precision for materials characterization.

2 Calibrated System

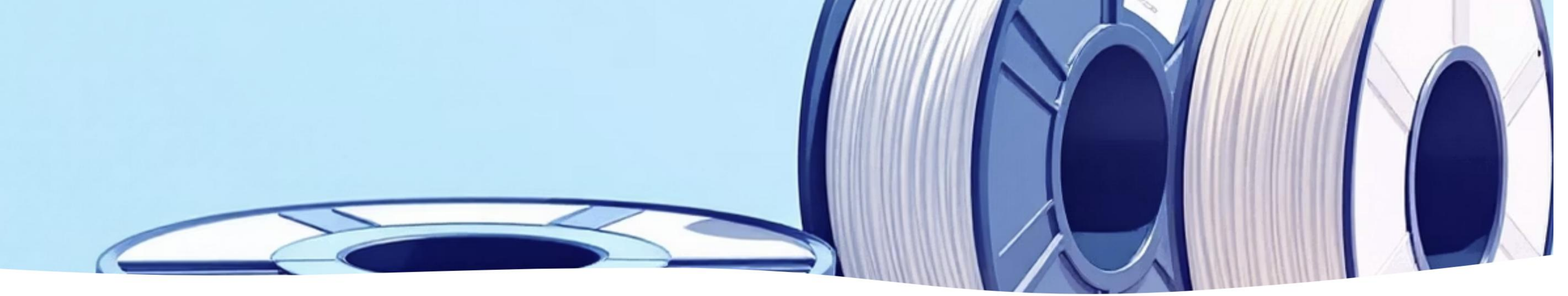
Completed calibration process resulting in measurements that align with theoretical expectations for known materials.

3 Cross-Platform Software

Created standalone software with MATLAB Runtime that will function independently of institutional licenses.

4 Safety Features

Implemented both physical (enclosure) and software (force limits) safety features to protect students and equipment.



Calibrated Test Results: PLA Varieties

23.80...

Mosaic PLA Yield

UTS: 25.76 MPa, E: 668.66 MPa

Lower than expected, broke at <350 N vs calculated 837 N

36.72...

Elegoo PLA Yield

UTS: 37.64 MPa, E: 680.89 MPa

Moderate strength, brittle failure

37.93...

eSun PLA Yield

UTS: 39.38 MPa, E: 722.29 MPa

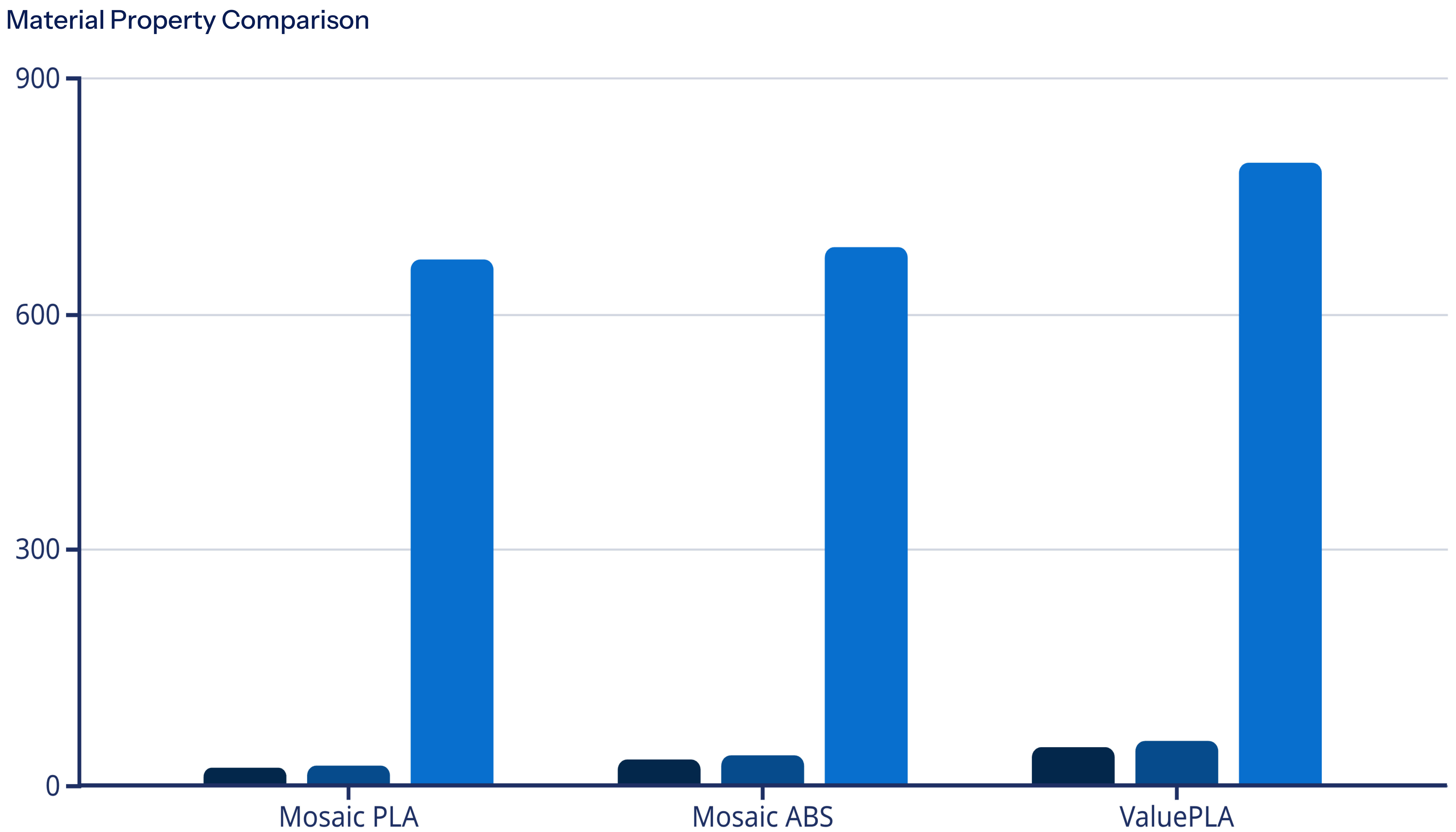
Similar to Elegoo, brittle failure

50.00...

ValuePLA Yield

UTS: 57.70 MPa, E: 792.88 MPa

Aligned with Granta data


Material Property Comparison
900
600
300
0
Mosaic PLA
Mosaic ABS
ValuePLA

Materials Testing: Calibrated Results

Material	Property	Calibrated Result
Mosaic PLA	Yield Strength (σy)	23.8 MPa
	Ultimate Tensile Strength	25.76 MPa
	Young's Modulus (E)	668.66 MPa
Mosaic ABS	Yield Strength (σy)	33.58 MPa
	Ultimate Tensile Strength	37.42 MPa
	Young's Modulus (E)	685.27 MPa
ValuePLA	Yield Strength (σy)	50.00 MPa
	Ultimate Tensile Strength	57.70 MPa
	Young's Modulus (E)	792.88 MPa

Calibration Analysis

After calibration, the results showed more realistic values, though with several notable findings:

- Mosaic PLA performed significantly below typical PLA specifications, suggesting quality issues or additives affecting mechanical properties
- ValuePLA showed better performance but still below calculated expectations, possibly due to previous testing that approached yield strength
- Mosaic ABS performed relatively well despite moisture exposure, achieving close to theoretical values
- Young's Modulus values were consistently lower than reference data across all materials

The calibrated tester showed good accuracy with measured forces:

- Mosaic PLA: ~350N (vs. calculated 930N)
- Mosaic ABS: ~500N (vs. calculated 570N)
- ValuePLA: ~750N (material previously stressed)