Compressive Specimen Holder for Spinal Devices

UC San Diego
JACOBS SCHOOL OF ENGINEERING
Shu Chien-Gene Lay Department of Bioengineering

Team 25: Parker Abramson, Rina Matsuo, Tsubasa Kitada, Abigail Smith

Background

- Spinal Interbody Fusion Surgery uses expandable spinal cages to restore disc height
- Spinal cages expand in x- and z-axis
  → Requires **biaxial validation**

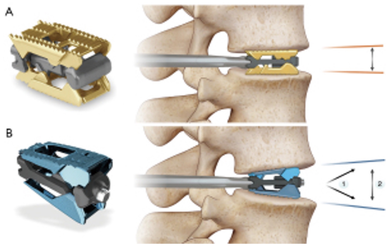


Figure 2. Application of expandable spinal cages [2].

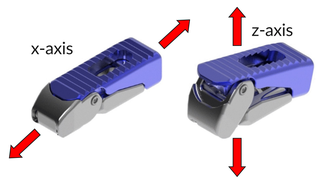


Figure 1. Expandable spinal cages in the x- and z-axis [1].

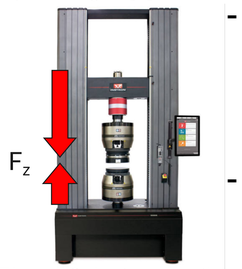


Figure 3. Instron Testing Machine [3].

- Instron Testing machine is limited to one axis testing and biaxial testing machines costs >$100k
- Previous biaxial testing involved benchtop compression from a passive spring fixture

→ **Fails during expansion**

Objectives

To develop a closed-loop compression testing system capable of:

1. **Maintaining a constant load** on expandable spinal cages during mechanical testing
2. Exerting up to **450 lb of force** on the cage
3. Enable **biaxial compression** when used in conjunction with the Instron Machine

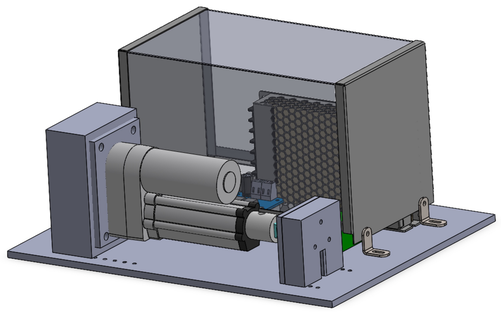


Figure 4. CAD model of compressive testing fixture w/ protective circuit enclosure.

Experimental Design

Develop a **Proportional-Integral-Derivative (PID)** controller connected to a force display

- Consider Kp (ratio of output change to input error), Ki (long-term error correction factor), and Kd (to react to changes in error)

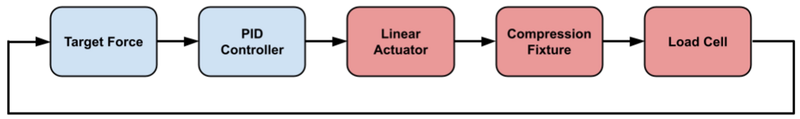
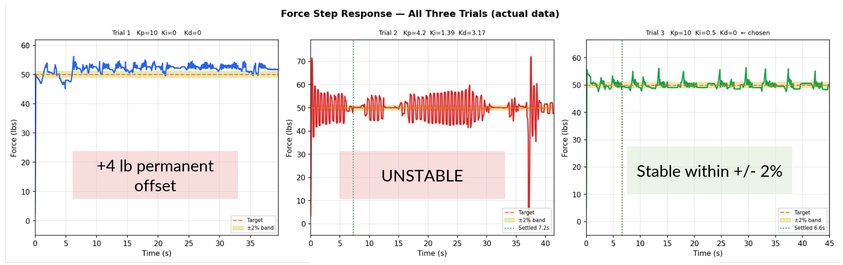


Figure 5. Control system block diagram demonstrating the signal flow from the initial target force input through the physical compression fixture.



Selected gains: $K_p = 10, \quad K_i = 0.5, \quad K_d = 0$

Figure 6. Force step response trials demonstrating tuning phases: (a) steady-state error, (b) instability, and (c) optimized stability.

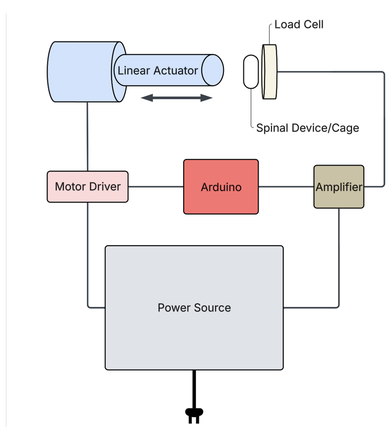


Figure 7. Block diagram of the closed-loop PID control system architecture.

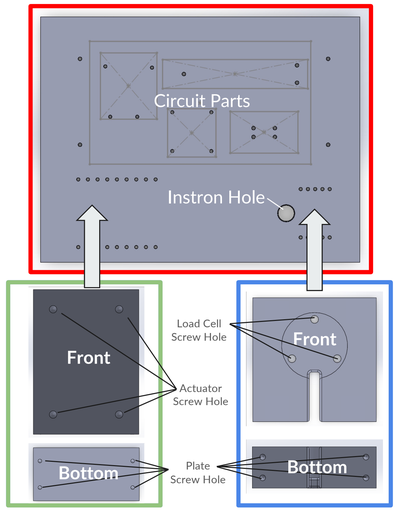


Figure 8. Aluminum 6061 base plate layout illustrating mounting locations for testing and circuitry components.

Circuit Components:

Logic: Arduino Uno
Power: Meanwell 12V Supply
Motor drive: Cytron SHIELD MD10
Compression: 500lb Linear Actuator
Feedback: Transducer Techniques LBO-500 Load Cell
Signal Amplify: Transducer Tech LCA-RTC Amplifier

Results

- Force measurement calibrated, easily recorded, and plotted
- Demonstrates sustained target force during both extraction and contraction
- **Force sustained** within 5lbf: ±5% of target
- The noisiest fluctuations are due to manual handling, not PID error

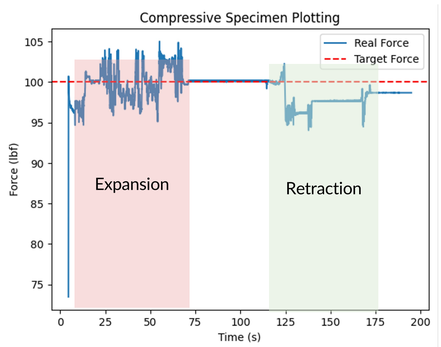


Figure 10. System performance demonstrating sustained target force within 5 lbf during dynamic testing.

Conclusions + Future Directions

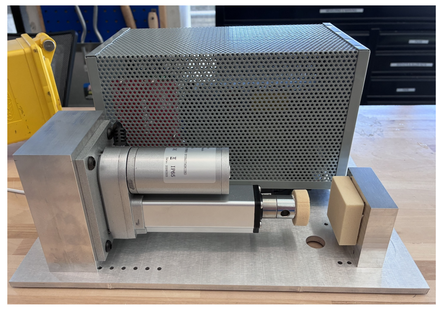


Figure 9. Final manufactured closed-loop testing system loaded with a sawbone spinal cage.

Fabrication:

- Aluminum 6061 frame
- Adjustable positions
- Sawbone spinal cage holders between actuator and load cell
- Enclosure for fragile and dangerous circuit parts at the back of the frame
- Circuit controlled by connection to Arduino through permanent USB-C cord

Future Direction based on Current Limitations:

- Mount loading cell in adaptive (instead of rigid) holder
- Install small display for device control

Acknowledgements & References

ORTHOFIX®

Mr. Zac Dooley, Dr. Alyssa Taylor

[1] Orthofix, "Explorer TO," orthofix.com.
[2] K. Jitpakdee et al., "Expandable cages... following MIS TLIF," J. Spine Surg., vol. 10, 2024.
[3] Instron, "Universal Testing Systems," instron.com.