Automated Climbing Robot for Steel Assembly

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Climbing Clankers

Introduction

- Ironworkers (construction) have one of the **top 10** most dangerous jobs[1]
- Ironworkers International have identified **12 workplace vulnerabilities**, including falls from tall heights[1]
- **1075 of 5283** occupational fatalities were in construction[2]
- Improve safety and work quality through automation
- Combine developments in climbing robotics and automatic bolting

Methodology

Manufacturing Methods

The prototype was fabricated using a combination of:

- **3D printing (PLA)** for lightweight and complex geometries
- **Waterjet cutting** for aluminum plates
- **Laser cutting** for mounting and electronics plates
- **Manual machining and assembly** for frame and integration

Design Tolerance

The system requires precise alignment for successful operation:

- Hole alignment tolerance: ±2 mm
- Clearance from 3D printed parts: ~0.015 in
- Bearing press-fit tolerance: ~0.001 in

Tolerances have been refined iteratively to ensure proper fit and smooth assembly.

Motor Control

The system relies on semi-closed loop control using a combination of sensing and control strategies:

- Motor encoders for closed-loop speed control and incremental positioning
- Current sensing as a proxy for torque in the fastening system
- Limit switches and photoelectric sensors for alignment and checkpoint detection

Design

System Overview

Locomotion – climbs vertically using wheel traction
Fastening – installs and tightens bolts
Structure/Frame – supports all components
Electronics/Control – powers and controls the system

Target Specifications

- Climbing speed: **≥ 0.10 m/s**
- Bolt torque: **8–12 Nm** (max 16 Nm)
- Cycle time: **< 15 seconds per bolt**
- Alignment Accuracy: **±2 mm**

Factor of safety (slip): **≥ 1.5**

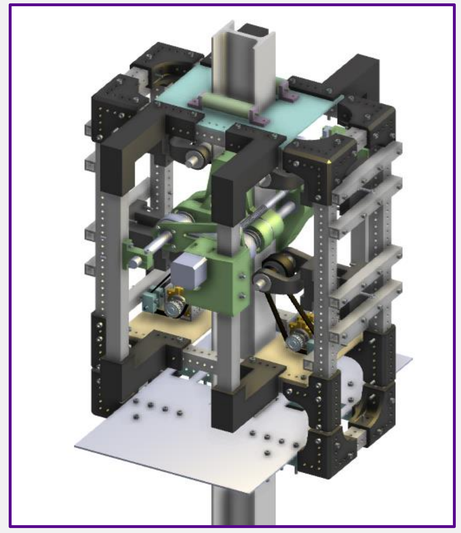


Figure 1: Full Robot Assembly

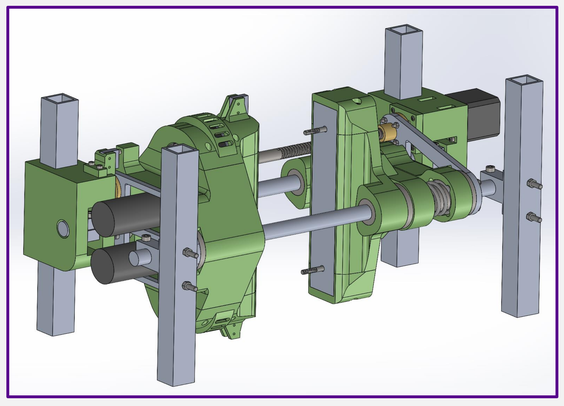


Figure 2: Fastening System

Fastening System

The fastening system uses a **dual-spindle design**:

- Two independent motors tighten bolts simultaneously
- Magnetic plate retention ensures stability during alignment
- Lead screw mechanism enables precise positioning

Torque control is achieved using motor current feedback ensuring bolts are tightened within the required range without damage

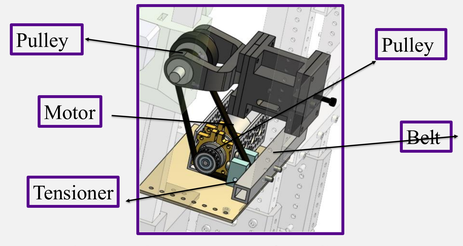


Figure 3: Locomotion System

Locomotion System

The robot uses **spring-loaded wheel modules** to grip the beam.
Springs generate normal force based on Hooke's Law
Friction between wheels and beam enables climbing
Two powered wheels provide motion via belt and pulley system

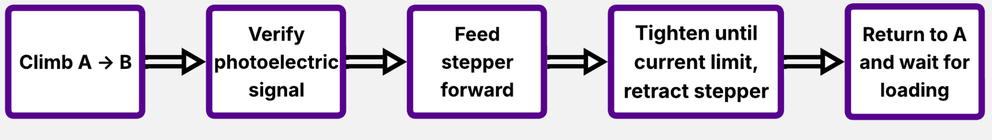


Figure 4: Cycle of Robot Process

Conclusion

Verification

- Run wheel drive system over full length of beam and verify traversal speed
- Read motor current and motor controller logs while bolts are installed on practice holes
- Compress stationary wheel module with 60 lb of force against tensioning component
- Measure positional error between tool and hole center for hole alignment accuracy

Improvements

- Shrink components to minimize operational weight of robot
- Incorporate active clamping mechanisms
- Remove unnecessary parts and further implement cost reduction strategy

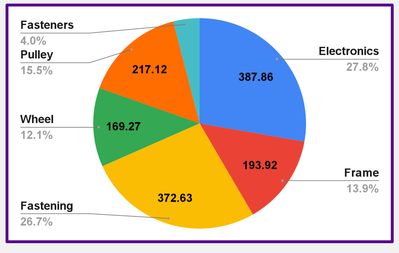


Figure 4: Total Product Cost - $1396.73

References

[1] "Ironworker Construction Accidents in New York City." *Rosenberg, Minc, Falkoff & Wolff, LLP*, https://rmfwlaw.com/practices/construction-injuries/ironworker-accidents
[2] "2023 Saw Most Construction Fatalities in Over a Decade." *GPRS*, 2024, https://www.gp-radar.com/article/2023-saw-most-construction-fatalities-in-over-a-decade

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