Pneumatic Elbow Exosuit for Therapeutic Application

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Mechanical and Aerospace Engineering

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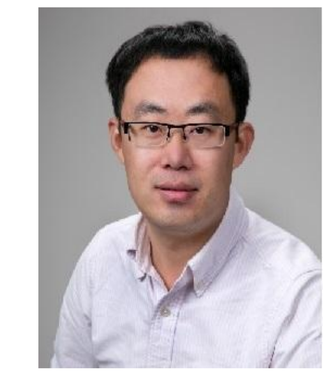

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This work is also supported by the NIDILRR grant 90DPGE0019

This work is supported by the National Science Foundation grant
- CAREER(CMMI 1944655)
- NRI (1830613)
- Future of Work (2026622)

Abstract

Existing upper limb actuators focus on aiding humeral elevation and elbow flexion. There exists a largely untapped need for a wearable actuator to assist in elbow extension. The goal of this project was to create a soft wearable actuator for elbow extension to be used for at-home therapeutic applications. The actuator utilizes an inflatable double layer X-shaped design mounted on the user through a customizable hook-loop fastener. The unique nature of the actuator-harness system allows for universal use on either elbow across a range of body types.

Motivation

Causes

- Neuromuscular conditions such as stroke, spinal cord injury, muscular dystrophy and ALS profoundly impact an individual's ability to perform activities of daily living (ADL).
- Approximately 77.4% of stroke survivors experience limitations in upper limb mobility immediately following a stroke [1].
- Elbow injuries themselves are becoming increasingly common, ranking fifth among all bodily injuries [2].

Rehabilitation

- Successfully regaining elbow mobility requires early and often muscular activation during the rehabilitation process [3].
- Current, rigid, actuators, lack compliance in multiple directions which raises concerns of the lasting effects they might have on a joint [3].

Access

- Patients are often limited in the ability to perform rehabilitation exercises by the availability and stamina of physical therapists.
- Most rehabilitation exoskeletons are expensive and tailored to clinical settings.

Fabrication

- The aluminum frame was infilled with a heat-resistant material to ensure that the air chamber and hose channel did not seal and attached to the heat press.
- Once the frame reached 300 degrees Celsius, it was pressed firmly on TPU-coated nylon for 20-30 seconds.

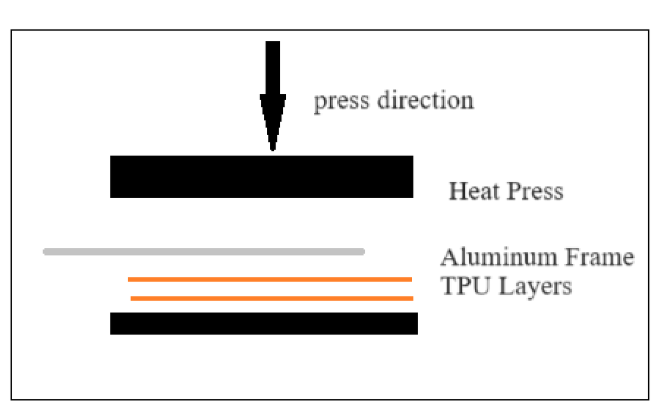


Figure 1: Fabrication Process

Figure 2: Heat Press Machine

- A nozzle was then inserted into the hose channel, sealed with silicon and a hose clamp, and allowed to set overnight.
- The air chamber was then tested to ensure a strong seal and if confirmed, the hook and loop fasteners were added to the actuator.

Control and Sensing

- SP 622 EC-BL-DUp-DV, Schwarzer Precision pump
- Arduino Uno R3 microcontroller
- Honeywell 100PGAA5 pressure sensor
- Load cell compression force sensor attached to test bench

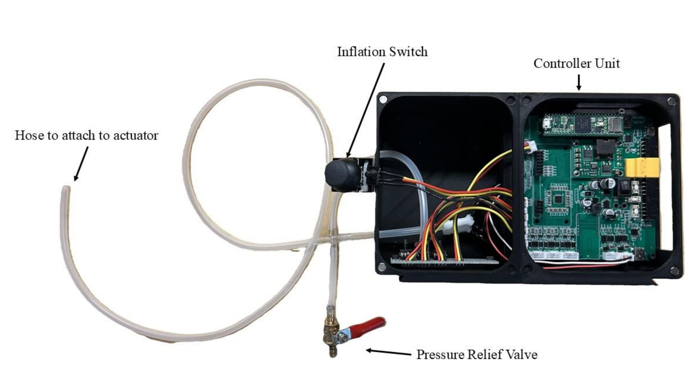
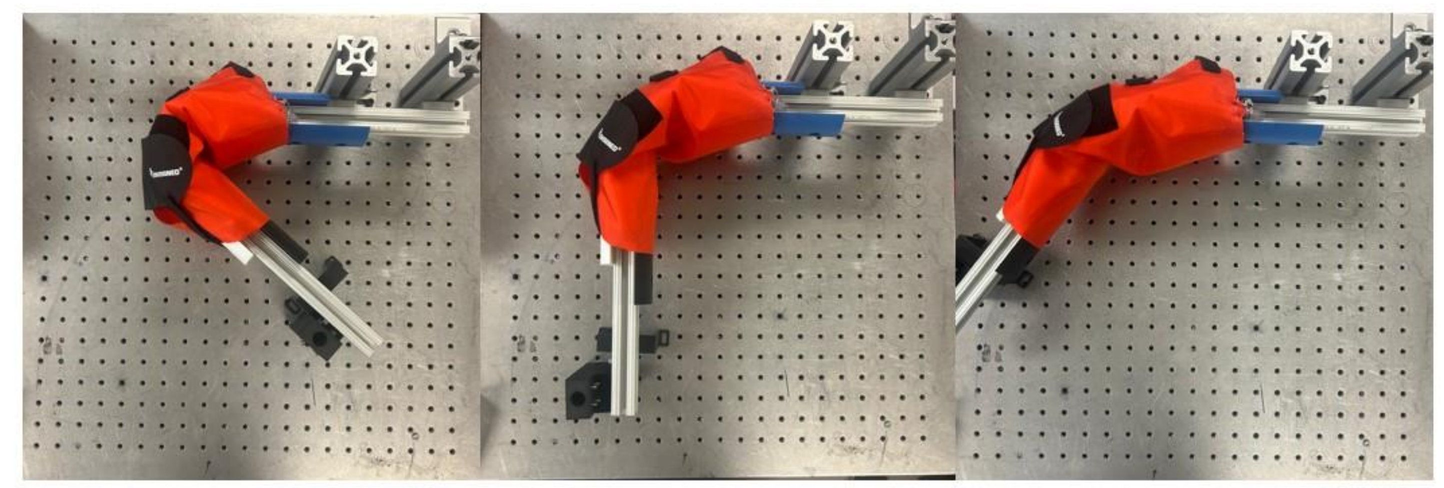


Figure 3: Actuator Controller

Testing

Benchtop Testing

- Force was measured and converted to torque in three different positions to gather a complete profile of assistive torque.
- All actuators were placed in each position and inflated until a pressure of 100 kPa was reached, recording the force read at a frequency of 500 Hz.



45° 90° 135°

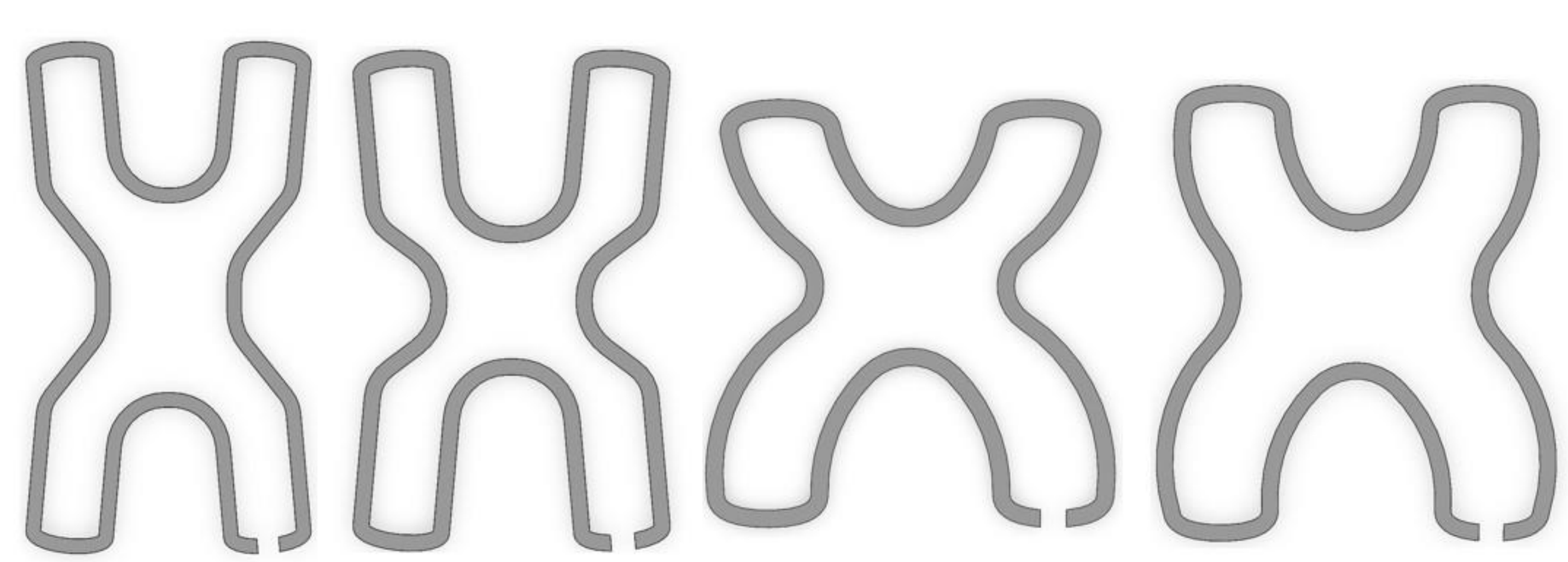
Figure 4: Test Positions

Fit Testing

- After measuring torque, we fitted each actuator and ran through a range of common elbow extension movements including opening doors and placing items down.

Figure 5: Real World Testing

Frame Evolution



V1 V2 V3 V4

Figure 6: Side-by-Side Frame Comparison

References

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Results & Discussion

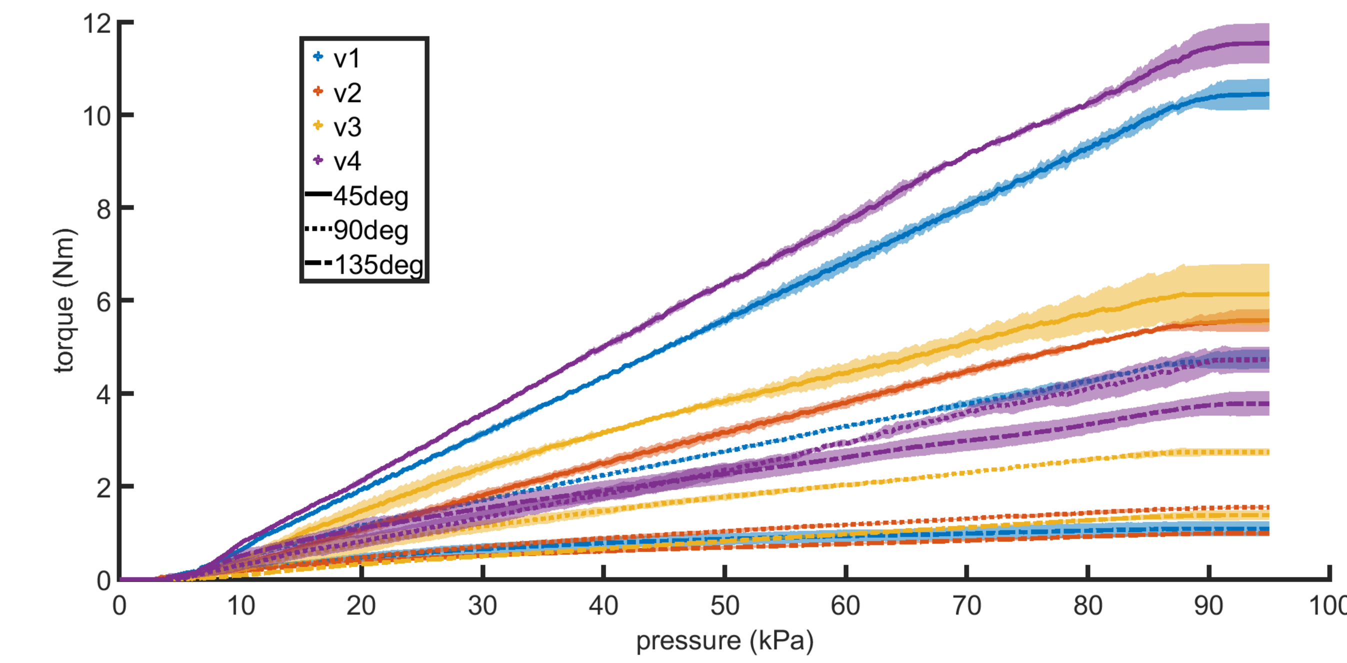

Figure 7: Torque vs Pressure for All Actuators with Strict Straps in Each Position

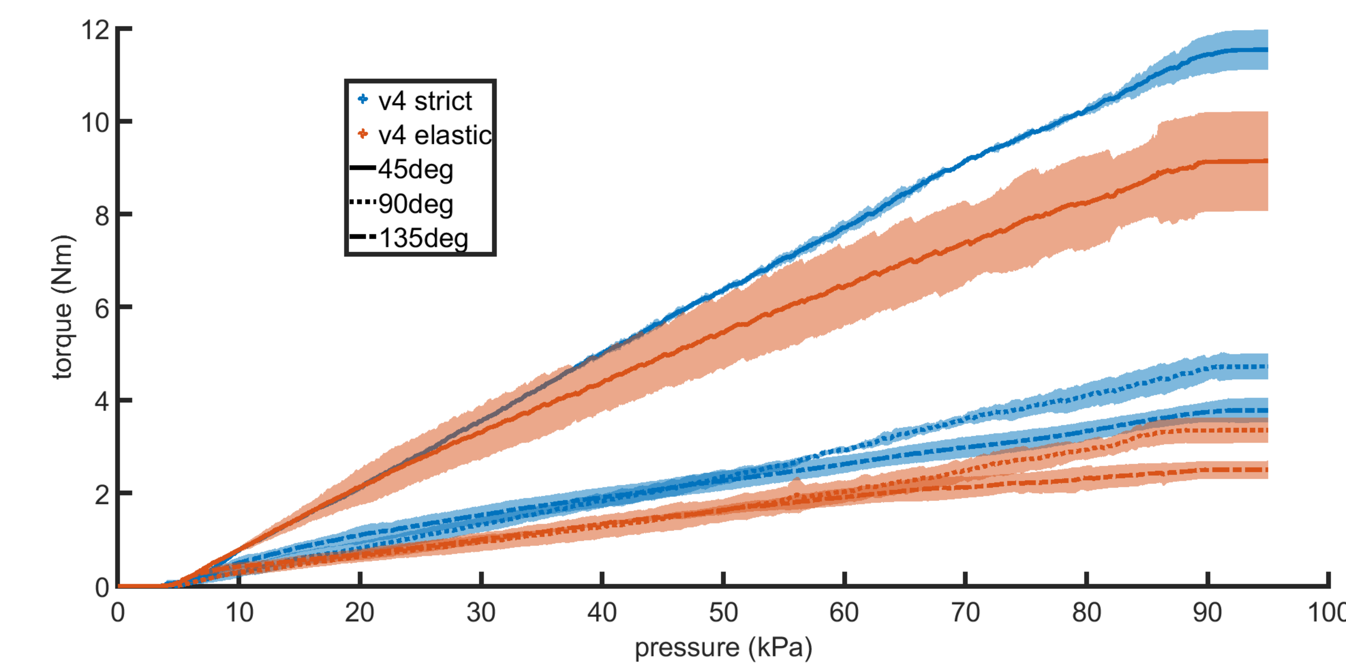

Figure 8: Torque vs Pressure for v4 Strict Versus Elastic

Table 1: Maximum Torque Outputs (Nm)

	V1	V2	V3	V4e	V4s
45°	10.89	6.18	5.90	9.25	12.11
90°	4.90	1.59	2.35	3.42	4.94
135°	1.11	1.00	1.43	2.51	3.84

- V1 produced strong baseline torque measurements but was uncomfortable.
- V2 improved comfort but lost some performance.
- V3 used an asymmetric shape about the x axis the retain comfort while improving some performance.
- V4 widened the main chamber rather than lengthening, retaining comfort but increasing total volume which corresponded to larger torque.
- While more comfortable V4e (elastic) provided less torque than V4s (strict).
- Note that one of the tests for V3 had to be excluded due to equipment malfunction.

Conclusions

V4

- Lightweight
- Easy to use
- Most comfortable
- Provides enough torque to properly assist in ADLs

Areas for Improvement

- Mounting system: the current way that the hook-and-loop fasteners are attached make it so that when the actuator inflates, it compresses the arm underneath (this is why we limited the pressure in force testing to 100 kPa)
- Manufacturing Process: the heat press can be hit or miss in creating a successful seal.
- Nozzle attachment: difficult to make and unreliable.