Miniaturized Pneumatic Actuator Array for Multipoint Deep Pressure Tactile Stimulation

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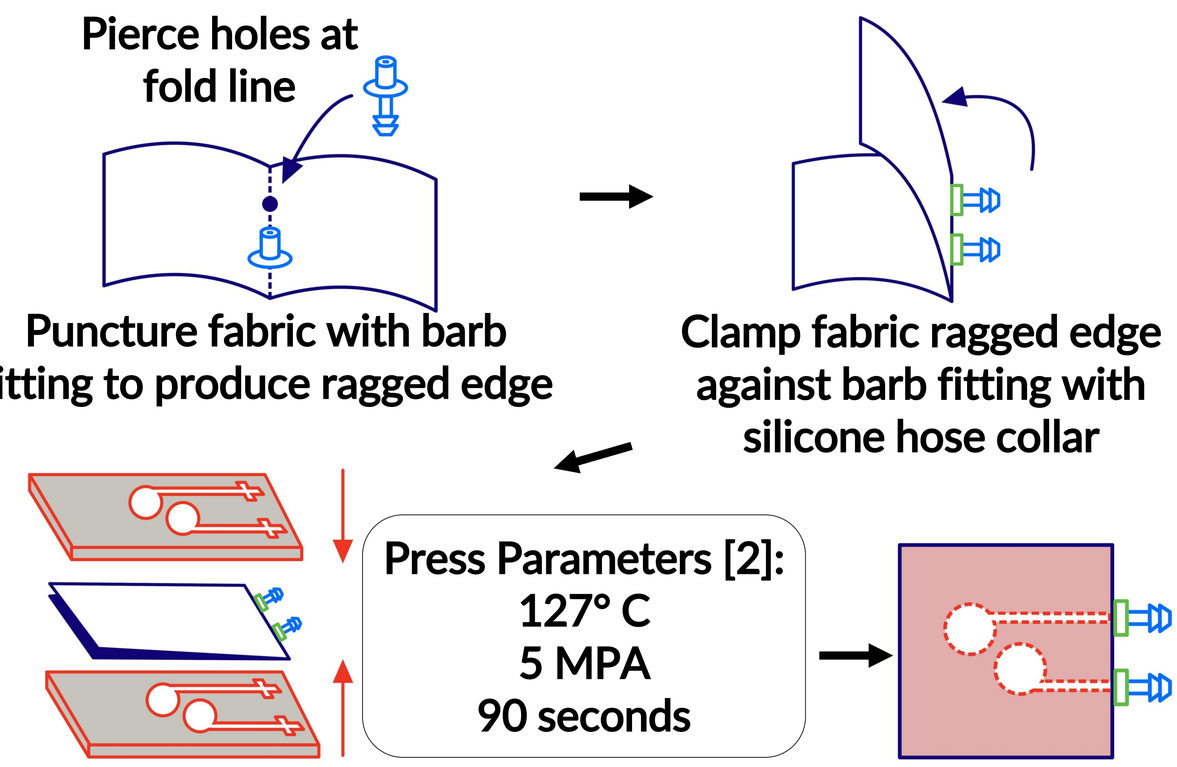
Motivation

Developing haptic wearables for individuals with **PIEZO2-LOF** (Piezo Type Mechanosensitive Ion Channel Component 2 Loss of Function) requires applying **deep pressure (>1N)**, since this sensation is preserved whereas proprioception, light touch, and vibration senses are absent in this population [1].

We present a method to fabricate **pneumatic multi-actuator devices** that can provide deep pressure stimuli even at fingertip scales. We measure force generation of a fingertip-sized 2x1 array and investigate feasibility of creating distinct and summed pressure stimuli.

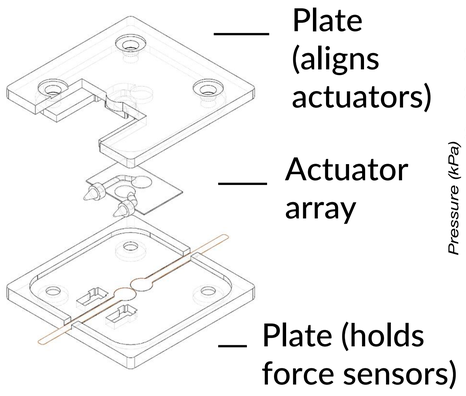
Fabrication Method



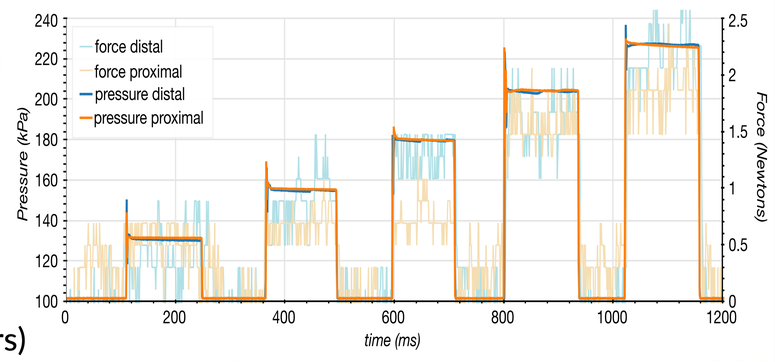
Fabrics (70 denier ripstop nylon with single-side TPU coating) are folded with TPU-side inward. High heat conductivity of aluminum molds seals only desired areas without sacrificial blocking layers. Resulting actuators sustain up to 375 kPa.

Blocked Force Characterization

Force Testing Setup



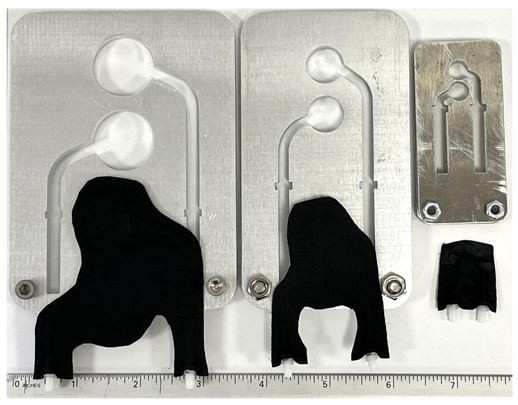
Force-Pressure Correspondance



Blocked force characterization conducted with a single 8mm sample yields > 2.1 N force transmission at 230 kPa.

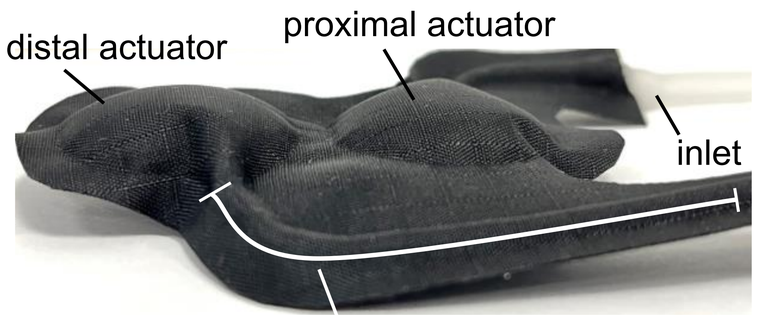
Textile Pneumatic Actuator Array

Scalable Stencils



Prototypes & Molds
⌀25mm, ⌀15mm, ⌀8mm
(5mm, 5mm, 1mm spacing)

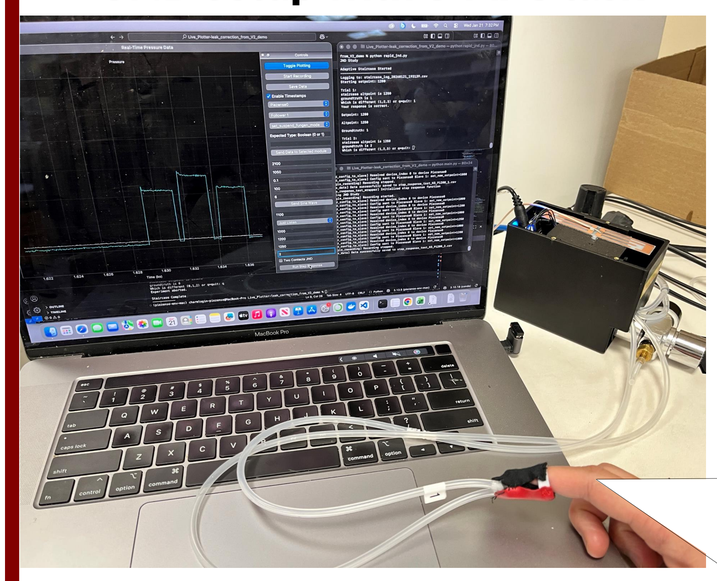
2x1 Array Arrangement



Method requires colinear air inlet placements but accommodates flexible tactor diameters and placement.

Fingertip Amplitude Perception

JND setup with 3-AFC task



3-Alternative Forced Choice (3-AFC) with modified rapid staircase [3]. User indicates alternative stimulus.

Task parameters:
2s duration, 0.5s pause.
Reference pressure: 120 kPa.

Task performed with one contact (distal tactor only) and two contacts

Preliminary Results: One vs Two Contacts

User 1: Identical JND (9.6 kPa) for both 1- and 2-contact stimuli.
User 2: Lower JND for 2-contact (4.1 kPa) than 1-contact (6.5 kPa), suggesting potential spatial summation at fingertip [4].

Conclusions & Future Work

- Developed a simple heat-pressing fabrication method to produce densely spaced, miniaturized textile actuator arrays
- Fingertip-sized prototypes achieved >2.1 N force at 230 kPa, demonstrating sufficient miniaturization and force generation for multipoint deep-pressure stimulation experiments

Future Work:

- Integrate actuators into wearables to provide multipoint haptic feedback in more locations, including forearm, wrist, and fingers
- Combine actuators with wearable motion tracking sensors to assist proprioception with a PIEZO2-LOF population

This work was supported in part by the National Institutes of Health (NIH) under grant R21EB036190

[1] L. K. Case et al., "Innocuous pressure sensation requires a-type afferents but not functional PIEZO2 channels in humans," Nature Communications, vol. 12, no. 1, p. 657, Jan. 2021
[2] M. C. Coram, A. M. Okamura, and C. du Pasquier, "Sealing the deal: Effects of fabrication parameters on the performance of textile pneumatic haptic actuators," arXiv, 2024. Available: https://arxiv.org/abs/2411.00295
[3] A. Pate, N. Ouvrai, Q. Consigny, and C. Fritz, "Two rapid alternatives compared to the staircase method for the estimation of the vibrotactile perception threshold," IEEE Trans. Haptics, vol. 17, no. 4, pp. 935–945, 2024.
[4] S. Kodali et al., "Spatial summation of localized pressure for haptic sensory prostheses," Haptics Symposium Work-in-Progress Paper, Apr. 2024. Available: https://arxiv.org/abs/2404.02565

WIP Paper Link

How-to video

Haptics Symposium WIP 2026