Structured Pneumatic Fingerpads for Actively Tunable Grip Friction

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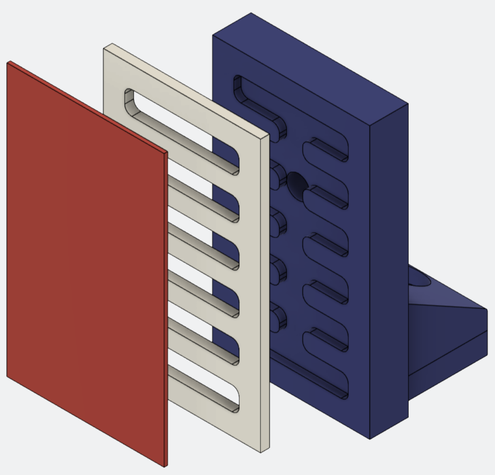
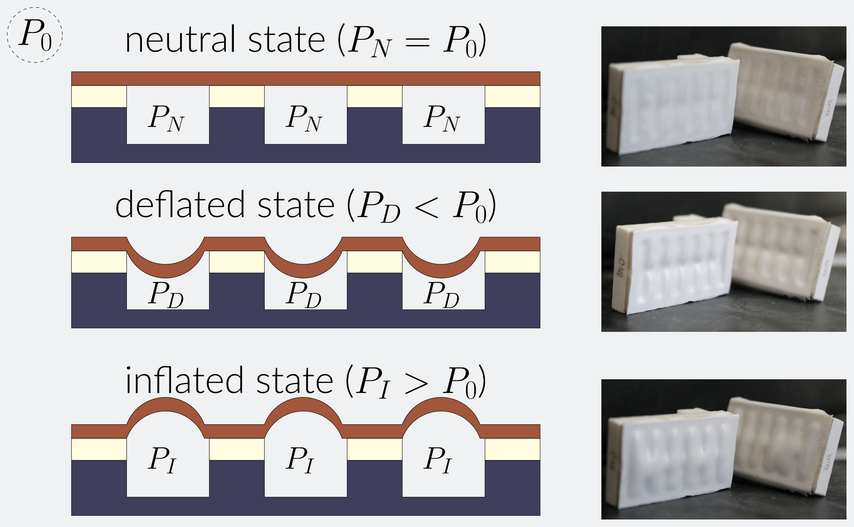
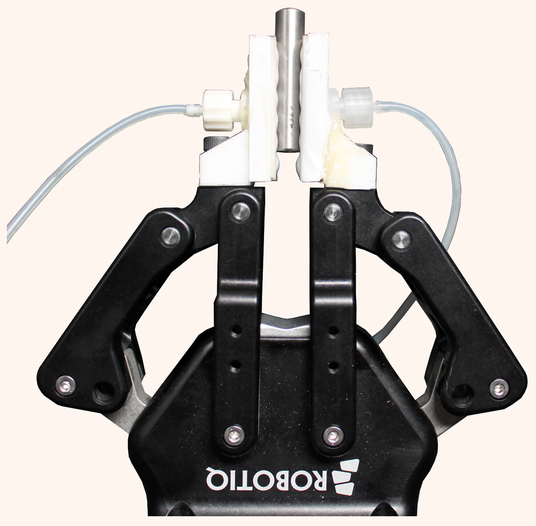
Fabrication: attach PVC tape to rigid base with **structured** adhesive



Actuation: use **pneumatic control** to pressurize channel in rigid base, deflecting **active regions** of tape



Characterization: actuate, then test **shear force** on gripped objects



Why tune grip friction?

High friction enables secure grasping (but inhibits release/in-hand manipulation) whereas **low friction enables smooth release** (but risks slip). Grip surfaces that can tune friction can **actively modify contact conditions** to suit different manipulation tasks.

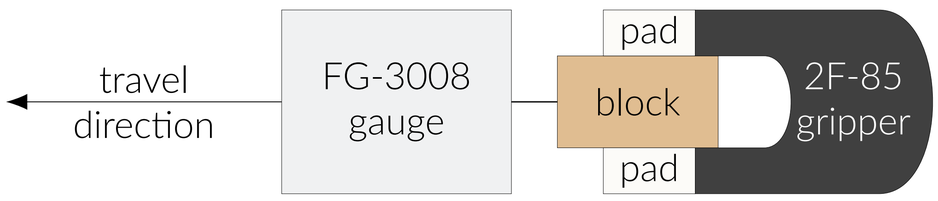
Why choose this design?

The (few) existing friction-tuning grip surfaces (e.g. [1]) typically tune friction effectively but are difficult to fabricate. In contrast, our design approach **prioritizes practical fabrication**:

- inexpensive, common materials **lower implementation barriers**
- rigid base and soft top layers **balance strength with compliance**
- simple layered structure facilitates **rapid repair and redesign**
- digital fabrication is **repeatable** and **reduces hands-on work**

How was friction tuning tested?

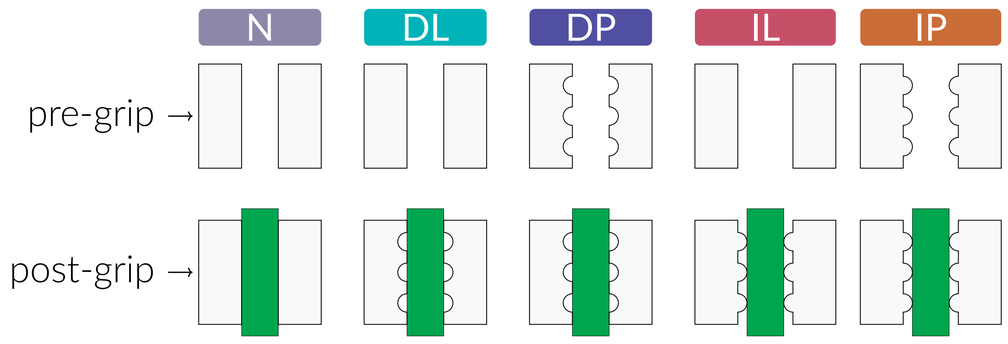
To assess frictional behaviour, we used a force gauge to **pull a gripped object** and **measured the shear force** opposing the object's motion.



We tested whether the following factors impacted friction:

- **actuation state** (neutral/inflated/deflated)
- **actuation timing** (prior to gripping/"live" during gripping)

This gave us **five actuation test cases**: neutral (N), deflated live (DL), deflated prior (DP), inflated live (IL), and inflated prior (IP).



How well do the fingerpads tune friction?

The inflated state enables significant friction tuning, with shear forces **2.8x higher in the IL case vs. the IP case**. The difference between IL and IP forces appears to **increase with actuation pressure** (Fig. 1).

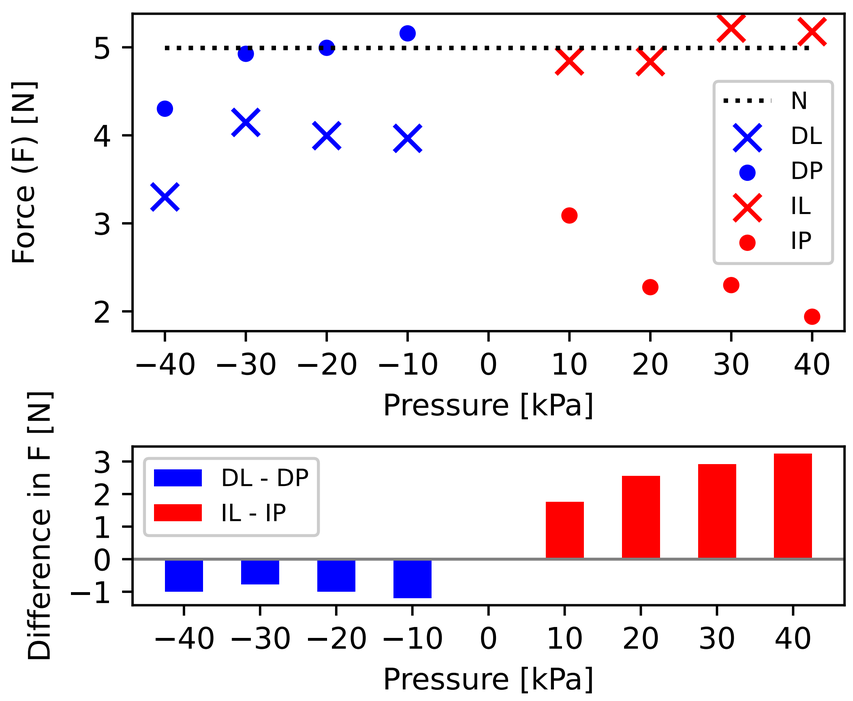
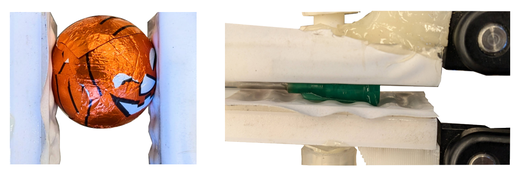


Figure 1. Average steady-state shear (friction) force across 3 trials (top) and difference between live and prior results (bottom) by actuation pressure.

What other features do the fingerpads have?

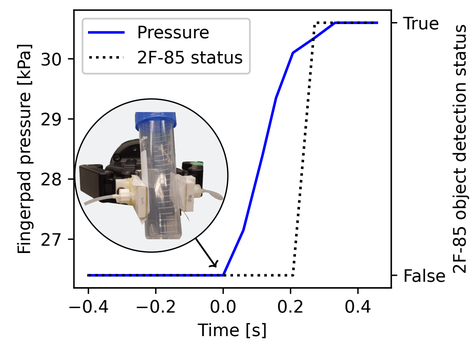
Enveloping and interlocking interactions with small object features

More **macro-scale frictional interactions** with the raised or recessed active regions are possible in some cases.



Pressure-based object detection

Inspired by [2], we implement object detection. Pressure in **inflated fingerpads** rises when a gripped object **compresses** the fingerpads, signalling contact.



Conclusion

Pneumatic fingerpads can **tune friction** through **deflection of a flexible contact surface** in structured active regions. Our design is **easy to fabricate or redesign**, facilitating implementation in existing systems. In future work, we will examine how varying the contact surface and active region design impacts performance.

References

[1] K. P. Becker, N. W. Bartlett, M. J. D. Malley, P. M. Kjeer, and R. J. Wood, "Tunable friction through constrained inflation of an elastomeric membrane," in *IEEE Int. Conf. Robot. Automat. (ICRA)*, pp. 4352–4357, May 2017.

[2] M. Pozzi, L. Franco, Z. Iqbal, M. Malvezzi, D. Prattichizzo, and G. Salvietti, "Soft pneumatic pads enable new sensing and actuation capabilities in soft-rigid grippers," in *IEEE Int. Conf. Soft Robot.*, pp. 485–491, Apr. 2024.

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