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Iterative Design of a Rolling Contact Joint

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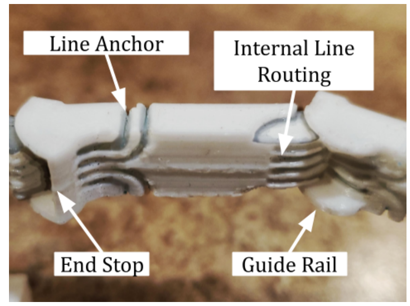
Overview

Designed and prototyped a **compact rotational joint** using a r**olling contact mechanism**, intended for biomimetic fingers and **optimized for 3D printing** of **complex internal features.** The joint employs nylon monofilament and internal guides to achieve precise motion while avoiding bulky bearings. **Iterative testing** revealed fabrication constraints and material trade-offs, informing future improvements in joint size, material selection, and multi-part printing strategies.



Key Features of Compact Joint Linkage

Tools & Skills

Fusion 360, 3D printing, Mechanical Design, Iterative Prototyping, Design for Additive Manufacturing, Tolerance Planning

Objective

Design and prototype a **compact, low-torque rotational joint** using a **rolling contact mechanism** with **integrated rotation limits.** Intended for a biomimetic finger, the joint should **avoid bearings** due to size constraints and **leverage 3D printing** to enable **intricate internal features.**

Highlights:

- **Nylon monofilament** selected for its **availability** and **high tensile strength**.
- **Interference-fit anchoring** securely holds the monofilament line in place while allowing for **easy assembly**.
- Internal line guides efficiently redirect the monofilament to subsequent alignment channels.
- **Guide rails** precisely **limit rotation** and **prevent joint overextension**.
- Rotational range configurable during design to replicate specific anatomical joint motions.

Lessons Learned

Switching to a finer monofilament line caused slippage and made assembly more difficult, underscoring the need to **balance material properties with practical handling**. Miniaturization was limited by printer resolution and assembly difficulty, shifting focus from design improvement to fabrication feasibility. However, **3D printing enabled rapid testing** of each joint **iteration**. Internal line guides worked well but depend on advanced fabrication methods. Print orientation conflicting with joint orientation caused layer lines to interfere with line anchoring geometry. While double joints closely mimicked ball joint motion for MCP joints, the inter-metacarpal linkages experienced binding due to incorrect motion profiles. At this scale, relatively large rails and endstops were needed to prevent twisting and over-extension of the joint.

Next Steps

Select a monofilament line size and material that **balances joint compactness while minimizing the risk of slippage** experienced with smooth nylon. Redesign metacarpal joints to prevent binding and failure. Increase joint size to **facilitate easier manual assembly**. Consider printing multi-joint linkages as separate parts to **avoid layer line interference** with monofilament anchoring.

References

Hong et al. *Rolling Contact Implant Design for PIP Joint.* J Orthop Surg Res, 2019.
https://doi.org/10.1186/s13018-019-1234-6

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