Hybrid Gripper with Passive Pneumatic Soft Joints for Grasping Deformable and Thin Objects

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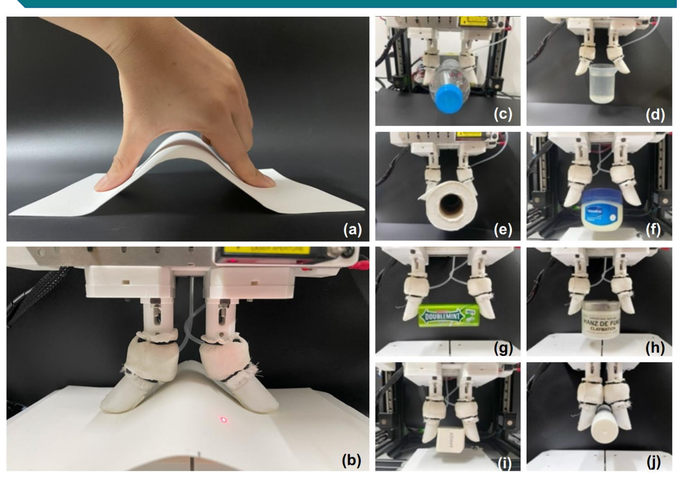
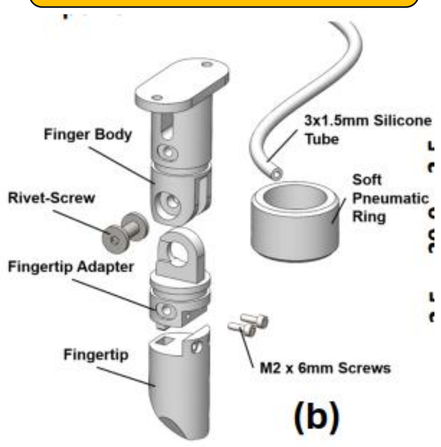
Introduction



- **Problem Addressed**: Grasping various objects, especially deformable ones like fabric or paper, remains challenging for robotic systems.
- **Biological Inspiration**: The way humans use two fingers with soft, flexible joints to grasp thin, large objects.
- **Proposed Solution**: A **hybrid gripper** combining **soft and rigid components**.
- **Performance Improvement**:
  - ✓ **Improved grasping efficiency**
  - ✓ **Reduced gripping distance** by up to **8 times** compared to rigid grippers.

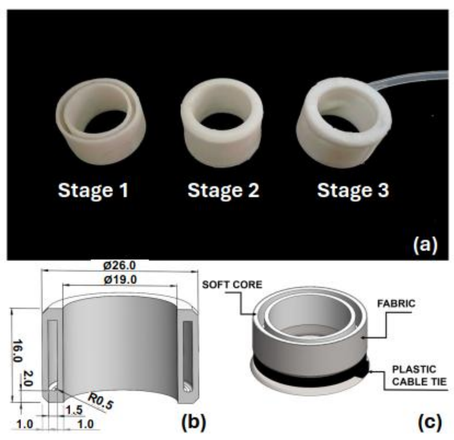
Gripper Design

Rigid Components



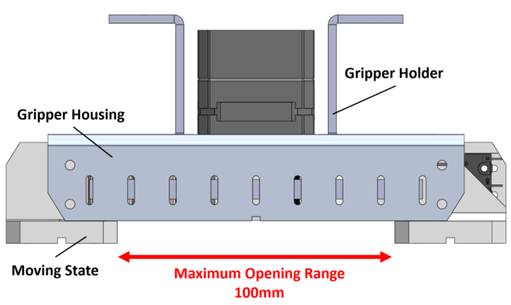
- ❑ **Contain Rivet-Screw and Bearing**
- ❑ **The distal link:** Fingertip + Adapter
- ❑ **Special Design Fingertip**
- ❑ **FDM 3D Priting method**

Soft Components



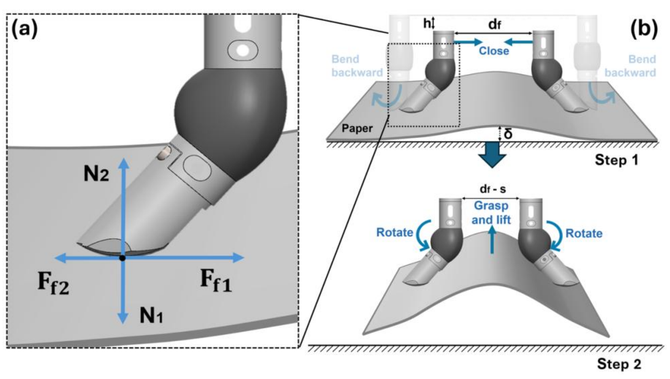
- ❑ **Shape of Ring**
- ❑ **Cover the Joint of the Finger**
- ❑ **Fabric Constraint Softcore Deflection**
- ❑ **Silicone Casting Method**

Gripper Module



- ❑ **Opening Range:** 100mm
- ❑ **Actuator:** Stepper Motor Nema 17
- ❑ **Driving Mechanism:** Rack and Pinion
- ❑ **Direction Mechanism:** Slider and Rail

Paper Grasping Hypothesis



- ➢ Each paper has a certain surface deflection behavior.
- ➢ Pressing the fingertip on the paper's surface generates a normal force.
- ➢ The normal force can be controlled by adjusting the air pressure in the soft pneumatic ring.
- ➢ As the fingers close and reach a certain distance, friction force is generated by the fingertip.
- ➢ This friction creates a bending torque.
- ➢ The resulting torque causes the paper to bend upward.

Goal Of Our Research

1. **The hybrid gripper** takes advantages of **Soft** and **Rigid Grippers**
2. **Having Fingers** to grasp various objects like related work
3. Ability to grasp a **large surface of paper** like the human hand

Grasping Parameters and Equations

Adjustable Grasping Parameter

- ❑ Bending angle (α)
- ❑ Pneumatic pressure (KPa)
- ❑ Closing distance (s)

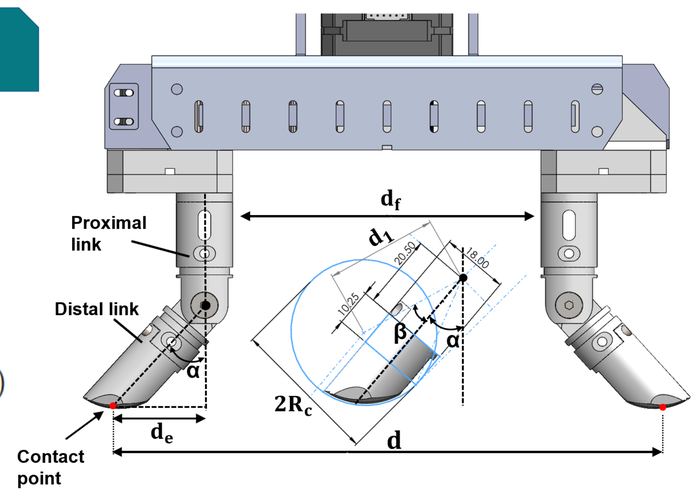
$$S_b = \frac{Et^3}{12}$$

$$M_b = (F_{f1} - F_{f2})\delta$$

$$M_b = (N_1\mu_1 - N_2\mu_2)\delta$$

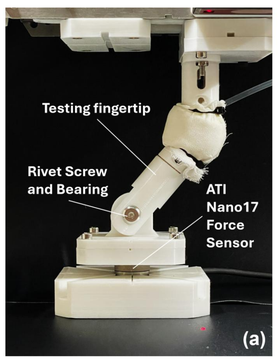
$$h = d_1(\cos(\beta) - \cos(\beta + \alpha))$$

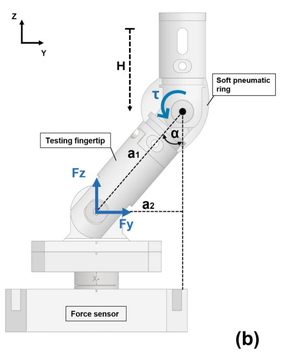
$$d = d_f + 2d_e$$



Experiment Setup And Results

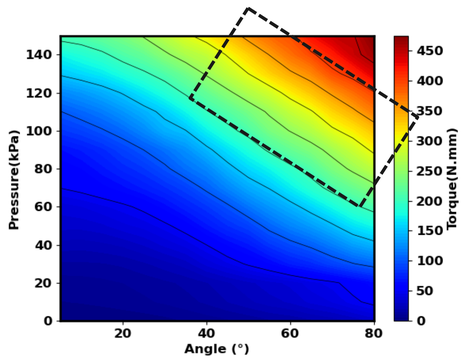
Soft Joint Stiffness Experiment





$$H = a_1(1 - \cos(\alpha))$$

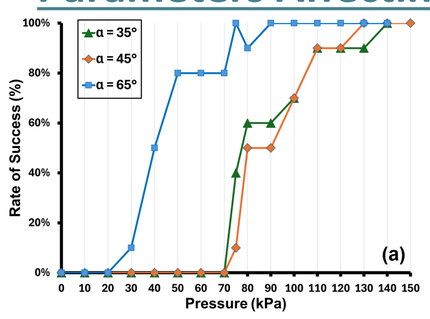
$$\tau = F_z a_1 \sin(\alpha) - F_y a_1 \cos(\alpha)$$



150–400 N·mm

=>Within the torque range of 150–400 N·mm, the pressure and bend angle are relatively proportional

Parameters Affecting The Grasping



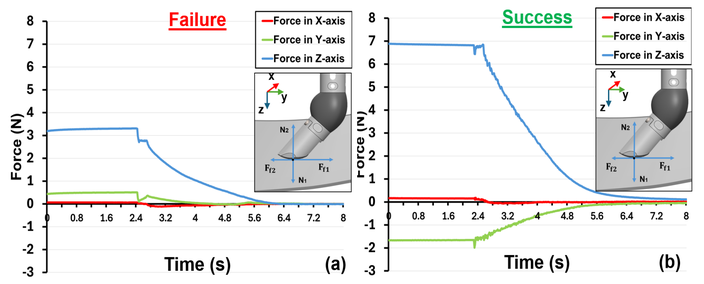
Closing distance:

- ❑ 5mm

Changed parameter:

- ❑ Air pressure
- ❑ Bending angle

=>Higher bending angle, lower air pressure is required to get same rate of success.



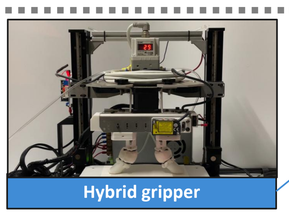
The Graphs illustrate **the force exerted by the fingertip on the surface**

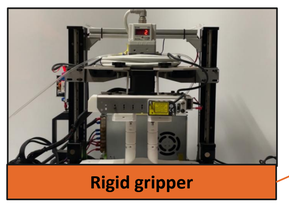
Comparison with Rigid Gripper

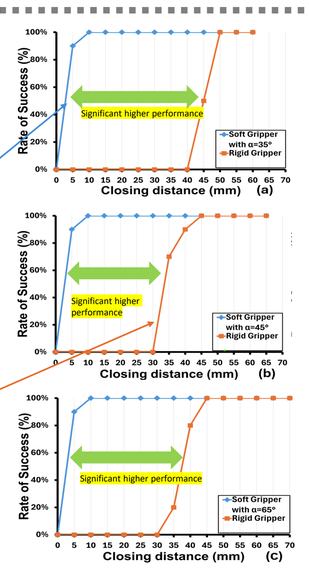
Grasp Conditions

- ❑ **Contant Closing Distance** (5mm)
- ❑ **Equivalent Vertical Force**

(a) α = 35◦ d = 60 mm $N1$ = 6 N
(b) α = 45◦ d = 65 mm $N1$ = 9 N
(c) α = 65◦ d = 70 mm $N1$ = 14 N

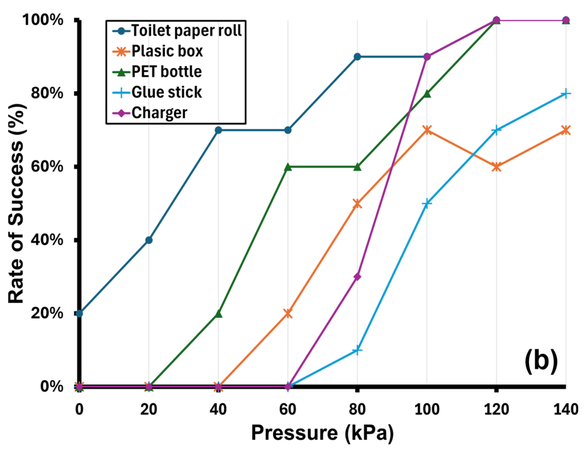






=> Closing distance of hybrid gripper to obtain a 90% rate of success only **a third** of that of rigid gripper

Grasping Various Objects Experiment



- ⊕ **Performs better with deformable objects** (toilet paper rolls, water bottles)
- ⊖ **With sharp edges and small contact areas** (charger and glue stick), the **Success Rate is low**

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