Motion Test and Grasping Force Modeling of a Flexure-based Anthropomorphic Gripper

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Introduction

[Grippers] Flexible / Flexure-based / Under actuated

PROS

applicable to various types of / unstructured objects (soft/hard/flexible/dangerous)

need less actuators
compliant grasping
impact resistance

CONS

nonlinearity
less controllable dofs

hard to get the modeling
hard to control

[Hybrid Gripper] Flexible hinge + rigid body / wire-driven

more controllable than flexible grippers

harder grasping realizable

A type of hybrid gripper (presented by DGIST)

still

nonlinear
hard to get modeling
hard to control

How to build the hybrid gripper model for its control?

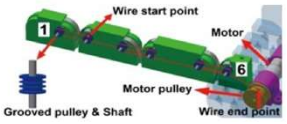
Motion test → Force test

in this study

Data driven full gripper modeling and control

Future works

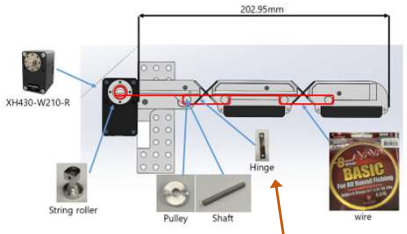
Flexure based hybrid gripper



Mechanism

- 4 finger grasping
- flexible hinges + rigid finger bodies
- 3 rigid bodies (2dof) / each finger
- under actuated (1 actuator / each finger)
- wire-driven
- attachable contact surface modules
- handles payloads up to 4kg

Single finger assembly of the gripper



Components

- wire: fishing wire in various thickness considered
- pulley: machined aluminum using 2mm shaft.
  pully width < 3mm
- shaft: 2mm SUS
- finger body: 3d printed ABS (working prototype) → machined metal (after conceptual study)
- bearings: installed on each shaft + pulley

Flexible hinges

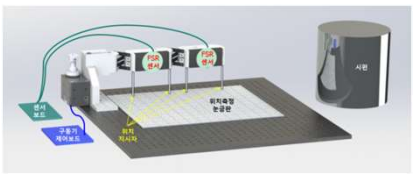
[requirements]

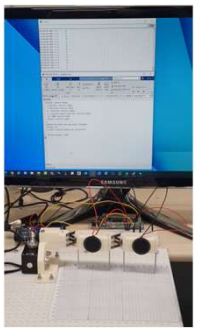
- operation/return force realizable with a small geared motor
- hard grasping before occuring hinge's plastic deformation

[candidate materials]

- ABS
- PC
- TPU
- SK5 (metal)

Motion repeatability tests





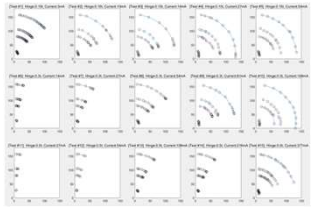
<Wire displacement(mm)>

Current (mA) / Hinge	3	10	14	27	54	81	108	216	377
SK5 0.15t	18.2	26.9	31.8	40.4	54.9				
SK5 0.3t			7.3	12.2	21.7	33	51.5		
SK5 0.5t				7.65	10.73		16.24	29.14	56.16

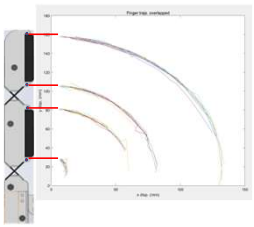
Green cell: plastic deformation occurred

Motion repeatability satisfied !!

Test result

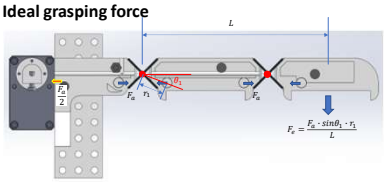


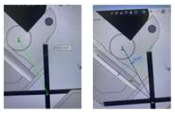
Overlapped trajectory of the finger motion



Grasping force test

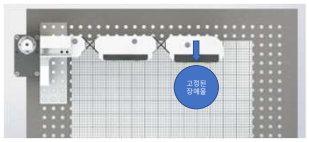
Ideal grasping force

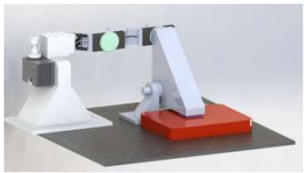




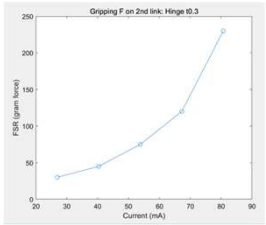
Test environment

- Hinges: SK5 in 0.3mm T applied
- FSR sensors attached and used to read contact force on the finger
- Sensor values are read and recorded when FSR output is stabilized in each test case
- Motor torque vs. grasping force is measured





Test result



Repeatable grasping force & resolution of the controllable force satisfied !!

CONCLUSION

- From the hinge candidates, 0.3t SK5 metal hinge is chosen and used in the test.
- Motion repeatability test showed we can regenerate the same motion using same actuator input in obstacle free environment.
- Cannot achieve back-drivability from small actuator with high gear ratio → this need to be considered when compliant grasping force control needed.
- Compliant grasping force control will be required when the gripper grasps and handles softer objects with weak structure.
- FSR force sensing structure is needed to be redesigned to achieve a stable and same force read regardless of the contact location on the finger surface.

FUTURE WORKS

- **Grasping force control**

  hybrid control of grasping force for a compliant grasping operation of the flexure based finger
  - grasping mode
  - force control mode

- **Compensation scheme for the absence of backdrivability**