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

Ki Hong Im*, Seung Hwan Kim, Jongwon Park and Jinyi Lee
Korea Atomic Energy Research Institute, Daedeok-daero 989-111, Yuseong-gu, Daegeon, 04535, Rep. of Korea
**Corresponding author: khim@kaeri.re.kr*

1. Introduction

With the increasing application of robotic arms for handling objects of various shapes, sizes, and softness, there is a growing need to handle these objects without changing the gripper attached to the robotic arm. To meet this demand, many types of soft or flexible grippers have been introduced and are currently used for real field applications, including food handling and manipulation of soft materials. A hybrid gripper design that uses flexible hinges to connect rigid finger bodies has recently been proposed as one of the applicable solutions [1-3]. Before designing and applying a control scheme for the flexure-based gripper, a prior study on the movement and dynamics of the gripper is necessary to build a model of it, since the higher nonlinearity of the flexure-based gripper makes its control more challenging than other conventional rigid grippers. In this paper, we present a series of tests and studies conducted to model these types of hybrid grippers.

2. Testbed Setup and Gripper Motion Test

The flexure-based gripper targeted in this study has a structure depicted in Fig. 1. It features a wire-driven, underactuated mechanism and is operated by an electric motor.

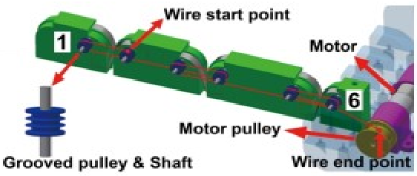

Fig. 1. Structure of a flexure-based anthropomorphic gripper.

While considering the feasibility of the gripper modeling, it is required to meet the repeatability of the gripper's bending motion first. Providing that, we can go into a higher-level modeling of the gripper. The test environment of the gripper motion is like in Fig. 2 and Table I.

Table I: Test Environment

Actuator	Dynamixel XH430-W210
Control board	OpenCM 485
Gripper body	ABS(3D printed)
Hinge Material	SK5(0.15t, 0.3t, 0.5t) heat treatment
Pully Material	Aluminum
Jamming Material	TPU(3d printed)
Wire	Fishing line PE 0.43t
Control SW	Matlab

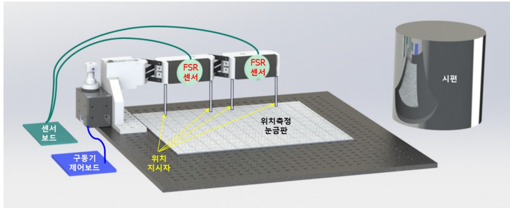

Fig. 2. Testbed setup for measuring flexure-based gripper's motion repeatability.

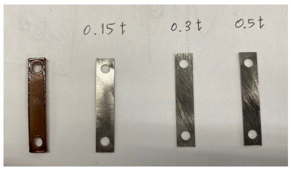

Fig. 3. Three kinds of SK5 hinges used in tests.

Tests was conducted on three types of flexible SK5 hinges in Fig.3, and the gripper's motion is measured by its finger bodies' coordinates. We accomplished this test result by installing 4 needles in Fig. 2 which can indicate planar coordinates of the finger's body, and recorded the motion by using two cameras from different sight. Fig. 4 shows the test results, and we can easily find the motion of idle gripper is reasonably repeatable regardless of the kind of hinge it is currently using.

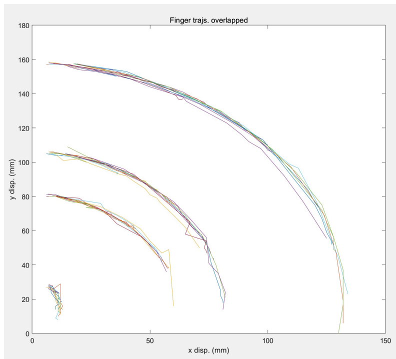

Fig. 4. Three kinds of SK5 hinges used in tests.

Based on this result, more test and studies are proceeded focusing on the tip force that our gripper can actually generate when it grasps an object. For this, we first derived an equation (1) from Fig. 5 for calculating the ideal force to be generated from the pulley-string driven mechanism.

$$F_c = \frac{F_a \cdot \sin\theta_1 \cdot r_1}{L} \quad (1)$$

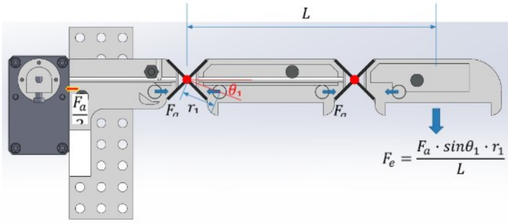

Fig. 5. Derivation of ideal grasping force.

After that, the actual finger-tip force is measured using loadcell. To isolate the gravitational force induced by gripper's weight, force direction is rotated and measured by using a joint mechanism in Fig. 6.

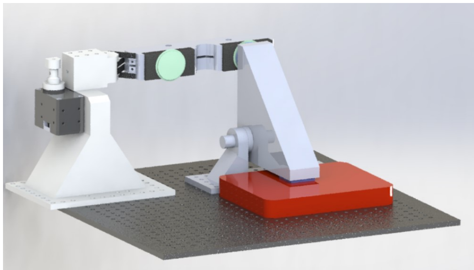

Fig. 6. Test environment for measuring grasping force on a fingertip.

A FSR sensor is attached on each finger's grasping face to measure the FSR value and the loadcell value at the same time. This approach enables the test to generate an end-to-end transformation table from driving motor torque to the actual grasping force on the finger's surface.

The test results are plotted in Fig. 7 and Fig. 8.

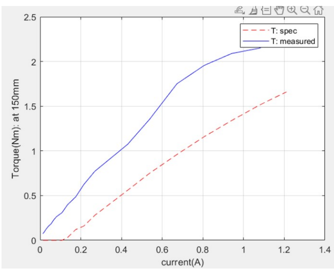

Fig. 7. Specified and measured torque comparison of the actuator.

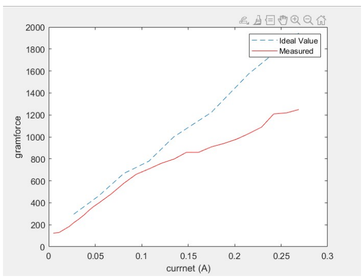

Fig. 8. Ideal and measured grasping forces.

3. Conclusions

To achieve a reasonable modeling and control algorithm for flexure-based anthropomorphic grippers, more and more studies would be needed to enable the grippers actual use for soft and adaptive grasping purpose. In this regard, we tried a series of physical tests to reveal some characteristics of flexure-based grippers. The result can be used to build a data driven model of the grippers using flexible hinges and to design a control scheme to actuate them in the next stage.

ACKNOWLEGEMENT

This work was supported by Robot Industry Core Technology Development Programs of the Ministy of Trade, Industry & Energy of KOREA(20018270)

REFERENCES

[1] Junmo Yang, Jeongseok Kim, Donghyun Kim, and Dongwon Yun, Shock Resistive Flexure-Based Anthropomorphic Hand with Enhanced Payload, Soft Robotics, Vol.9, p.266, 2022.
[2] Xu Pei, Jingjun Yu, Guanghua Zong, and Shusheng Bi, An effective pseudo-rigid-body method for beam-based compliant mechanisms, Precision Engineering, Vol.34, p.634, 2010.
[3] Fulei Ma and Guimin Chen, Modeling Large Planar Deflections of Flexible Beams in Compliant Mechanisms Using Chained Beam-Constraint-Model, J. Mechanisms and Robotics, Vol.8, 2016.