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Development of Bar-shape Nonlinear Series Elastic Actuator

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***Abstract*—This study focuses on nonlinear series elastic actuators (SEAs) which have the potential to overcome the performance limit of fixed stiffness SEAs, design a spring unit, and experimentally validate the static characteristic. The result will provide insights into the design of nonlinear SEAs.**

Keywords— Modeling and Design of Mechatronic Systems, Actuators

I. Introduction

Series elastic actuators (SEAs) have gained attention as a human assist device [1]. This study focuses on nonlinear SEAs which have the potential to overcome the performance limit of fixed stiffness SEAs[2], designs a spring unit that fits the human joint shape, and experimentally validates the torque accuracy of the kinematic model using a prototype. The result will provide insights into the design of nonlinear SEAs for human assist devices.

II. Design and Static Experiment

A. Kinematic Model of the Nonlinear Spring Unit

As shown in Fig. 1 (a), the spring unit consists of two bars which are coaxial rotating around point O, and springs. The length of springs l changes based on cosine law as:

$$l(\theta) = \sqrt{r^2 + R^2 - 2rR\cos\theta} \tag{1}$$

The output torque of bars can be calculated by:

$$\tau(\theta) = nrRk\frac{l - l_o}{l}\sin\theta \tag{2}$$

where n and k correspond to the number and stiffness of springs, l_o denotes the rest length of the springs.

B. Static Experiment

The experimental platform is shown in Fig. 1 (b). It consists of a motor and a torque sensor, a nonlinear spring unit designed based on the model shown in Fig. 1(a). The number of springs n is 2, the stiffness of springs k is 19.6 [N/mm], and the lengths R and r, l_o are 90[mm] and 39[mm], 51[mm]. One side of the spring unit is connected to a motor with an encoder inside, and the other is fixed with a torque sensor. Fig. 1 (c) shows a comparison plot of the torque measurement results and design values when the motor deflects the spring unit by one degree The stiffness was changed as designed. RMS error of torque was 0.3 Nm. The error in the small torque range is attributed to spring pretension, while the error in the large torque range is attributed to unexpected deformation of components other than the spring.

III. Future Works

Fig. 1 (d) shows the ongoing design of actuator. The application is a posture control assist device for people at high risk of slips and trips, falls; active elders and workers, etc.

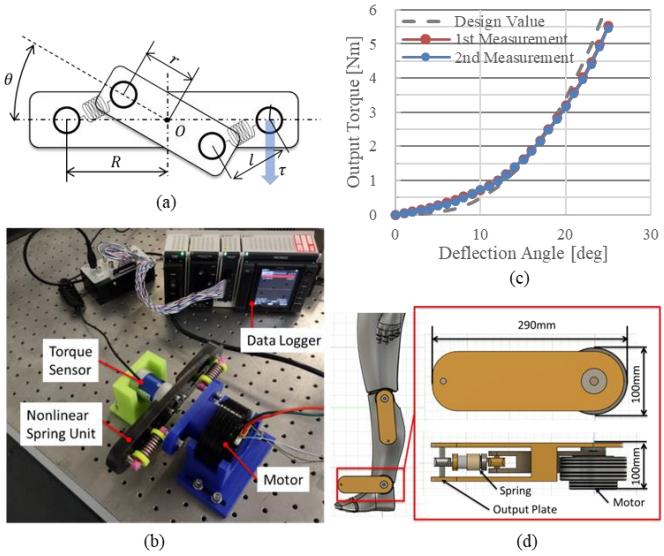

Fig. 1. (a) Schematic Picture of the Nonlinear Spring Unit. (b) Experimental Platform. (c) Comparison of Torque Measurement Results and Design Value. (d)Future Design

References

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