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Design of Knee Joint Support Suit with Fabric-type Artificial Muscles

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***Abstract*— In this study, we introduce a knee joint support suit applying shape memory alloy-based fabric-type artificial muscles (fabric muscles). An everyday pants-type strength-assist suit has fabric muscles attached to the location of the quadriceps to assist knee extension movements. We describe the performance of the fabric muscle that provides the assistive force, as well as the design process and composition of the suit.**

I. Introduction

As aging populations rapidly increase and the number of elderly individuals living alone rises in countries such as Korea and Japan, there is a great deal of interest in the development of wearable robots that can assist in their mobility. Elderly individuals are prone to frequent falls due to insufficient muscle strength in their knees, causing sudden joint buckling. To prevent this, wearable robots that can assist knee joint strength are necessary, primarily. However, to ensure that elderly individuals can comfortably wear wearable robots in their daily lives, they must be as lightweight as pants. To achieve this, a new type of actuator is required, rather than conventional motors or pneumatic actuators. We have developed a knee joint support suit in the form of pants using a shape memory alloy (SMA)-based fabric artificial muscle that can generate a actuating force of 10 kgf with a lightweight mass of 10 g. In this study, we introduce the design process and configuration of the developed fabric muscle and suit.

II. Fabric Muscle and Knee Joint Supprot Suit

The process of producing spring threads involves coiling a shape memory alloy (SMA) wire, with a diameter of 40 μm, around a molybdenum core that has a diameter of 160 μm, followed by heat treatment [1]. **This results in very thin and flexible spring threads that can be used in the production of woven fabrics using a weaving method. A fabric muscle with a width of 90 mm and a length of 110 mm was fabricated on a small manual loom, with ordinary threads arranged as warps and spring threads as wefts. The weight of the SMA used in the fabric muscle is 5 g and has a actuating force of 5 kg. Using two layers of 5g fabric muscle, an fabric-type artificial muscle with a actuating force of 10kg was fabricated. The fabric-type artificial muscles are very lightweight and flexible, allowing them to be easily attached to pants like fabric on muscle areas that require strength assistance, without interfering with body movement. To assist knee extension, the artificial muscle should be attached to the position of the femoral muscle. To easily attach and detach the artificial muscle to regular pants, a zipper was sewn onto the upper part of the fabric-type artificial musclet and the front hip joint area of the pants. To ensure that the pulling force of the artificial muscles is transmitted to the calf, a webbing strap attached to the end of the artificial muscle is connected to a buckle attached to the shin. A knee guard was attached to the pants knee area, mimicking the patella in the human knee joint, to increase the moment of the knee joint generated by the contracting force of the artificial muscles. To minimize the sagging of pants caused by artificial muscle contraction and increase the efficiency of force transmission, a crossed waistband was added inside the pants.**

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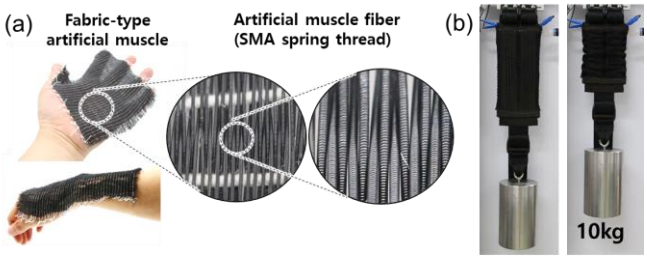

Figure 1. (a) Shape memory alloy spring-based fabric-type artificial muscle, (b) A fabric muscle weight of 10 g can lift a weight of 10 kg.

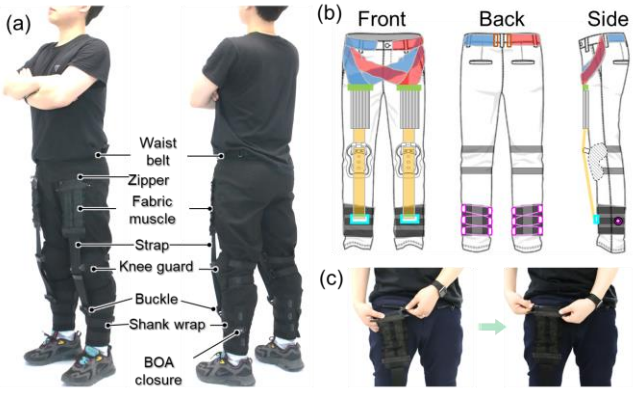

Figure 2. Configuration of the knee strength assistance suit. (a) Components of the suit, (b) Detailed illustrations of the suit, (c) Attaching the fabric muscle using a zipper.

III. Conclusion

The developed knee joint assist suit has the advantage of being easy to put on and take off due to its structure similar to everyday clothing, and it is lightweight and comfortable to wear. We plan to improve its performance through the evaluation of the assist effect of the suit in the future.

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References

[1] S. Park, K. Choi, H. Rodrigue, and C. H. Park, "Soft Exosuit Based on Fabric Muscle for Upper Limb Assistance," *IEEE/ASME Trans. Mechatronics*, vol. 28, no. 1, pp. 26–37, Feb. 2023.