Super Long Stroke Pneumatic Muscle for Articular Mechanisms

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Abstract: The pneumatic artificial muscle (PAM) actuator (e.g. McKibben type) has only limited stroke. Especially, the articular mechanism requires long stroke for the large range of motion. We propose novel actuator called Drag-in Pneumatic Artificial Muscle (D-PAM). The conventional PAM consists of braided sleeve and fluidic bladder which are fastened together on the both ends. In contrast, the D-PAM has separated sleeve and bladder. We derived force-length characteristics of the new actuator. The theoretical results show that the stroke of D-PAM can be up to 70% or more. The total energy output of the D-PAM is bigger than McKibben muscle in same diameter. We also propose light-weight and compact sealing method for manufacturing D-PAM and built prototype. The proposed D-PAM provides desired torque profile and range of motion on the pulley-wire mechanism for the articular robots.

I. Introduction

The pneumatic artificial muscle (PAM) is a group of translational actuators which provide contractile motion. For example, the McKibben muscle is a classic actuator which is invented in 1950's [1]. The typical contraction ratio of McKibben muscle is from 20% to 35%. In order to improve the performance of PAM, the several types of modified PAMs are proposed [2] [3]. We found that the contraction of the sleeve of PAM is disturbed by the axial expansion of the elastic tubing. We propose new pneumatic artificial muscle which has self-supported bladder separated from braided sleeve (Fig.1). We can use flexible but non-elastic material for the tubing which improves durability of the muscle. The drag-in action of the braided sleeve provides super long stroke which is suitable for articular mechanism of bio-inspired robot.

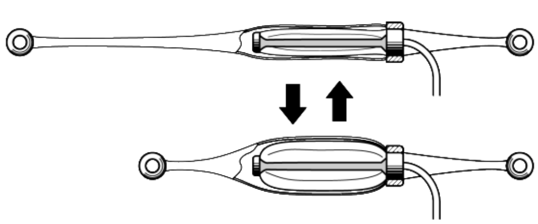

Fig.1 Principle of the Drug-in PAM.

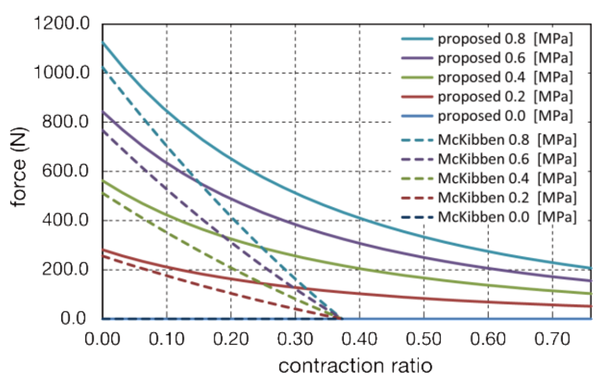

Fig.2 Comparison of basic characteristics.

The characteristic of proposed new PAM is described as eq.1. The static characteristic of pneumatic muscle is derived from the energy conservation law. From the comparison between McKibben muscle and the Drag-in PAM (Fig.2), proposed D-PAM has extremely wide contraction ratio. However, theoretical maximum contraction ratio of the D-PAM is unbounded, the filament diameter of the braided sleeve limit the deformation of the mesh in an actual situation.

$$F = p\frac{C}{(\varepsilon + 1)^3} \qquad \text{where,} \quad C = \frac{\pi D_0^2}{2\tan^2\theta_0} \tag{1}$$

II. Manufacturing

An end sealing of the PAM support braided sleeve and bladder under the huge pressure and external force. The conventional solution for the sealing problem is use of press forming of metal ring or screwed collar. It detracts advantage of light-weight of the pneumatic muscle. We propose a method using wire placed around end cap (Fig.2)

We build prototype of proposed D-PAM. The Fig.3 shows that the new muscle contract 90mm (72%) with 0.5MPa supply. Low friction tubing made of fluorocarbon polymer is used for the bladder. We also design the pulley-tendon mechanism driven by D-PAM. For the super long stroke motion, we can use braided sleeve of the muscle as flexible tendon.

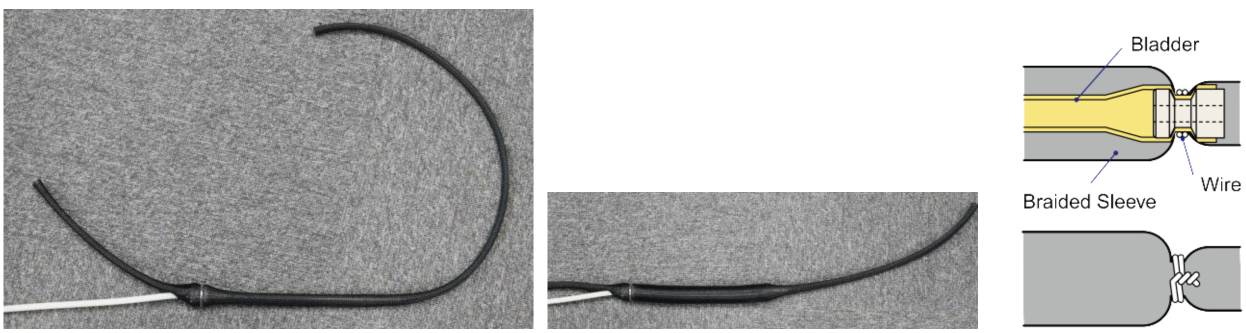

Fig.3 The drag-in action of the prototype Dragn-in PAM and double wire methodology for end sealing.

III. Conclusion

We describe concept and structure of novel muscle actuator with super long stroke. We derive theoretical characteristics of the proposed Drag-in Pneumatic Artificial Muscle (D-PAM). We also propose sealing method using double wire. The muscle consists of self-supported bladder and flexible braided sleeve. The uses of braided sleeve as tendon allow large range of motion of the articular mechanism for musculoskeletal robot.

References

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