Untethered High Force Hydraulic Artificial Muscles for Soft Wearable Robots

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Hydraulic actuation for robotic applications has increased in recent years, thanks to the advantages of high force density and high robustness to impact [1]. Hydraulically artificial muscles, using the working principle of the pneumatic McKibben muscle, is soft and conformal to human anatomy. Thus it can avoid the limitation of joint misalignment between human and robotic joints suffered by rigid wearable robots [2]. However, most hydraulically artificial muscles are heavy and bulky, not suitable for human augmentation.

We have developed a new type of hydraulic artificial muscle that generates high force (373N) and also untethered (1.2 Kg overall mass), thus ideal for wearable robot applications including exoskeletons and prosthesis. The hydraulic actuated muscle consists of an inner bladder made of rubber tubing, an outer braided sleeve over the bladder, two end caps, and four pinch clamps, two for each end, as shown in Fig. 1. The tube fittings are made of aluminum 6020 T8 and the braided aramid sleeve is designed with initial braid angle of 30 degrees to achieve a largest contracting distance. The rubber bladders were made of latex, nitrile rubber, and silicone. The hydraulic actuated muscle has a diameter of 1" and a length of 8". Experimentation is conducted using muscle assemblies of high-temperature fluorosilicone and latex tubing, in conjunction with aramid Kevlar sleeve and the vibration resistant pinch clamps and end caps. Fig. 2 depicts a proximately linear relation of the force and pressure of the hydraulic actuated muscle. The muscles were tested in a static apparatus, at pressures of up to 160 psi. The hydraulic actuated muscle (overall mass is 1.2 Kg including the pump) is capable of lifting a weight of up to 82.2 lbs (37.3 Kg) with a maximum contraction ratio of 16.3% and a Durometer 40A latex bladder of ⅛" wall thickness at 120 psi. The hydraulic actuated muscle acts similar to a dynamic, variable stiffness, nonlinear spring, which has potential use in soft robots. It has significantly better performance than state of the art soft robot [3] (22 Kg lifting force with 1.3 Kg overall mass). Further work includes optimization of the system and muscles as well as the creation of an untethered end effector.

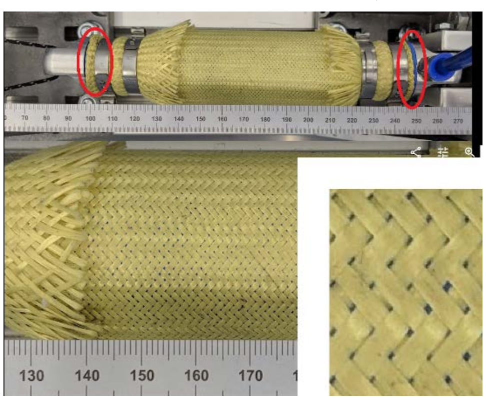

Fig. 1 Assembly of an untethered hydraulic actuated muscle.

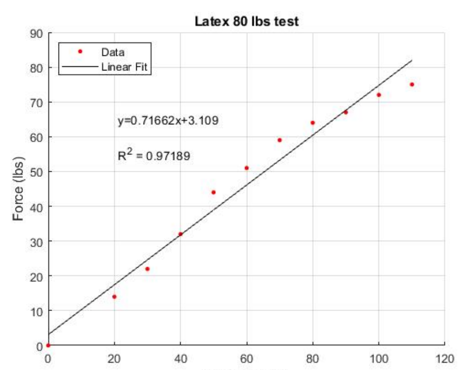

Fig. 2 Relation between force and pressure.

[1] Mori M, Suzumori K, Seita S, et al. Development of Very High Force Hydraulic McKibben Artificial Muscle and Its Application to Shape-Adaptable Power Hand. 2009 IEEE International Conference on Robotics and Biometics (ROBIO). December 19-23, Guilin; 2009. p. 1457–1462.

[2] K. Klute, J. M. Czerniecki, and B. Hannaford, "Artificial Muscles: Actuators for Biorobotic Systems," The International Journal of Robotics Research, vol. 21, no. 4, pp. 295–309, Apr. 2002.

[3] Li, S., Vogt, D.M., Rus, D. and Wood, R.J., 2017. Fluid-driven origami-inspired artificial muscles. Proceedings of the National Academy of Sciences, 114(50), pp.13132-13137.