The Effect of Diameter and Length on Blocked Force and Free Contraction of Various Pneumatic Artificial Muscles

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ABSTRACT

The Pneumatic Artificial Muscle (PAM) is a long-standing actuator technology class in the field of soft robotics. These muscles typically use an input pressure to produce an expansion, contraction, or rotational motion. PAMs are renowned for their extremely high force output to weight ratio and comparatively low cost to traditional robotic actuators. Advancements in materials and manufacturing methods offer more opportunities for PAMs to improve their functional performance and expand their applications. Theoretical models for the force output of a pneumatic muscle would be essential for the design and optimization of PAMs to meet the application needs. Unfortunately, existing models are limited and are often backed by experiments conducted on a small sample of actuators.

This study aims to evaluate the robustness of existing models for real-world applications by applying them to the design and optimization of PAMs made with multiple manufacturing methods and materials. Both fiber reinforced elastomer actuators and traditional McKibben actuators will be tested with varying geometric parameters. Traditional McKibben actuators consist of an inflatable inner bladder surrounded by an expandable woven sheath. Fiber reinforced elastomer actuators operate in the same way. However, the woven sheath is imbedded in the inflatable elastomeric bladder. Both types of actuators are a subcategory of Fiber reinforced elastomer enclosures (FREEs) and traditionally hold a cylindrical form factor.

The effect of the actuator length was often neglected as radius appears to play a larger role in theoretical analysis, which will be considered in this test. The experimental data of the relationship between the blocked force output and the input pressure will be used to evaluate the theoretical models. The results will likely show that the theoretical models deviate from the experimental results because of the numerous assumptions required to generate a reasonably simple theoretical model including the assumptions of perfect cylindricity throughout inflation and neglecting friction. A comprehensive comparison between the tested PAMs will be provided considering the performance, material cost, end of life disposal, and ease of manufacturing. In summary, this study will provide insight into the accuracy of theoretical models used to predict the force output and contraction of a PAM in real world applications in addition to helping guide the future research and development of soft robotics.