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Improving the design of pneumatic muscles: Simulation and analysis of the dynamic behavior of the system

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Improving the design of pneumatic muscles: Simulation and analysis of the dynamic behavior of the system using a balloon

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1.Abstract

The goal of designing this muscle is to create a low-cost, lightweight and accessible solution with optimal performance that can effectively replace traditional artificial muscles (like festo, mckibben, etc) in soft robotics(Pneumatic Networks actuators, elastomer, etc.), rehabilitation and flexible mechanical systems(Examples include compliant mechanisms, robotic grippers, etc) applications. To simulate this muscle, a latex balloon is used as a hyperelastic material that has higher elasticity than the elastic material which cause higher reversibility of the muscle and a polyethylene mesh is used as the muscle framework. The materials were selected using various parameters such as mesh material for finding the best choice for muscle frame, nozzle angle to investigate its effect on muscle contraction, mesh length to find a ratio between ballon and net length, etc. By comparing the speed and displacement of the muscle to find the best material due to its reversibility, contraction and resistance of the material. To control the system, a pneumatic air valve 2 position 5 way model was used to control the contraction, a timer to control the contraction time and a pressure regulator to keep the air pressure constant. Results indicate that increase in air pressure results in larger contractions but also triggers more higher internal stresses. Insertion speed has a significant effect on wave propagation within the muscle, with higher injection speed resulting in higher speed in contractions. Nozzle angle was found to affect the quality of expansion and contraction, with the application of a 0° angle producing higher frequency and more active motion in 0 to 45 degrees because of the ballon placement . In addition, weight load testing showed that larger weights inhibited contraction and hindered wave propagation, with a 200g weight generating strongly localized wave patterns and lower energy transfer that can show the resistance of isotonic type of this project muscle. Polyethylene mesh produced the strongest contraction of all the tested material, with more efficient energy return and response times than polyethylene and foam nets. Increased balloon sizes enhanced energy storage and range of contraction, whereas higher wall thickness lowered contraction efficiency by restricting flexibility. This project supports the UN SDG 3th because this muscle can be used in simple prostheses for patients with lower price, 4th this muscle can plays roll in educational uses in teaching robotic to pupils and 9th because this muscle can be used in soft robotics in industrial uses and also experimental uses . This muscle costs 10 times lower than the other pneumatic muscles that is shown in this article by calculating the costs material and making process of pneumatic muscles.

The results indicate that the new design of the pneumatic muscles has better efficiency, faster response rates, and more consistent pressure distribution than conventional designs. The mechanical performance enhancements indicate its potential use in assistive technology and robot actuation, eventually leading to greater mobility and quality of life among physically disabled individuals.

.Keywords: elasticity/ stress and strain/ pressure jump across the membrane /muscle efficiency /muscle dynamics