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Dynamic modeling of a soft pneumatic actuator

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Soft robotic systems are new but promising field of research. Because of their low material stiffness soft robotic systems have a inherent safety and are seen as advantageous for human machine interaction. They are of special interest for the field of medical and surgical application such as minimal invasive surgery. Still there is a lack of methodologies to model and describe the behavior of these systems comprehensively. While there are various approaches for static modeling [1, 2] the dynamic behavior is still not fully investigated. This challenge needs to be addressed when bringing soft robotic systems into application. One approach to model the dynamic behavior is the finite element method. In this paper it will be shown how the well known and sophisticated method can be used for modeling soft robotics systems at the example of a soft pneumatic actuator. This actuator consists of two different elastomers and three air chambers around its longitudinal axis. Each chamber is fiber-reinforced to prevent the chamber from deforming strongly. The chambers can be pressurized with air separately in order to realize trajectories. In this paper it is shown how the actuator responds to dynamic excitation under consideration of the highly elastic and nonlinear material. Therefor a hyperelastic as well as a viscoelastic material model is introduced. The viscoelastic material model, which is of special interest for dynamic simulations, is modeled by a prony series. In the paper the dynamic behavior of the soft actuator is demonstrated for three different load cases: periodic excitation through external forces, decay test and periodic excitation through pressurized chambers. The advantages and limitations of finite element modeling for specific applications such as design optimization or control are evaluated.

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