Variable Stiffness Actuator with Electrically-Modulated Stiffness for Human-Friendly Robotics

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Technology description

The presented dielectric elastomer system (DES) variable stiffness actuator (VSA) is designed to address the commercial challenges of a powered ankle-foot orthosis (PAFO) by optimizing peak power reduction in a compact device form factor. Fixed-stiffness, series elastic actuators have been used in PAFOs to reduce peak motor power, but their fixed stiffness values only yield optimal power reduction for one set of gait parameters. Since gait type, user weight, and gait speed are all parameters that vary during normal use of orthotic devices, VSA technology is desirable to compensate for these variations. State-of-the-art VSAs often have a bulky variable stiffness mechanism and an additional motor to control it. These extra components increase the cost, weight, and size of the actuator, and decrease its durability. Our design uses a DES to modulate actuator stiffness via changes in the electric field, thereby eliminating the requirement for a second motor and reducing the overall weight of the device. This innovation enables lighter, faster, and simpler stiffness modulation compared to traditional methods, allowing for improved portability and compliance with the user.

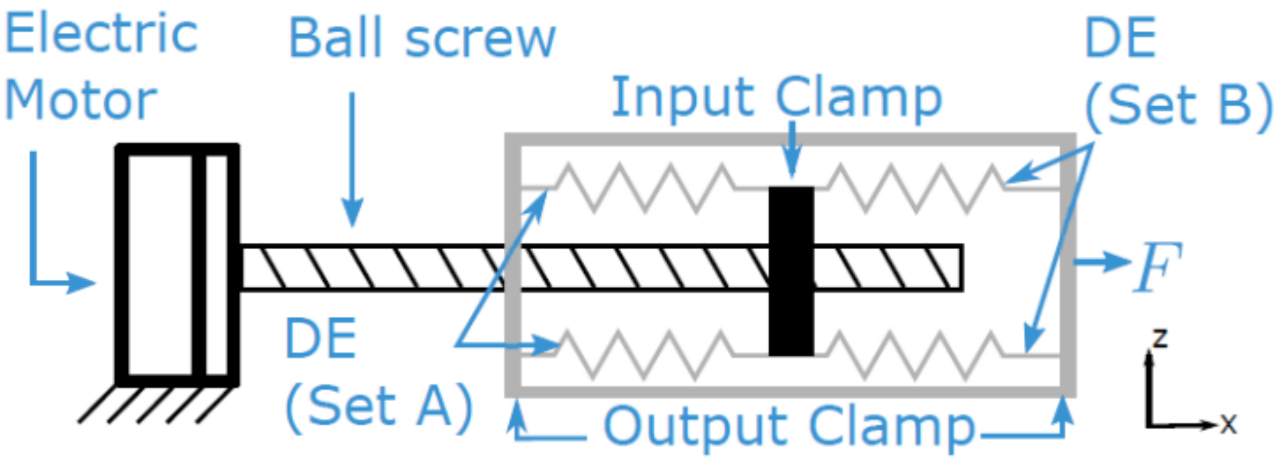

Figure 1: Schematic Representation of DES VSA Design.An electric motor drives a ball screw causing the input clamp to translate in the x-direction. The input clamp is elastically connected to the output clamp through two sets of dielectric elastomers (DE, represented as springs). The load (F) is applied to the output clamp.

Technical Summary:

The described design implements DE as series elastic elements, so that actuator stiffness can be modulated via changes in electric field. The prototype is designed to supplement human ankle torque during both normal and fast walking. The configuration of the DES could allow for regeneration of energy during cyclic operations, such as walking. Furthermore, the system can act as a strain sensor that measures force output of the actuator without requiring additional position or force sensors. The DES VSA actuated joint is back-drivable and capable of shock absorption, providing a safer human-machine interface than rigid orthosis and prosthesis actuators. It also provides stiffness modulation with less mechanical complexity than state-of-the-art VSAs.

Application area

Assistive Health Technology– Powered orthotic and prosthetic devices
Wearable Robotics– Exoskeletons, rehabilitation robots
Industrial Robotics– Beneficial for robots operating in variable environments; suitable for devices requiring light and compliant actuation
Human-Interaction Robots– Manufacturing robots that work side-by-side with humans, toy robots, exhibits

Advantages

The DES VSA establishes a novel approach towards orthotic and prosthetic devices that are capable of optimizing actuator stiffness and gait assistance throughout operation. This human-friendly design not only eliminates the need for a secondary stiffness-modulation motor (while improving modulation efficiency), but also enables energy regeneration, inherent force output measurements, and optimization of peak power reduction throughout use.
Power Efficient– Capable of reducing peak power requirements by 64 % over rigid actuator motors; cyclic operation (such as walking) enables regeneration of energy
Small Form Factor– Electrical modulation of actuator stiffness eliminates need for additional stiffness-modulation motor, reducing overall device size and weight
Active Stiffness Modulation– Adjustable stiffness throughout operation to compensate for changes in gait and maintain optimal peak power reduction
Inherent Control– Actuator output forces can be calculated from measured contraction/extension of the elastic element, reducing cost for closed-loop force control
Human-Friendly– Optimizes gait assistance by adjusting stiffness throughout operation; Actuated joint is back-drivable and capable of shock absorption

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