Clutchable Series Elastic Actuator for a Gait-Assistive Active Orthosis for Subjects with SCI

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Abstract

A spinal cord injury (SCI) disrupts the motor and sensory functions of the nervous system, limiting motion capabilities and reducing the quality of life of affected people. An active stance-control knee-ankle-foot orthosis was developed and tested to aid incomplete SCI subjects by increasing their mobility and independence [1]. A further improvement of the orthosis is conducted by the incorporation of elastic actuation to utilize advantages of the compliant system regarding efficiency and human-robot interaction, as well as the reproduction of the physiological compliance of the knee joint. The optimal structure and parameters is determined via optimization using elastic actuator models while considering the efficiencies of various components. This leads to the concept of a series elastic actuator with a locked actuator position during the first half of the gait cycle by an additional mechanism. The series compliance is selected to mimic the physiological stiffness of the knee. During the second half of the gait cycle, a desired motion of the knee is realized with an EC-motor, controlled by means of impedance control. The locking mechanism avoids operation of the motor in a period of the gait cycle, where its efficiency is low due to the respective torque-velocity characteristic. In addition, the selection of an optimal gear ratio for the second half of the gait cycle maximizes recoverable energy. Simulations of this clutchable series elastic actuator (CSEA) yield a theoretical generation of 1.52 J per gait cycle in contrast to a consumption of 6.3 J of the directly-actuated system. Control strategy and actuation system are implemented in a test bench, modeling the foot and shank as a pendulum. The conducted experiments provide a proof-of-concept while revealing gear friction as the main limitation of the system. Future work could improve the prototypic CSEA to generate a light and aesthetic design for the implementation at the active knee-ankle-foot orthosis.

References

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Short Biography

Florian Stuhlenmiller studies Mechanical and Process Engineering at Darmstadt University of Technology. He works on elastic actuation for assistive robotics since 2012 and (co-) authored several papers in international conferences. This work is conducted as part of his final degree project in cooperation with the Biomedical Engineering Research Centre at Universitat Politècnica de Catalunya in Barcelona.