Single-motor actuated semi-rigid hip exoskeleton design capable of assisting flexion and extension while walking

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Introduction

- Aim of design: to reduce the cost of walking by actuating the hip during walking
- Design is a soft exosuit with one actuator and two electroadhesive clutches per leg
- Most exoskeletons are commonly designed with rigid mechanical components which allow the necessary torque to be delivered but reduce the flexibility of the subject and add a significant amount of weight on the user
- Soft exoskeletons are an alternative that allow the user to maintain a high flexibility while being capable of delivering the necessary amount of force to assist [1]
- However while soft systems are lighter and do not inhibit the natural human movement of walking, they do not provide the support necessary to handle unwanted high compression forces transmitted to the individual
- The compromise of this semi-rigid design will allow for the support necessary to handle compressive forces while allowing flexibility and natural walking dynamics
- The preliminary results: manual actuation during walking shows that the design efficiently transfers force and is comfortable to the user

Design & Fabrication

Overall Design Consideration: To allow for all degrees of freedom of the hip to maintain full range of motion while efficiently supplying assistance to flexion and extension of each leg

Design Fabrication:

- Soft components - fabric knee and hip braces were sewn to a leather belt.
- Rigid components - Four pulleys redirect the force from the Bowden cable down to the site of the clutch. Any rigid-soft component joint was achieved with fasteners and washers on either side
- Clutch - the electroadhesive clutch was ordered from ESTAT Actuation [3]
- The exosuit consists of two hip braces sewn together and attached to a leather belt. On the belt, four pulleys are bolted on to redirect two cables. There are four attachment points, two per leg, two per phase of assistance.

Method

Exosuit

- Designed to be as flexible as possible
- Force delivered intended to be equivalent in efficiency
- Use of fabric garments with few rigid components to keep design light
- Actuation source: off-board Humotech cable actuator through Bowden cables

Force Engagement/Transmission

- The clutch was tested separately
- Four clutches are used in the design to differentiate flexion and extension assistance
- A rotary encoder digitizes the walking angle of the legs
- A control system analyzes the encoder signal and determines the correct timing to produce four torque spikes per gait cycle

Results

- Suit was tested for comfort and range of motion on a subject walking on treadmill while measuring metabolic cost as metric [2]
- Metabolic cost increased 20%
- A subject, while wearing the suit, has degrees of freedom in the flexion/extension axis, the abduction/adduction axis, and the internal/external rotation axis on each leg.
- The only actuated degree of freedom is in the flexion/extension axis.
- Clutch was tested for reliability and load capacity using up to 2kg of weight
- At 275V the clutch could reliably hold the weight

Fig. 1 Different angles of the exosuit design

Discussion

Exosuit

- The design produced was a flexible, comfortable, versatile device
- Increase in metabolic consumption will be addressed with a robust controller
- Next steps are tofine tune before validating or invalidating the design
- Design is controllable, comfortable, and versatile

Electroadhesive clutch

- The clutches in combination with a hip exoskeleton are the most notable developments
- Since the clutch is capable of transferring up to 100N of force [3] it allows for the design to reduce the amount of motors necessary

Conclusion and Future Works

- This project successfully produced a prototype hip exoskeleton capable of actuating both flexion and extension

Future Work

- Refine mechanical aspect
- Instrument exoskeleton with sensors
- Achieve controlled actuation with high level controller
- Undergoing thorough testing with the clutch mechanisms
- Collect more reference data
- Mobile version free to go out of the lab setting

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