Development of a powered knee-ankle prosthesis for transfemoral amputees

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August 31, 2012

Abstract

This paper presents the development of a powered knee-ankle prosthesis based on a variable compliance actuator. The prosthesis design is focused on the transfer of the energy dissipated by the knee during normal walking (negative work) to the ankle joint at plantar flexion (positive work). This work is part of the Cyberlegs project which consist in the development of a powered lower-limb orthosis-prosthesis system to assist unilateral amputees in daily activities.

The ankle joint of the prosthesis is assisted by a sliding-bar mechanically-adjustable-compliance-and-controllable-equilibrium-position actuator (MACCEPA), a variant of previous MACCEPA designs used for biologically inspired robots. In contrast to its predecessors based on cable transmissions [1], the sliding-bar MACCEPA has a rigid three-link configuration with a sliding bar, as shown in Figure 1. The new configuration preserves the energy-storage and variable-compliance functions of the previous actuators and avoids some of the problems related to the cable transmission (attachment issues, premature fatigue failure, etc.) The sliding-bar MACCEPA also provides a stiffening effect that might be convenient for human-robot interaction and the development of energy-efficient assistive devices [2].

In Figure 1, the nonlinear compliance of the actuator will be adjusted by means of a compression mechanism m that will act upon the linear spring of stiffness k. The torque at the ankle will be generated by controlling the position of the lever arm ac with respect to the fixed bar (attached to the shank of the prosthesis), and the interaction of the sliding bar cb and the spring (attached to the foot).

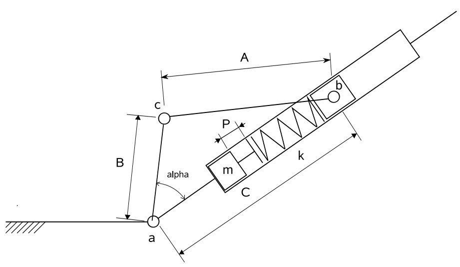

Figure 1: MACCEPA using rigid linkages.

Based on simulations of normal ankle-knee behavior during ground-level walking of a 80-kg person (see Figure 2), the sliding-bar MACCEPA with a linear stiffness of 100×10^3 N/m allows a reduction in the peak power of the ankle motor from 304 W to 110 W. This allows a reduction of the total weight of the system and a potential increase in both autonomy and level of assistance for the user. Elastomer springs will be used in the construction of the prototype to reduce the weight of the system.

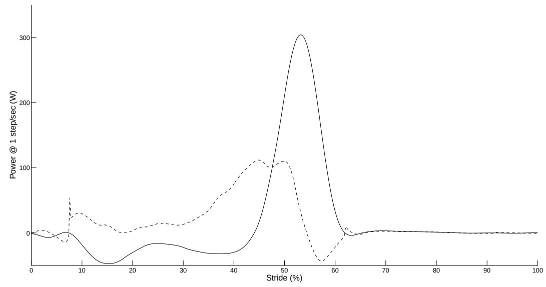

Figure 2: Ankle power during one gait cycle: Healthy ankle (solid line), motor (dashed line).

The combination of energy-storage elements and a connecting cable between the knee and the ankle joints is being explored to find an efficient way to transfer the energy dissipated at the knee to the ankle.

Acknowledgements

This work has been funded by the European Commissions 7th framework Program as part of the project Cyberlegs under grant no. 287894.

References

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