Experimental evaluation of actuation systems for a gait-assistive active orthosis using a test bench

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Abstract

In order to support spinal cord injured subjects in their daily life, a low-cost active knee-ankle-foot orthosis prototype is currently developed within the *Biomechanical Engineering Lab* of the *Universitat Politècnica de Catalunya.*

To fulfil the natural knee requirements and to ensure the safest interaction between the subject and the orthosis, the development of a series elastic actuator knee joint is an active research topic. To experimentally estimate the usefulness of such actuator, a test bench has been constructed in the lab, as represented in Figure 1. The test bench consists of the actuator to which loads can be submitted to simulate actual human gait, as it can be seen in Figure 2. A series of sensors are used and calibrated to control the system and have reliable measurements. Investigation of the theoretical dynamic behaviour of the system is done in order to compare with the experimental trials. Tests are used to determine the physical parameters and disturbances influencing the dynamics of the system.

The direct actuator as well as the series elastic actuator are firstly compared. For the highest loading phases, the series elastic actuator is able to locally reduce the mechanical power consumption thanks to energy recuperation in the spring. However, this effect is quite limited on the current test bench due to the high stiffness of the spring and hardware limitations, as it can be seen in Figure 3a for the corresponding stance phase of the gait cycle. The series elastic actuator might increase the comfort of the user as well as the human-orthosis interaction safety. The power consumption also depends on how accurate the position control system has to be.

On the other hand, an electromagnetic clutch is also implemented on the test bench to lock the system for small knee angle variations as it can be seen in Figure 3b. This is modifying the natural movement of the knee but may allow a decrease in the energy consumption.

Lastly, an electro-mechanical simulation tool of the system is implemented enabling offline results and improving the control.

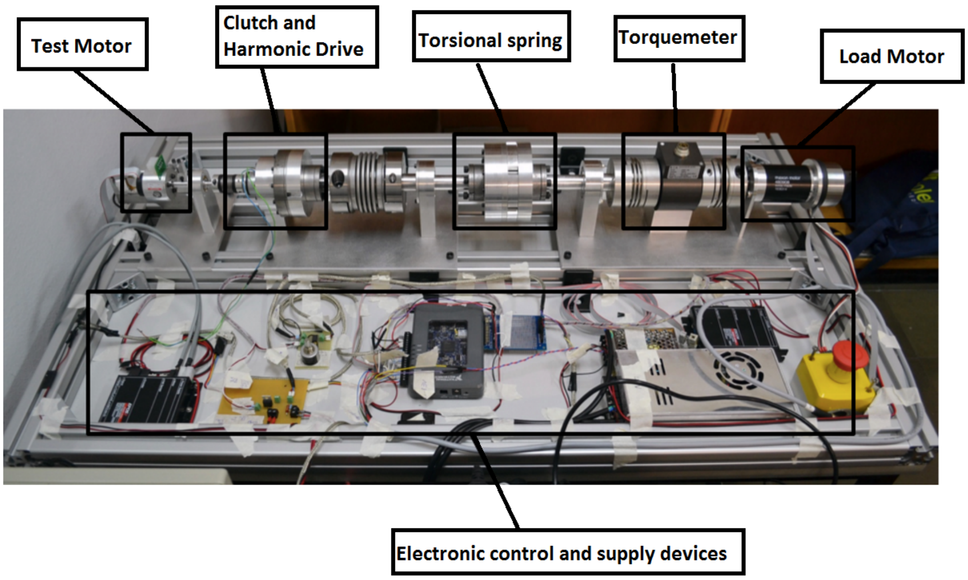
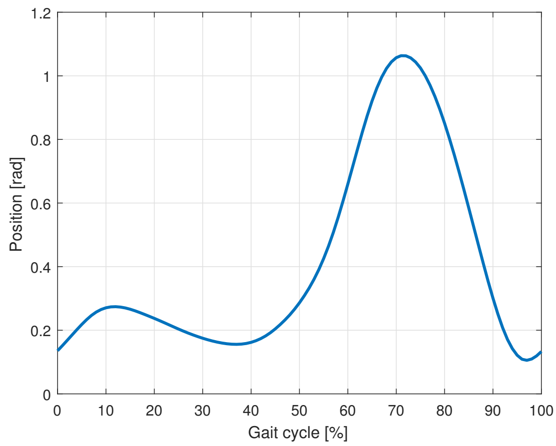
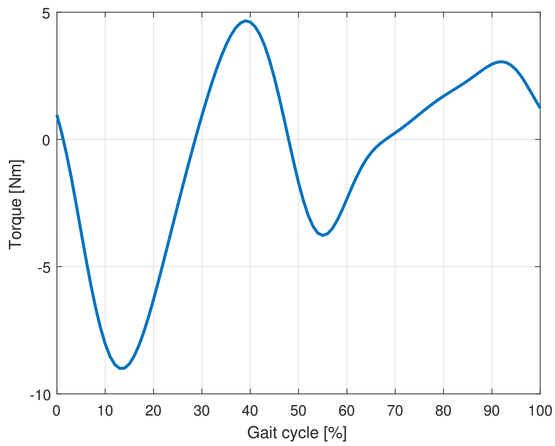


Figure 1: Test bench of the knee actuators

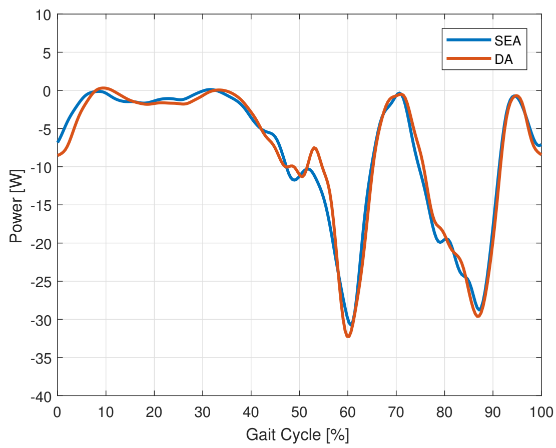


(a) Knee angle deflection during gait

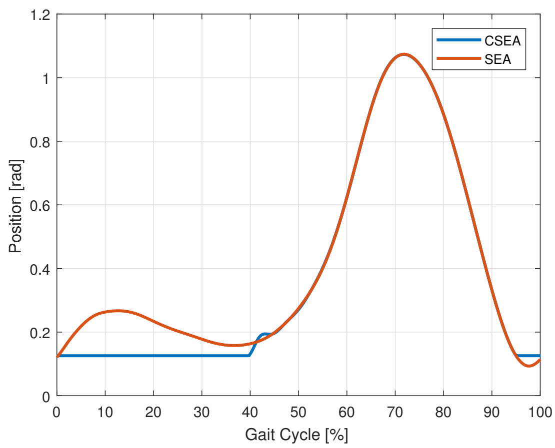


(b) External load torque applied on the knee during gait

Figure 2: Angle-torque characteristics used for the tests



(a) Experimental lost mechanical power during gait between the series elastic actuator (SEA) and the direct actuator (DA)



(b) Knee joint position comparison between the series elastic actuator (SEA) and the clutchable series elastic actuator (CSEA)

Figure 3: Experimental testing of the actuators