HYDRAULIC KNEE CONTROLLERS: AN ACCURATE TEST-BENCH FOR CHARACTERIZING A NOVEL MECHANICAL DEVICE

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INTRODUCTION

The hydraulic knee controller (HKC) – basically a component attached between the femoral and tibial section of the prosthetic knee – plays critical and essential roles in both stance and swing phase of human gait. Every HKC practically operates like a damper-accumulator of energy. Inside of it, a swing resistance adjustment device presents two distinct hydraulic circuits, each fitted with a control valve to adjust, in a selective and independent way, the oil flow - the resistance - during descent (joint flexion) and ascent (joint extension) of the piston rod in the unit.

Some studies have been published dealing with in-vivo tests of commercial HKCs (i.e. Ossur, Blatchford Endolite, etc) [1], but none dealt with rigorous bench-tests. ISS was asked to characterize a novel mechanical HKC by VPc, whose major differences with respect to the existing devices are: i) a novel swing phase controller; ii) the introduction of a geometrically variable tank filled with nitrogen gas, aimed at energy storing. The opportunity of changing pressure by means of an outer connector completes the unit features allowing to customize the dynamic performances of such unit, hence of the prosthetic knee, according to the patient activity level, also including sport activities.

METHODS

Test-bench. An accurate test-bench (relative error: 1.1%; displacement accuracy: 0.01mm) was arranged and implemented at ISS which was based on a MTS-858 Table Top System equipped with an actuator controlled by electrohydraulic servo-valves and a 2.5kN load cell. A digital controller features an high speed communication between hardware and software achieving data from test, signal conditioning with PID controllers and function generation for dynamic tests. Once the tests had been designed, ad hoc software procedures were implemented to suit with test requirements and to perform data acquisition and monitoring on delivered and recorded forces, displacements, and timing. A force limit detection process was enabled during compression and traction procedures in order to safe the device; an active compensator granted a correct output signal from command signal.

Test protocols. The device under test was connected to the test-bench by fixing its rod to the MTS rod and its bottom part to the MTS load cell. Force and displacement zeroing was performed at its rest position. During each test, and with the MTS working under high pressure conditions, a sinusoidal force command was applied over the rigid body connected to the load cell and, after a manual PID signal compensation, force and displacement data were collected.

Basically:

- the compression test procedure supplied: i) a constant velocity ramp from 0 to -20mm; ii) the data acquisition process during compression; iii) a slow ramp to return back to the starting position;
- the traction test procedure supplied: i) a positioning slow ramp from 0 to -20mm; ii) a constant velocity ramp from -20 to -2mm; iii) the data acquisition process during traction.

Tests aimed at characterizing and comparing the dynamic answer of the novel VPc HKC and of the traditional Catech 700R under fixed velocities ranging from 10 to 250mm/s, for a maximum rod stroke of 20mm. On both devices trials were repeated according to several valve adjustment levels, both for compression (knee flexion), and traction (knee extension). Data were collected at the sampling rate of 2000Hz and analysed in Excel.

Mechanical short fatigue tests – compression-traction for 48 hours, velocity 80mm/s, displacement 20mm – and maximum endurance tests – ramp of force from 0 up to the occurrence of 5mm displacement of the blocked rod, slope 25N/s - had also been designed and will be soon performed.

RESULTS AND DISCUSSION

Preliminary results clearly proved the good dynamic answer of VPc160 which perfectly acts like a damper-accumulator under both compression and traction. Its curves are much more constant than those obtained by Catech700R (Fig.1).

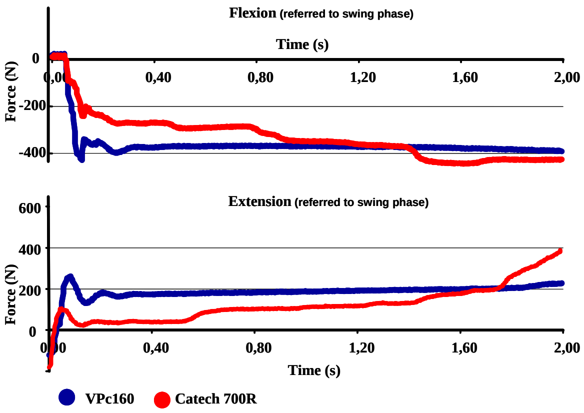

Figure 1: Compression and traction forces measured while testing VPc160 and Catech700R at 80mm/s.

CONCLUSIONS

The ISS test-bench proved to be highly reliable and to allow an accurate characterization of HKCs performances. Work is still in progress; anyway, preliminary results proved that the novel VPc160 has better dynamic performances than traditional HKCs in terms of damping and energy storage during landing and swing phases. The above features are critical to improve gait performances of amputees in both everyday life and sport activities.

REFERENCES

1. Hydraulic knee units Mauch, Ossur (Iceland), Hydraulic knee units Catech, Blatchford Endolite (UK).