Prototype of active ankle orthosis with specific actuator design and capitalizing on additive manufacturing

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I. INTRODUCTION

Stroke, spinal cord injury, cerebral palsy, and other medical conditions can strongly affect the ankle flexor and extensor muscles, which are crucial to provide vertical support and forward progression of the body during walking [1].

In this paper, we describe the prototype of active ankle orthosis developed in the framework of the FEDER project bio-manufacturing. The main originalities of the ptototype consist of an original actuator and an intensive usage of additive manufacturing.

II. ACTUATOR

A specific linear actuator has been designed from scratch. It is based on an hollow shaft brushless servomotor coupled with a roller screw which transforms the rotation of the shaft to a linear motion. This particular design brought on one hand a better compacity than commercial solutions and on the other hand a good efficiency thanks to a spring arranged in parallel with the actuator. The actuator has been dimensioned, according to simulation results and typical values of the mechanical power developed by a healthy ankle. It ensures the thrust in all phases of gait.

III. ADDITIVE MANUFACTURING

The additive manufacturing technique has been intensively used. Namely, the shells in contact with the patient are built in order to perfectly match the patient's morphology. In practice, a plaster mold of the patient's leg is realized and digitalized with the help of a 3D scanner. The corresponding geometry is retrieved in computer aided design software and is used to draw the complete orthosis with the actuator, the ankle hinge and the sensors. The model is checked by finite element and possibly revised to decrease the weight of the orthosis. For our application, 2 materials have been used : titanium alloys and resin. Titanium ensures good mechanical properties and lightness while resin is chosen for contact with the patient's skin. The titanium parts are built up layer-by-layer from titanium alloy powder melted by a powerful electron beam. The mechanical resistance of titanium enables to significantly decrease some sections of the prototype but also permits an original design.

IV. CONTROL

As classically proposed in recent developments [2], a compliant control is used during stance phase while position control is used for swing phase. It is managed by a state machine implemented on a microcontroller which detects the different phases of walking from various measurements, including pressure sensors put under the heel and under the toes. For the compliant control, the force exerted by the actuator is measured by a specific sensor. The compliance and the rest length implemented by the controller are adapted for heel support, flat foot and preswing phases. For the swing phase, the path to be followed is obtained by a PCPG [3] (Programmable Central Pattern Generator) algorithm. It is a kind of Fourier series decomposition and is composed of several adaptive oscillators. This algorithm is able to learn a standard gait pattern. Ideally, it could be derived from the subject himself before his accident or, more probably, from a similar subject in terms of gait parameters such as age, height, etc. For the long term, muscle signals (EMG) and/or brain signals (EEG) could enrich the physical measurements to improve the behavior of the orthosis and hopefully to anticipate the intention of the patient.

V. PHYSICAL TEST

Physical tests on a voluntary patient should be driven in a near future, within a collaboration with the hospital of Jolimont (La Louvière).

ACKNOWLEDGMENT

The authors want to express their gratitude for the financial support provided by Fonds Européen de Développement Régional and Région Wallonne.

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