A dynamic analysis of an integrated lower limb-orthosis model for interface contact pressures estimation

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Introduction

In this study, the integration of a knee-ankle-foot orthosis into a musculo-skeletal model of the lower limb has been carried out, in order to estimate the contact pressures developed at the subject-device interface. The study arises from a research project in which an active Stance-Control Knee-Ankle-Foot Orthosis (SCKAFO) prototype to assist the gait of incomplete spinal cord injured (SCI) subjects has been built[1]. From this design, a preliminary and simplified study of the human-orthosis contact interaction has been developed, considering the orthosis to be passive.

Materials and methods

The analysis has been performed along the entire human gait cycle. The lower limb-orthosis interaction has been modelled using two different contact models available in OpenSim[2]: the Hunt and Crossley (H&C) model and the Elastic Foundation Model (EFM). In both models, the contact has been assumed to be between spheres and planes[3], as it can be seen in Fig. 1.

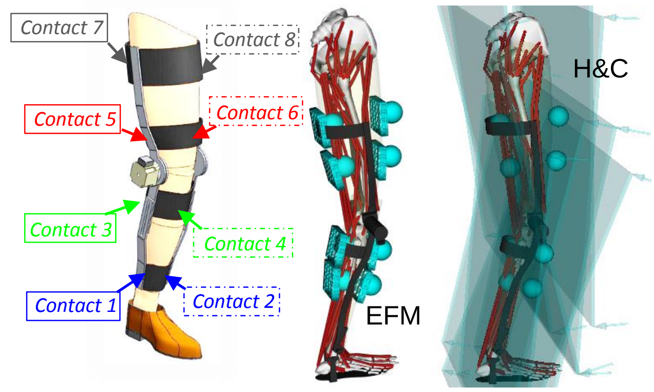

Fig. 1: Contact points numeration and integration of the orthosis using the EFM and H&C models.

Before having the orthosis integrated into the model, (i) normal gait motion data is captured in the laboratory; (ii) inverse kinematic analysis is done to obtain joint angles based on markers positions; (iii) inverse dynamic analysis is carried out, based on human and orthosis inertial parameters and ground reaction forces; (iv) finally, once the contact model is introduced, estimation of muscle forces leading to the measured kinematics is done with the Computed Muscle Control (CMC) tool in OpenSim. This algorithm allows calculating contact forces and, consequently, contact pressures.

The measured kinematics has been imposed to the leg, so the orthosis motion will be related to the contact forces developed at the lower limb-orthosis interface. Thus, a suitable contact model is necessary to generate those forces, so that the orthosis is able to follow the leg without slipping or producing extremely high contact pressures.

Results and discussion

The results of the simulation indicate that the contact pressures obtained using both models are below the Pressure Pain Thresholds[4] (PPT), above which the patient would feel pain and his or her tissues would be injured. Fig. 2 shows the pressures at the contacts defined in Fig. 1 when the H&C model is applied.

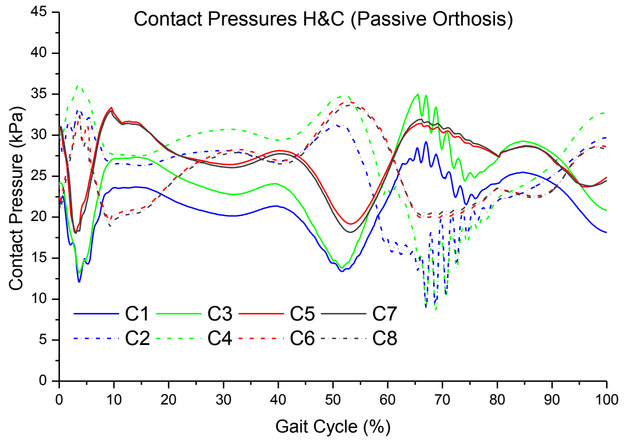

Fig. 2: Simulated contact pressures for the H&C case.

These pressures are sensitive to the number of contact points and their localization, to the mechanical properties of the contact surfaces, and to the main features of the orthosis such as its inertial parameters or the required adjustment of the straps to avoid oscillations.

Conclusion

This study presents a methodology to estimate the transmitted loads at the lower limb-orthosis interface using simple geometric shapes and contact models available in OpenSim. This approach can be useful to predict the gait of subjects wearing an assistive device. The resulting contact pressures are below the PPT and both models give realistic and comparable results. In future works, validation of results by experimental measurements will be investigated and actuation of the orthosis will be introduced to study the subject-orthosis co-actuation problem.

Acknowledgements

This work was supported by the Spanish Ministry of Economy and Competitiveness under the project DPI2012-38331-C03-2, co-funded by the European Union through ERDF funds.

References

[1] Font-Llagunes J.M. *et al.*, Procedia IUTAM. 2:68–81, 2011.
[2] Delp S. *et al*., IEEE T. Bio-Med Eng. 54:1940-1950, 2007.
[3] Silva P.C. *et al.*, Multibody Syst. Dyn. 24:367–388, 2010.
[4] Belda-Lois J.M. *et al*., Wearable Robots (Pons J.L., Ed.), John Wiley & Sons, Ltd. 154-156, 2008.