8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

OPTIMIZATION OF THE FORCE DISTRIBUTION AT THE LOWER LIMB/ORTHOSIS INTERFACE FOR COMFORT DESIGN

*** Paula Silva [1], Miguel Silva [2] and Jorge Martins [3]**

[1] IPSetúbal
ESTSetúbal
Campus IPS, Estefanilha,
2914-508 Setúbal, Portugal
psilva@est.ips.pt

[2] IDMEC/IST
Inst. Sup. Técnico
Av. Rovisco Pais 1
1049-001 Lisboa, Portugal
MiguelSilva@ist.utl.pt

[3] IDMEC/IST
Inst. Sup. Técnico
Av. Rovisco Pais 1
1049-001 Lisboa, Portugal
martins@dem.ist.utl.pt

Key Words: *Multibody model, orthosis AFO, forces distribution, optimization, comfort.*

ABSTRACT

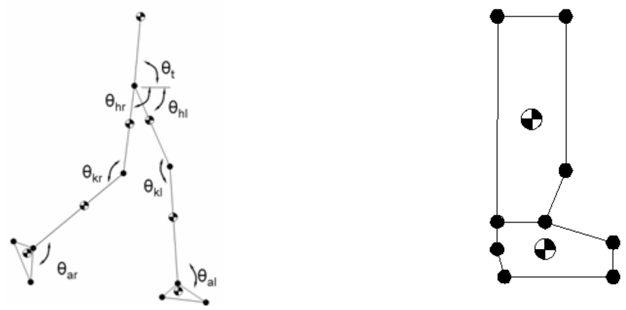
The design and development of orthoses has evolved largely by educated experience rather than by formal engineering methods [1]. In order to design an AFO (Ankle Foot Orthosis) one important step is to decide where the contact between the lower limb and the orthosis should occur and what are the forces generated in such interface. The knowledge of these forces is critical as they directly influence the performance of the device either in terms of body support, gait assistance and wear/use comfort. These forces are directly associated with the pressure and shear developed between the lower limb soft tissues and the AFO [2]. The application of optimization tools to minimize these is therefore addressed in this work and considered as a natural step towards the integrated design of orthotic devices.

A multibody formulation with natural coordinates is used for the description of the human lower extremity model [3]. The formulation considers that the position of each rigid segment is fully described by the Cartesian coordinates of a set of points located in specific anatomical landmarks which are usually associated with the joints and extremities of the anatomical segments. The selected multibody formulation generates dependent coordinates and therefore a set of algebraic kinematic constraints of rigid body and joint type is introduced to express these dependences. The equations of motion of the integrated model are assembled in a systematic way and solved in a forward dynamics approach as an initial value problem using a direct integration procedure.

The multibody model is 2D and described by nine rigid segments interconnected by ideal kinematic pairs that describe the biological joints. It integrates in a comprehensive manner the description of the human locomotion apparatus and the description of an AFO. The movement of the locomotion apparatus is prescribed throughout the analysis using kinematic data obtained in a gait lab for a stride of a healthy subject. The kinetic data is also acquired in the gait lab using a pressure plate and applied to the AFO model. The integrated multibody model allows for the estimation of the forces transmitted between both sub-models. The multibody model is briefly presented in Fig. 1.

The AFO model is attached to the human model by means of non-linear force elements and the contact between both systems described using a non-linear continuous contact/impact force model that accounts for the stiffness and damping characteristics of the surfaces in contact.

Maximum allowed forces on the lower limbs varies according to the localization of the contact area. Specific *loci* such as bony prominences and superficial nerves or vessels should be avoided for force transfer purposes [4]. Well established thresholds are available for comfort design and can be used during the optimization procedure to minimize the objective functions that account the contact forces and the contact areas with higher thresholds.



a) *b)*

Figure 1: Multibody integrated model: a) biomechanical model; b) AFO model.

The results depicted in Fig. 2 are preliminary but allow one to conclude that there is good integration between sub-models. It also show that the force elements and the non-linear contact/impact force model are working properly and therefore the optimization of the interface forces and corresponding contact areas can be carried out and used in the design of orthotic devices.

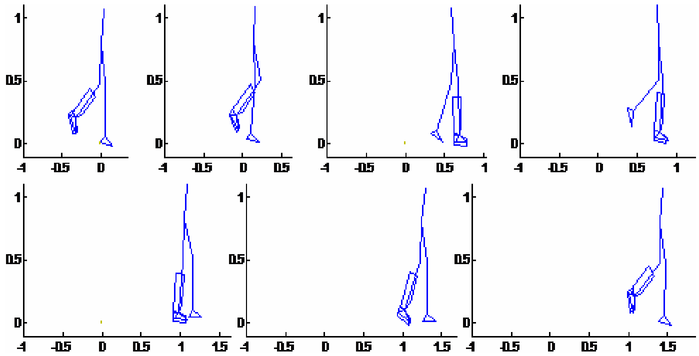


Figure 2: Simulation results of a gait stride.

REFERENCES

[1] G. Johnson, et al., "Performance specification for lower limb orthotic devices", *Clinical Biomechanics*, 19, p. 711-718, 2004.

[2] J.C. Moreno, F.J.B., J.L. Pons, J.M. Baydal, R. Barberà, "Rationale for Multiple Compensation of Muscle Weakness Walking with a Wearable Robotic Orthosis", in *IEEE International Conference on Robotics and Automation*, Spain, 2005.

[3] J. Jalón and E. Bayo, *Kinematic and Dynamic Simulation of Multibody Systems - The Real Time Challenge*, Springer-Verlag, 1993.

[4] R. Goonetilleke, "Designing to minimize discomfort", *Ergonomics in Design*, vol 3, July, 1998.