Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
*Young Researches and Scientist Paper / * Supervisor, Mentor*

DESIGN OF A NEW HUMAN KNEE PROSTHESIS BASED ON CAM MECHANISM

COPILUSI, C[ristian] P[etre]; MARIN, M[ihnea] I[on]* & RUSU, L[igia] D[iana]

Abstract: *In this paper, we intend to elaborate a new prosthetic mechanical system used in the human lower limb structure knee joint disarticulation. The prosthetic system includes a cam mechanism that assures the angular amplitude corresponding to the one created by the human knee joint but it also ensures the damping necessary for extension/ flexion process fulfilment. The design of this prosthesis includes a kinematic and dynamic study of the human lower limb with a view to obtaining the connection forces and the motion law developed at the knee joint level. By means of this important data, we will be able to establish some dimensions and to adapt the new prosthetic system to the human lower limb structure. The new mechanism has a FESTO shock absorber integrated in his structure.*
Key words: *cam mechanism, knee prosthesis, dynamics.*

1. INTRODUCTION

As far as knee prostheses are concerned, they are made up of mechanisms developed to ensure a complete flexion process for different human activities (walking, stair climbing, changing the body position, etc.). For example, figure 1 shows the Otto Bock 3R95 mechanism as an ordinary prosthesis mechanism. At present, different prosthetic mechanism types are used in this special field of biomechanics, but none of them uses cam mechanisms. One also knows the advantages and disadvantages for all prosthesis types used for amputees.

The main characteristics that have to fulfil an ordinary prosthesis mechanism are: construction simplicity, low weight, shockless amortization, easy dumper coefficient adjusting possibility, etc. We consider the fabrication costs a main disadvantage. From this viewpoint, modern knee prosthesis cannot be cheap in order to be accessible for any social citizen category.

By implementing a cam mechanism in a new prosthetic mechanism design, we took into account the main characteristics and the fabrication price in such a manner, that the new prosthesis mechanism can achieve high performances at a low price acquisition point.

In the other paper (Copilusi et al., 2009) significant results were got by implementing a cam mechanism in ankle prosthesis structure.

By taking into account the experimental cinematic analysis in the PhD Thesis (Copilusi, 2009) performed by means of SIMI Motion, (SIMI Reality Motion Systems GmbH, 2007) at the Faculty of Physical Education and Sport, University of Craiova, we obtained the angular amplitude for human knee joint. Figure 2 shows the walking process. The angular amplitude developed by a male lacking locomotion disability was 46 degrees. We obtained the kinematic parameters by means of video capture and image analysis. The diagram in figure 2 made us conclude that the prosthesis must take into account the angular amplitude at the knee joint, which is 40…65 degrees.

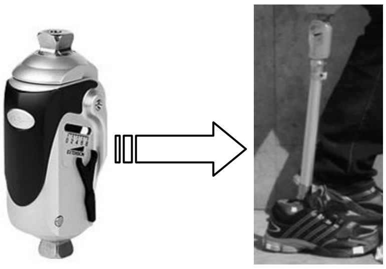

Fig. 1. Otto Bock 3R95 knee prosthesis mechanism

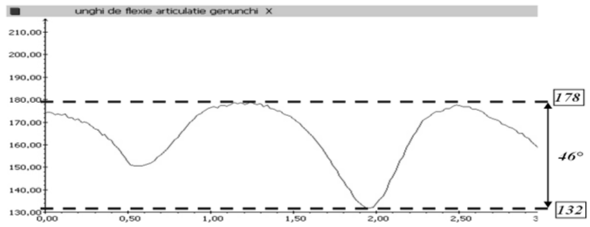

Fig. 2. Knee angular displacement, – flexion/extension, depending on time

2. DYNAMIC MODEL ELABORATION EQUIVALENT TO HUMAN LOWER LIMB

We elaborated the mathematic model for the human lower limb inverse dynamic analysis (figure 3) by taking into account the experimental kinematic analysis (Dumitru & Nanu, 2008). Using an algorithm performed in MAPLE program, we calculate the connection forces of the mathematic model kinematic joints (Copilusi, 2009).

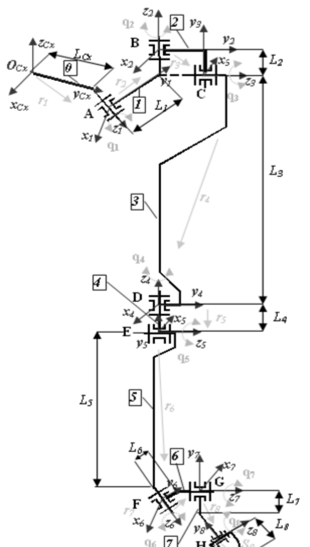

Fig. 3. The human lower limb kinematic scheme

The relations for computing these connection forces, by considering the Lagrange multipliers are:

$$\begin{cases} F_i^{''r(i,j)} = [R_{i,i''}]^T \cdot \left[A_{oi}\right]^T \cdot \left[\lambda\right]^{(i,j)} \\ T_i^{''r(i,j)} = \left[\left\{S_i^{'M}\right\}^T \cdot \left[P_{oi}\right]^T \cdot \left[I\right] - \left\{S_i^{'M}\right\}^T \cdot \left[P_{oi}\right]^T \left[\lambda\right]^{(i,j)} \right] \end{cases} \quad (1)$$

The connection force component variation for the knee joint is presented in figure 4. With this connection force we can develop a mechanical system used in a new prosthesis design and it help us to create virtual simulations in order to validate the mechanical system proposed to use in the new prosthesis structure.

3. THE NEW PROSTEHSIS SYSTEM DESIGN

Regarding the anterior data, the best mechanism which can be implemented on the prosthesis structure was a cam mechanism. We integrated the FESTO YSR-20-25-C shock absorber in the prosthesis resistance structure, which enables some axial adjustments with a view to establishing the prosthesis alignment. Figure 5 shows the new knee prosthesis design. This is where we identify 1-femur component, 2-cilindrical joint, 3- cam follower, 4- cam, 5- tibia component, 6-FESTO shock absorber, 7-aditional shock absorber mechanism. After simulating the virtual model and validating the cam mechanism through calculation, we executed and adapted this prosthesis in accordance with an amputee's needs and suggestions (Dumitru & Margine, 2000). In figure 6, we present an aspect from the new prosthesis experimental tests.

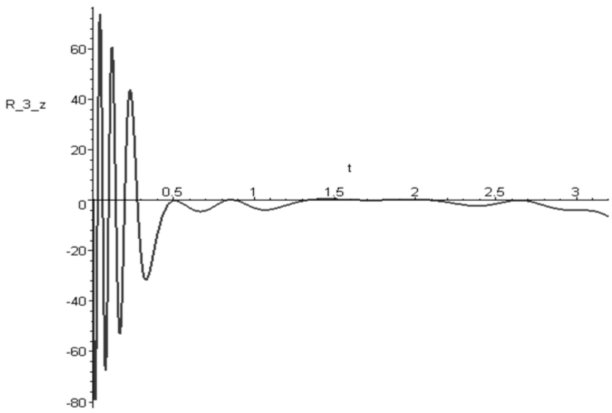

Fig. 4. The variation of the connection force for the knee joint on z direction

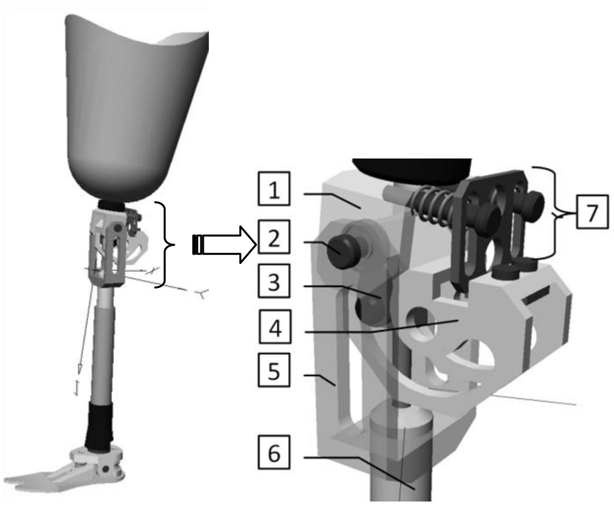

Fig. 5. Virtual model of the prosthesis used in human knee disarticulations

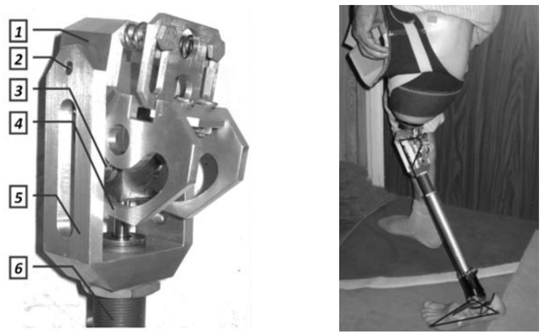

Fig. 6. The new knee prosthesis and an aspect from the new prosthesis experimental tests achieved with SIMI Motion software

4. CONCLUSIONS

The cam mechanism represents the novelty element of this prosthesis. We perfectly adapted this mechanism, which obeys the imposed conditions, to the prosthesis structure. The amplitude developed by the new prosthetic mechanical system, which replaces the knee joint functions (flexion/extension in walking activity), was 63 degrees (figure 7). This value is comparable with the one of a human subject without locomotion disabilities (about 40°… 65°). This confirms the prostheses improvement used in human lower limb amputations from above the knee disarticulations. The next research step will be to perform other experimental tests, (stairs climbing, dancing, running, etc.) in order to improove the quality of this prosthesis type. In the future we want to apply the theoretical methods used for this prosthesis design, on a new human lower limb orthoses development.

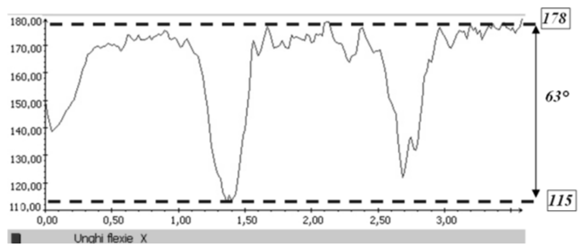

Fig. 7. The new prosthesis flexion/extension angular displacement variation, depending on time

5. REFERENCES

Copilusi, C., Dumitru N., Rusu L., Marin M.; (2009). Implementation of a Cam Mechanism in a New Human Ankle Prosthesis Structure, DAAAM International Conference, pp. 481-483, ISSN 1726-9679, Vienna.

Copilusi, C.; (2009). Researches Regarding Some Mechanical Systems Applicable in Medicine, PhD. Thesis, Faculty of Mechanics, Craiova.

Dumitru, N.; Nanu, G.; Vintilă, D.; (2008). *Mechanisms and Mechanical Transmissions. Modern and Classical Design Techniques*, didactic printing house, ISBN 978-973-31-2332-3, Bucharest.

Dumitru, N.; Margine, A.; (2000). *Modelling Bases in Mechanical Engineering,* Universitaria printing house, ISBN 973-8043-68-7, Craiova.

McGeer, T.; (1990). Passive Dynamic Walking, *International Journal of Robotics Research*, vol. 9, no. 2, pp. 62-82.

*** (2007) http://www.simi.com - SIMI Motion, SIMI Reality Motion Systems GmbH, *Accessed on: 2007-09-18*

*** (2006) http://www.southwest-ortho.com - Southwest Orthotic Centre, *Accessed on: 2006-08-13*

*** (2008) http://www.ottobock.com - Otto Bock Prosthetics Institution, *Accessed on: 2008-10-25*