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FRICTION FORCE DETERMINATION FOR A UNICOMPARTIMENTAL KNEE PROSTHESIS

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Abstract: *Using an unicompartimental knee prosthesis design a simplified calculus model was performed by means of the finite element method in order to determine the friction force between the two prosthesis components. HEMA (hydroxilmethacrilat) was considered as material for the tibial component, because presents mechanical proprieties similar to the ones for the human cartilage and for the femoral component were considered three types of titanium alloys. The results obtained for these three types of titanium alloys were compared.*

Keywords: *knee prosthesis, Ti12Mo alloy, Ti25Nb25Ta alloy, friction force, HEMA, friction coefficient*

1. INTRODUCTION

The shortcomings of the titanium alloys currently used for manufacturing prosthesis consist in adverse reactions due to the release of Al and V ions after long term use in biological enviorement. Another disadvantage is given by their poor tribological behaviour (Long & Rack 1998, Zardiackas 2006). Therefore, new titanium alloys that exceed these incovenients have been analyzed from a wear behaviour point of view. (Crisan et al. 2011). Models of knee joint with or without prosthesis are numerous in literature. The study presented in this paper has a comparative character. For this, a simplified model of the knee hemiarthroplasty was considered for the calculations performed by finite element method.

In (Crisan et al. 2011) the friction coefficients were experimentally determined for the material couple Ti6Al4V, Ti12Mo (Gordin et al. 2005) and Ti25Nb25Ta (Bertrand et al. 2010) – used for the femoral component, slided against a HEMA counterface – used for tibial component (table 1, columm 3).

2. CALCULUS MODEL

In literature exists many models for numerical simulations, which use the finite element method. Using this type of simulations, the distributions and values for the stress for both prosthesis components can be obtained.

The study presented in this paper, having a comparative character, a simplified calculus model was considered. The particular differences in the behavior of each type of titanium alloy were followed. For this, not all parameters that could influence the results were taken into account.

So the developed model presents the following simplifications:

- relative movement restriction in the anterior-posterios plane, made in reality by the crosslinked ligaments inserted on the femoral condyl, was performed on the model by blocking in this plane the displacement of the elements situated on the model lateral sides;
- the total blocade of the tibial component support surface on the tibial bone;
- in the simulated flexion movement, for which the stress analysis was performed, the possibility of femoral bone pivoting movement was not considered;
- the materials used to manufacture the prosthesis component had a constant Young modulus;
- the yield limit is not exceeded in any point, so the problem is a linear one from a material point of view.

The outline of the prosthesis components, taken into account for elaborating the calculus model was made using the dimensions from the product catalogue PROTETIM.

The analysis for the stress and strain state was carried out using the SolidWorks 2010 software. Because of the complicated geometrical shape, elements type tetrahedron with 10 nodes were used for the mesh, resulting a network with 7574 elements and 12285 nodes with 35745 degrees of freedom. The femoral component lateral flanks and the tibial component contact surface with the tibia were blocked.

The calculus model, the considered blocades and the load are shown in figure 1.

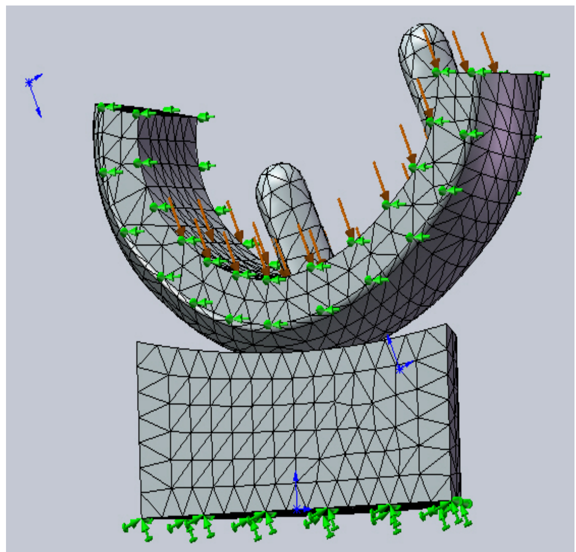

Fig. 1. Calculus model – blocades and load applied

Because the structure considered consistis of two components of different materials, it was necessary to solve the nonlinear contact problem of the two surfaces. It was choosed an incremental approach. The number of steps was generated automatically by the software.

A load of 1200N was applied vertically on the joint. Only 600N were considered to act on the unicompartimental prosthesis.

The numerical simulations were performed for nine flexion positions of the femur on the tibia. The maximum value was obtained for the 10° position – position of maximum demand.

3. RESULTS

The diagram for maximum stress variation by the angle of flexion between the tibial axis and the femur one is shown in figure 2 for the material couple Ti25Nb25Ta/HEMA.

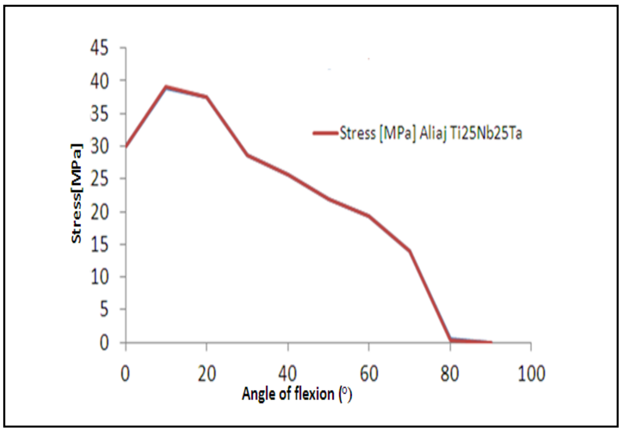

Fig. 2. The diagram for maximul stress variation for Ti25Nb25Ta/HEMA

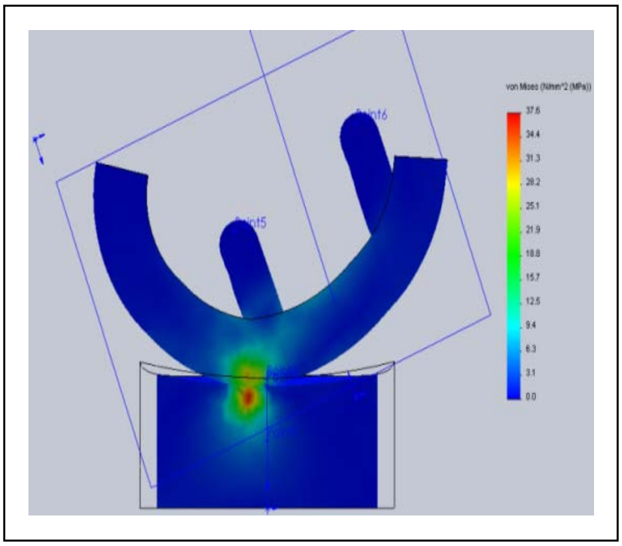

Fig. 3. The stress distribution in prosthesis components for 10° position for Ti25Nb25Ta alloy

As example, in figure 3 is given the shape of distribution of stresses in the prosthesis components and in figure 4 the distribution of stresses, σ_n, on normal direction on the contact spot for Ti25Nb25Ta alloy femoral component. By these stresses the friction force F_n was calculated:

$$F_n = \mu \iint \sigma_n \, dA \qquad (1)$$

A= contact spot area;
μ = friction coefficient – experimentally determined;
The values from table 1 have resulted

Femural component	Tibial component	μ	F_n[N]	F_f[N]
Ti12Mo	HEMA	0.5	212.475	106.23
Ti25Nb25Ta		0.4	245.871	98.34
Ti6Al4V		0.7	212.711	148.89

Tab. 1. Results for friction force

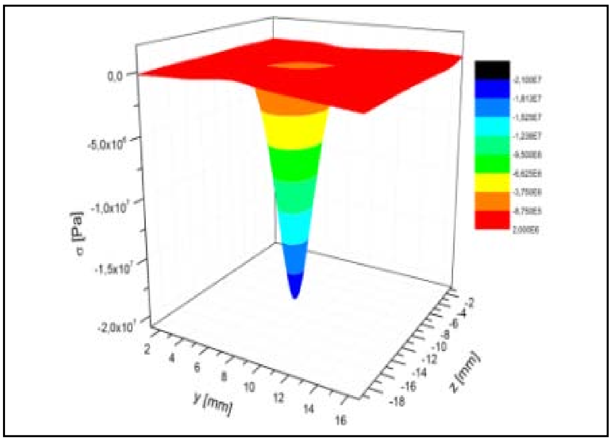

Fig. 4. The normal stress in contact spot for Ti25Nb25Ta femoral component

4. CONCLUSIONS

The analysis of stresses and movements showed that the worst position is when the tibial axis is tilted at 10° from the one for the femur.

In comparison with the Ti6Al4V alloy component, currently in use, there were no significant differences in term of stresses distributions.

The two new titanium alloys, Ti12Mo and Ti25Nb25Ta produce a lower friction force than Ti6Al4V alloy. The normal force at the contact spot for the Ti25Nb25Ta is higher, but because of its lower friction coefficient, the friction force in this case is the smallest.

5. ACKNOWLEDGEMENTS

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