THE STUDY OF STRESS DISTRIBUTION FOR THE FEMORAL BONE IN BIPODAL SUPPORT – 3D MODELING

A.I. BOTEAN[1] I. TAKACS[1] M. HARDAU[1]

Abstract: *Considering bipodal position, each of the two femoral bones take over half the body weight, the main load that they are subject to beeing the eccentric compression.*
The purpose of this paper is the qualitative evaluation of the femoral bone in the proximal area. The experimental method used is photoelasticimetry through transparency, while for the numerical analisys we used the finite element method (ANSYS).

Keywords: *femoral bone, bipodal support, 3D scanning, photoelasticimetry.*

1. Introduction

The study of the state of stresses in the femoral bone raises a number of problems due to the high co mplexity of the bone structure geometry and the v ariety of mechanical characteristics in different areas of the bone such as the distal end, the shaft and the proximal end. [1].

The 3D analysis starts from a plane model [2] (Figure 1) were was highlighted the state of stresses distribution, particularly the proximal femur, an area where, in certain situations (accidents, osteoporosis, etc.) can occ ur cracks or fractures [3] (Figure 2).

The object of th is study is to qualitatively determine the state of streses for the 3D model (Fig. 3) using both the finite element method and photoelasticimetry through transparency.

Due to the complexity of the exter ior geometry, for the finite element analysis the surface of the real model was scanned and for t he photoelastic study an impression (mold) of t he human femoral bone was done using silicone.

2. Numerical analysis

Scanning the real model involves surface preparation in advance by covering the surface areas of the insertion points of the tendons with a layer of putty then appling a coat of clear lacquer. Using STINGER II system (Figure 4) was ob taind a cloud of points (approximately 14 x 10^6 points) (Figure 5). Using this basis a polygonal surface was generat ed, which was converted into a CAD model (Figure 6) and imported in finite element analysis program (Figure 7 and Figure 8)

3. Experimental analysis

[1] Technical University of Cluj-Napoca, Department of Mechanical Engineering (Strenght of Materials), Romania.

For the experimental analysis it was used photoelasticimetry through transparency as the method. Here the trial is conducted on a cast model made from an optically active material.

To obtain the cas t model we did an impression of the real fe moral bone in order to obtain a mold made from silicone Essil 291 that is mainly used for rapid prototyping (Fig. 9). T he mold has two parts and the main reason why we ch oose silicone Essil 291 for its realization is that once it has cured, it retains flexibility.

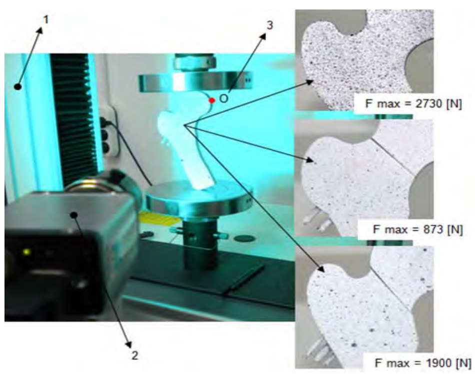

Fig. 1. *Experimental setup: 1) Instron 3366; 2) Q-400 DIC system; 3) the point were the displacement is measured*

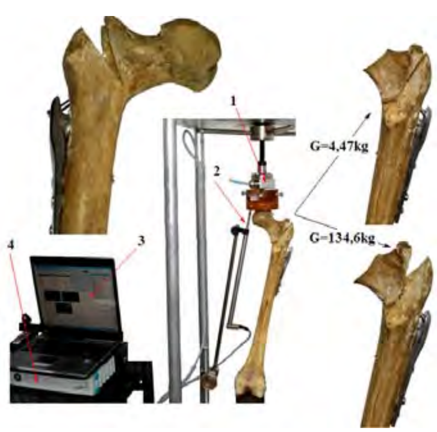

Fig. 2. *Experimental setup for testing the model with the DHS system: 1 - force transducer; 2 – displacement transducer; 3 – data acquisition interface; 4 – Spider8.*

The optical active ma terial used for casting the model is epoxy resin. To avoid yellow areas due to t he phenomenon of accelerated polymetization, the amount of hardner used should vary between 7-8 %.

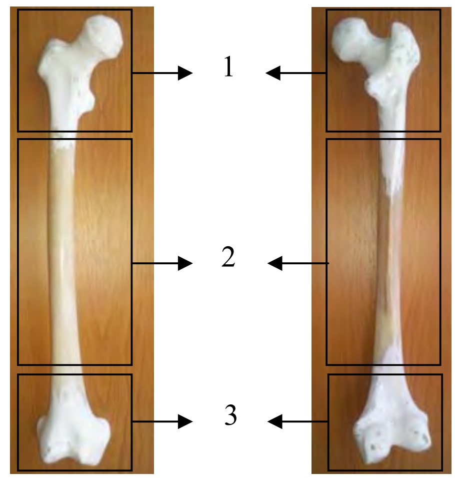

Fig. 3. *Real femoral bone model: 1 – proximal femur; 2 – the shaft; 3 – distal femur*

Fig. 4. *Scanning the femoral bone: 1 – the femur; 2 –STINGER II system; 3 – sensor.*

Fig. 5. *The cloud of points aquired with STINGER II system – proximal femur*

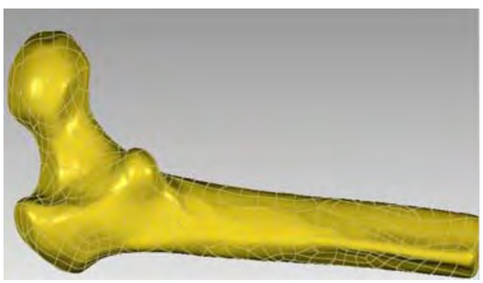

Fig. 6. *Cloud of points transformed in CAD object*

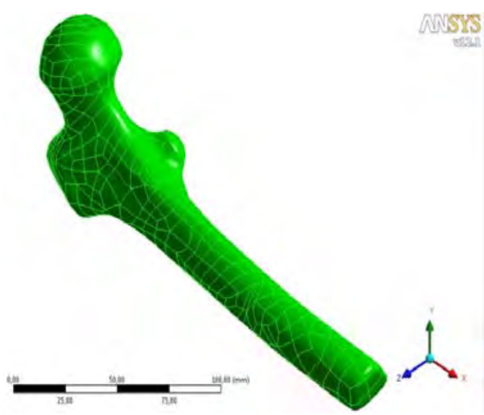

Fig. 7. *CAD model imported in the finite element analysing program ANSYS*

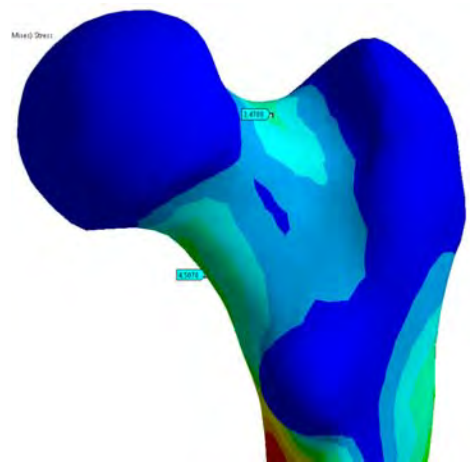

Fig. 8. *Distribution of equivalent stresses in the femoral neck area*

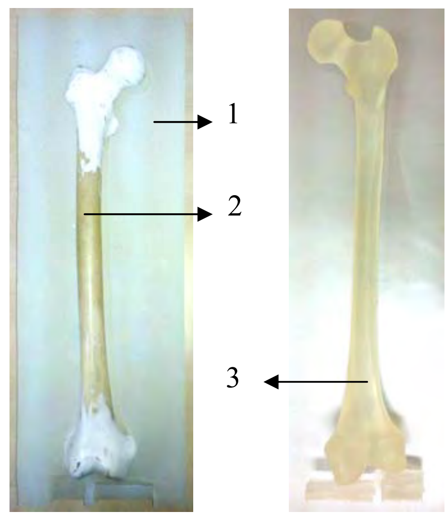

Fig. 9. *Obtaining the epoxy resin model: 1 – silicone mold; 2 – human femoral bone; 3 – epoxy resin cast.*

For complete polimerization the model takes about three days, the surface obtained is identical to the real bone.

The 3D epoxy model was loaded with compressive force and placed in the oven at 90 degreed Celsius for one hour, the cooled within two degrees Celsius / hou r. To assess the state of stresses a lenghtwise strip was cut.

In Figure 10 is prezented the distribution of the fringes in the proximal femur area.

In the femoral neck area two singularity points can be noticed; in their surrounding the rank of the fringes has the value k=2. Carefully observing Figure 10 it can be said that the requested maximum area of the proximal femur is the femoral neck.

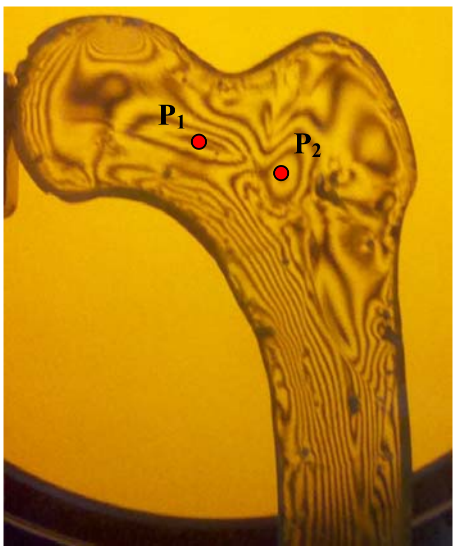

Fig. 10. *Qualitativ evaluation of the state of stresses; P_1 and P_2 representing the singularity points in the proximal femur area*

Acknowledgements

This paper was supported by the project "Improvement of the doctoral studies quality in engineering science for development of the knowledge based society-QDOC" contract no. POSDRU/107/1.5/S/78534, project co-funded by the European Social Fund through the Sectorial Operational Program Human Resources 2007-2013.

4. Conclusions

It was noted that the requested maximum level area of the plane model [4] coincides with the 3D model, thus validi ng the method of study for the following studies that will focus on the state of stresses of the femoral bone.

The novelty element presented in this paper is the CAD model of the femoral bone made of the cloud of points obtained from the 3D scanning STINGER II.

The qualitative findings of th e state of stresses in the p roximal femur done with photoelasticimetry through transparency method were confirmed by the numerical study.

The following research directions can be highlight:

- femoral bone geometry modeling considering its variable longitudinal and transverse section to study its behavior for bending and buckling loads.
- the study of field of displacements and state of stresses on the human femur.

References

1. Takacs, I.A., Botean, A.I, et.al.: *Studiul fortelor care actioneaza asupra osului femural*, A XI-a Conferinta Nationala multidisciplinara – cu participare internationala “Profesorul Dorin Pavel – fondatorul hidroenergeticii romanesti”, Sebes, 2011.
2. Takacs, I.A., Botean, A.I., et.al.: *Numerical and experimental analysis of the state of stresses of the femoral neck - plane modeling*, YSESM, Chemnitz, Germany, 2011.
3. Botean, A.I., Takacs, I.A., et.al.: *The study of massive trochanterion fractures*, Meditech, Cluj-Napoca, Romania, 2011.
4. Botean, A.I., Takacs, I .A.: *Photoelasticimetry applications in biomechanics*, Acta Technica Napocensis, 2011.