Computational modeling of the behaviour of the ceramic head for total hip joint endoprosthesis

***†V. Fuis[1] and P. Janicek[1]**

[1]Institute of Thermomechanics - The Czech Academy of Sciences – branch Brno, Technicka 2, Brno, Czech Republic.

*Presenting author: fuis@fme.vutbr.cz
†Corresponding author: fuis@fme.vutbr.cz

Abstract

Functioning of every joint in human organism is ensured by the kinematic pair between two adjoining bones. Loss of the functionality of the kinematic pair in the form of pathologic changes to contact surfaces means that the joint loses its functionality. The most frequent cause of these changes consists in degradation changes in cartilages, sometimes leading to entire disappearance. The joint function can be reestablished by surgery – implanting of the total endoprosthesis (currently mostly hip, knee and elbow).

Instances of *in vivo* fractures of the ceramic (Al_2O_3) heads fixed to the austenitic steel stem have been recorded lately in a statistically significant number of patients having total hip joint endoprosthesis (see Fig. 1). The results of computational and experimental modelling have shown that one of the causes for the above damage lies in the shape deviations from the ideal shape of the conical contacting surfaces of the head and the stem [Fuis (2009)]. These deviations can be divided into macro-shape (deviations from global parameters, e.g. taper and ovality) and micro-shape that are superposed on the macro-shape deviations [Fuis (2009)]. The shape deviations of the cone contact areas increase the tensile stresses in the ceramic head (calculated using FEM system ANSYS) and therefore reduce the head's reliability based on the Weibull weakest link theory [Bush (1993)]. Mentioned analyses were realized under conditions (ISO 7206-5 - testing of the ceramic heads, or oblique loading) where the head's loading is different from the physiological loading during the gait process [Bergmann et al. (1993); Bergmann et al. (2010)].

The research has been supported by the project of the Czech Science Foundation GA CR nr. 13-34632S "Increasing the level of computational modeling of the behaviour of the ceramic head for total hip joint endoprosthesis".

Figure 1. In vivo destructed hip joint ceramic heads

Keywords: Hip joint endoprosthesis, Destructed ceramic heads, Weibull weakest link theory, Material parameters of bioceramics, Destruction tests

References

Bergmann, G., Graichen, F.and Rohlmann, A. (1993) Hip Joint Loading During Walking and Running Mesured in two Patients. Journal of Biomechanics, Vol. 26, No. 8, 969-990.

Bergmann G., Graichen, F., Rohlmann A., Bender A., Heinlein B., Duda G. N., Heller M. O. and Morlock, M. M. (2010) Realistic loads for testing hip implants. Biomed Mater Eng. 20(2), 65-75.

Bush, D. (1993) Designing ceramic components for structural applications. Journal of Materials Engineering and Performance, ASM Int., 2, 851-862.

Fuis, V. (2009) Tensile Stress Analysis of the Ceramic Head with Micro and Macro Shape Deviations of the Contact Areas, Recent Advances in Mechatronics: 2008-2009, Proc. International Conference on Mechatronics, Brno, Czech Rep., 425-430.

ISO 7206-5 (1992) Implants for surgery - Partial and total hip joint prostheses. Determination of resistance to static load of head and neck region of stemmed femoral components.