18th International Conference
ENGINEERING MECHANICS 2012
Svratka, Czech Republic, May 14 – 17, 2012

pp. 344–345
Paper #340

RELATIONSHIP BETWEEN FATIGUE LIFE AND STRUCTURE OF HUMAN TRABECULAR BONE

T. Topoliński*, A. Mazurkiewicz**

Abstract: *In the work results of investigation of fatigue behaviour of human trabecular bone are presented. In total, 61 samples were collected from human trabecular bone after hip arthroplasty. Samples were examined on microCT device. As the result, values of four structural indices (BV/TV, Tb.Th, Tb.N and BS/BV) describing the structure of trabecular bone were obtained. The fatigue tests of the samples were carried out with stepwise increasing amplitude. From the test obtained fatigue life N_s was found between $3{,}75 \cdot 10^3$ cycles and $5{,}02 \cdot 10^4$ cycles. Relations between fatigue life and structure indices were described by determination coefficient R^2. Values of the coefficient were found in range 0,49-0,69. On the base of the obtained results we ascertained existing relation between selected structure indices and fatigue life obtained from test with stepwise increasing amplitude.*

Keywords: ***Trabecular bone, Fatigue life, Structure indices of trabecular bone***

1. Introduction

A typical loading for bone, e.g. during gait is the cyclic loading variable in time, and thus behaviors under such loading are fatigue behaviors (Taylor & Tanner, 1997; Martin, 2003).

The aim of the work is to determine relationship between fatigue life under cyclic loadings with stepwise increasing amplitude and structural indices of human trabecular bone.

2. Material and Method

Investigated material were 61 samples of human trabecular bone. Samples were collected from osteoporotic and coxarthrotic femoral heads gained in result of hip arthroplasty. Diameter of the samples was 10 mm and height 8,5 mm. The age of the patients ranged from 46 to 88 years with an average of 73 years. The samples were obtained from 40 women and 21 men and were stored in 10% formalin solution at the room temperature. Samples were examined using a microCT device (μCT80) with resolution 36 microns (parameters: 70 kV, 114 μA, 500 projections/180°, 300 ms integration time).

The bone sample fatigue tests were carried out under compression with stepwise increasing loading using the testing machine INSTRON 8874. The frequency of sinusoidal loading was 1 Hz, the minimum loading for all the loading levels was 5-7 N. The maximum loading started from 20 N with a gain every 10 N at successive steps. Each level of load maintained 500 cycles realized under constant amplitude loadings. Program of the fatigue test is presented in Fig. 1.

The test was conducted in 0,7% NaCl water solution in constant temperature 37±2 ^{0}C.

* Prof. dr eng. Tomasz Topoliński: Department of Mechanical Engineering, University of Technology and Life Sciences, Kaliskiego 7 Street; 85-789 Bydgoszcz; PL, e-mail: topol@utp.edu.pl

* Dr eng. Adam Mazurkiewicz: Department of Mechanical Engineering, University of Technology and Life Sciences, Kaliskiego 7 Street; 85-789 Bydgoszcz; PL, e-mail: adam.mazurkiewicz@utp.edu.pl

3. Results

Fatigue tests with stepwise increasing loading demonstrated the fatigue life N_s of the trabecular bone samples between $3{,}75 \cdot 10^3$ cycles and $5{,}02 \cdot 10^4$ cycles (time of test between 1,04 h and 13,95 h). Structural indices of trabecular bone obtained from microCT investigation are presented in Tab. 1. Relationship between fatigue life and structure indices BV/TV, Tb.Th. Tb.N. and BS/BV (Parfitt & Drezner, 1987) estimated by determination coefficient R^2.

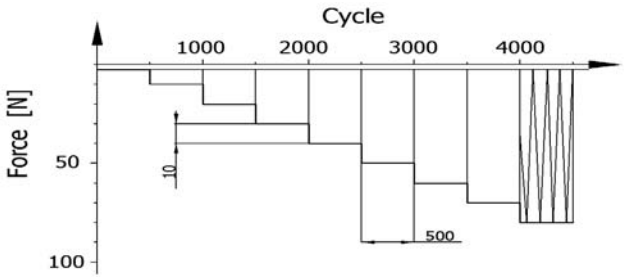

Fig. 1: Program of the fatigue test.

Tab. 1: Value of selected indices structure of trabecular bone and R^2 coefficient.

Indicator	Value					
	Min	**Max**	**Mean**	**SD**	**RSD**	**R^2**
BV/TV,-	0,0759	0,4595	0,2049	0,0759	37 %	0,69
Tb.Th, mm	0,1053	0,2677	0,1714	0,0354	21 %	0,50
Tb.N, 1/mm	0,511	1,544	1,133	0,222	20%	0,49
BS/BV, 1/mm	5,206	18,995	11,998	2,747	23%	0,49

Min - minimum value, Max - maximum value, Mean - mean value, SD - standard deviation
RSD - relative standard deviation

4. Conclusions

Indices BV/TV and Tb.Th are often use to description of the microstructure of trabecular bone. For the investigated samples value of indices varying in wide range (0,08-0,46 and 0,11-0,27 for BV/TV and Tb.Th respectively) and significant values SD or RSD.

Directly comparison obtained relation between fatigue life and structure indices with results other investigators was impossible, because majority fatigue tests trabecular bone was carried out with constant load amplitude. Therefore it is possible to compare our results with the similar relations obtained during this kind of test.

Concluded, the relationship between the fatigue life results and structure indices, does exist. The highest value coefficient of determination R^2=0,69 obtained for bone volume fraction. In opinion of authors these relations cover not only the bone properties (structure characteristics, damage and the effects of remodeling) but also the specificity of the fatigue damage process for stepwise loading with the dynamics, also associated with the bone properties.

References

Martin, R.B. (2003) Fatigue microdamage as an essential element of bone mechanics and biology. *Calcif Tissue Int.*, Vol. 73, pp. 101-107.

Parfitt, A.M. & Drezner, M.K. (1987) Bone histomorphometry: Standarization of nomenclature, symbols and units. *J. Bone Miner. Res.*, Vol. 2, pp. 595-610.

Taylor, M. & Tanner, K.E. (1997) Fatigue failure of cancellous bone: a possible cause of implant migration and loosening. *J Bone Joint Surg.*, Vol. 79-B, pp. 181-182.