УДК 615.461

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COMPUTER SIMULATION OF FRACTURE OF THE INTERFACE IMPLANT-BONE FOR TOTAL HIP PROSTHESIS

Важливою особливістю моделювання та виготовлення протезів стегна є мінімальна витрата матеріалів, але при цьому вони повинні забезпечити необхідний рівень міцності. В усіх випадках, аутопластичність призводить до зміни умов навантаження кісткок, за яких вони б змогли адаптуватися під час заживлення та експлуатації, а також їх структури і механічних властивостей. Найважливішою умовою ефективної адаптації кістки до ендопротезів є забезпечення довгострокової стабільності імплантату, а саме надійна первинна фіксація. Було зроблено детальний аналіз напруженого стану кісткової тканини в області її контакту з ендопротезом. Ми дійшли висновку, що для всіх з'єднань найбільш небезпечним з точки зору цілісності і можливого фретингу контакту є напружено-деформований стан, за якого можливе відносне зміщення поверхонь у 2– 6 мкм.

An important feature of hip prostheses is their minimum consumption of materials, while maintaining the necessary level of strength. The autoplastic in all cases leads to changes in loading conditions bone which they adapt to new conditions, changes its structure and, consequently, mechanical properties. The most important prerequisite of effective adaptation to the bone to endoprosthesis and ensure long-term stability of the implant it is a reliable primary fixation. A detailed analysis of a strained state of the bone in the areas of its contact with the endoprosthesis was made. We concluded that for all connections the most dangerous in terms of integrity and possible contact of fretting is a stress-strain state for which the possible relative displacement surfaces in 2– 6 µm.

Keywords: integrity, reliability, contact.
Ключові слова: цілісність, надійність, контакт.

THE GENERALLY PROBLEM

The total hip prosthesis on today is one of the most dynamically developing directions in an orthopaedic. His specific gravity considerably grew at different diseases of mainly hip joint in the last few years. In other, the number of diseases of hip joint grew considerably, that it is linked, foremost with the increase of life-span at elderly patients and increasing unfavourable influence of environment – harmful productions, radiation, quality of products, social terms.

Artificial joint replacement is a common treatment for joints that have been affected by trauma, artrosis, or rheumatoid arthritis. In globally, 1 million total hip replacements and 500,000 total knee replacements are performed every year. The maximum lifespan of prosthesis will be about 15 to 20 years [1]. Loosening starts with progressive micromotion, in the range of 0.2– 1 mm [2], of the prosthesis relative to the surrounding bone. Once it has started, it is a continuous process that will destroy bone, and as a result, the prosthesis will start to migrate over larger distances. At present, this process of prosthetic loosening and bone destruction can only be stopped by revision of the prosthesis. Initial micromotions into interface steam-cement-bone were studied using the finite element method (FEM) in the work [3, 4]. It was found that at the interface of component of implant the relative micromotion are a few microns.

Unfortunately, this is the natural status of the requested system, as well as the mechanics of the contact calls of these movements in order to reduce tension in the structure. There are many methods for modification of materials and methods of changing the design and geometry of the endoprosthesis. However, all efforts should have such a tendency, when the cyclic micromotion optimally meets the stress-strain state interface. The article presents new data on modeling state stress in the rod-cement-bone with micromotion.

SIMULATION IS STRESS – DEFORMED STATE TO THE HIP PROSTHESIS FOR FEA

Replacement of numerical model with the continuous distributing of parameters and endless number of degrees of freedom of discrete model lies in the basis of the use of numeral methods, which has the eventual number of unknown. The quantity of unknown in numeral methods can be very large and relies on the requirements, which are pulled out to computation and computer possibilities. Among the numeral methods of most distribution acquired the method of the finished elements, which allows approaching work of model to reality. Complication of our model to prosthesis consists in simultaneous co-operation of different on materials and by form objects of model. Above all things this variety of the systems of interface: a metal is a polymer, a polymer is cement, a bone is a metal, bone – cement and etc. Simulation of work to prosthesis by FEM enables to define the terms of the permanent fixing of stem, even distributing and optimum loading in interfaces, to decrease cutting away stress on boundary implantant – bone, line of microdisplacement of prosthesis in distal direction without damage of cement mantle. By us the FE model of fixing of stem was used in femoral to the bone on the base of software product „IMPACT" (Khmelnitckiy National University).

The comfort of model consists in that that any eventual-element system in IMPACT can be decided in the dynamic raising, setting the law of change of the operating loading and maximum terms only. Component parts of the system: a stem is steel Cr-Co-Mo, cement-PMMA, bone. The last constituent consists of external and internal part (under extremity of stem after a cement cork) (fig. 1).

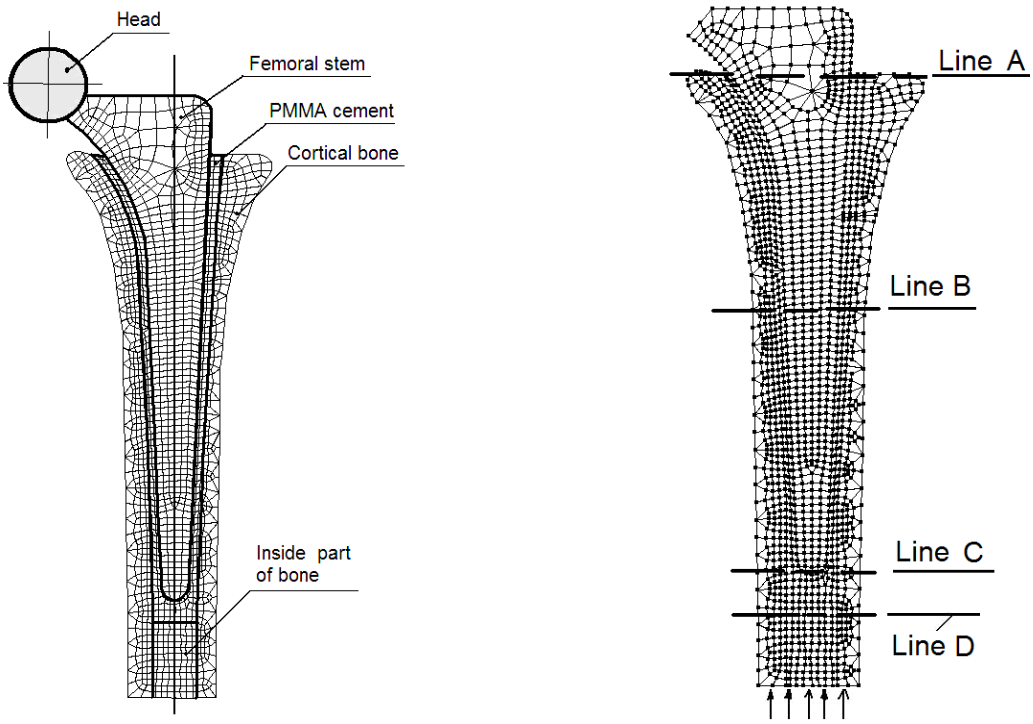

Fig. 1. FE model of the system is bone – cement, stem – cement for hip prosthesis and lines which were explored

From clinical researches there are the known most reliable places of loss of integrity of interface between a bone and stem. This place of output of stem from a bone (proximal line A fig.1,b), middle part (line B) region of clench of extremity of stem and cement (distal line of bone C), region of output of cement in cortical (internal) part of bone (line D). For every line, motion and equivalent stress at the proper line was found. Loading were modelled for a man weighing 70 kg in the post operation state and frequency 0,5 Hz. The hard jamming was set in the region of head of stem, and squeezing periodic stress was put on low part of bone. Mechanical properties descriptions of materials were definite from [3].

RESULTS

Numeric values displacements and equivalent stresses to show the level B (fig.2,3,4)

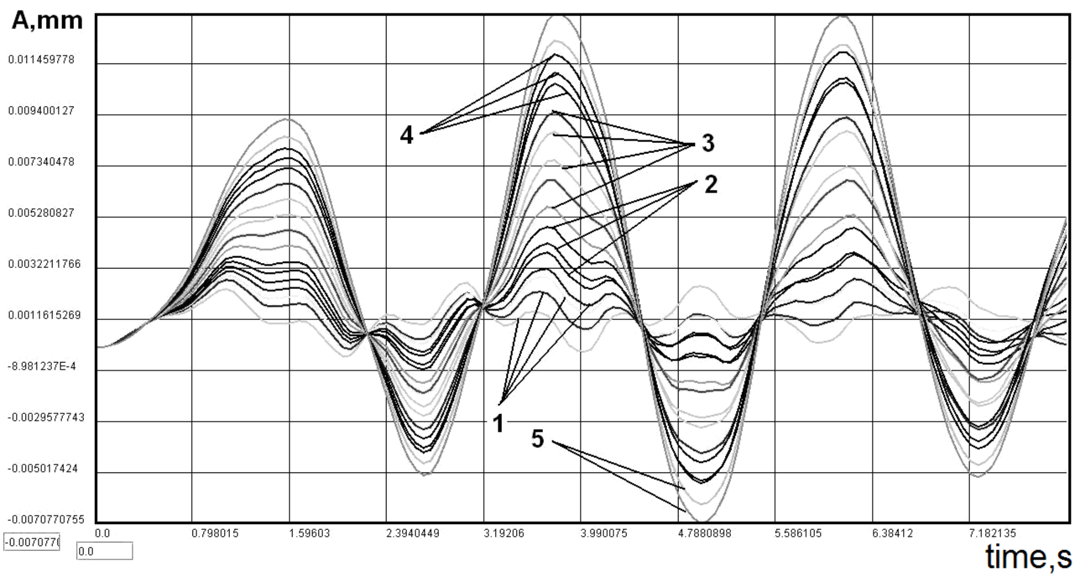

Fig. 2. This is displacement of nodes on line B on vertical direction at walking of man.
1 – microdisplacement of nodes for medial part of bone, 2,4 – cement mantle, 3 – nodes of stem, 5 – lateral part of bone

Maximal stress are reach in medial part of metallic stem, that is confirmed by the less motion of nodes of this part and make 3,0– 3,5 MPa. In medial part the stress have the greater gradient of falling of stress than in lateral. Stress in this part more even and make 0,6– 1,1 MPa. Stress, that are set in a bone cement on an order less than in a stem and make 0,006– 0,046 MPa.

Thus equivalent stress at the line of the proper to the cut to prosthesis distributing with a large unevenness, that creates in the places of border on materials possibility of initiation of change and periodic relative motion in interfaces. For determination of possible deformation of bone subject to the condition loss of integrity or partial damage of cement mantle numerical taking into account damage of separate elements of joint was conducted.

On fig. 5 the shown result of simulation of scenario-damage of cement mantle that is begun with the region of top collar which naturally relaxes due to a bone cavity. Damage of interface between a stem and bone will lead to deformation bone in radial direction. Clearly, that cyclic expansion of bone will be considerable only in the case of integrity of proximal part of joint.

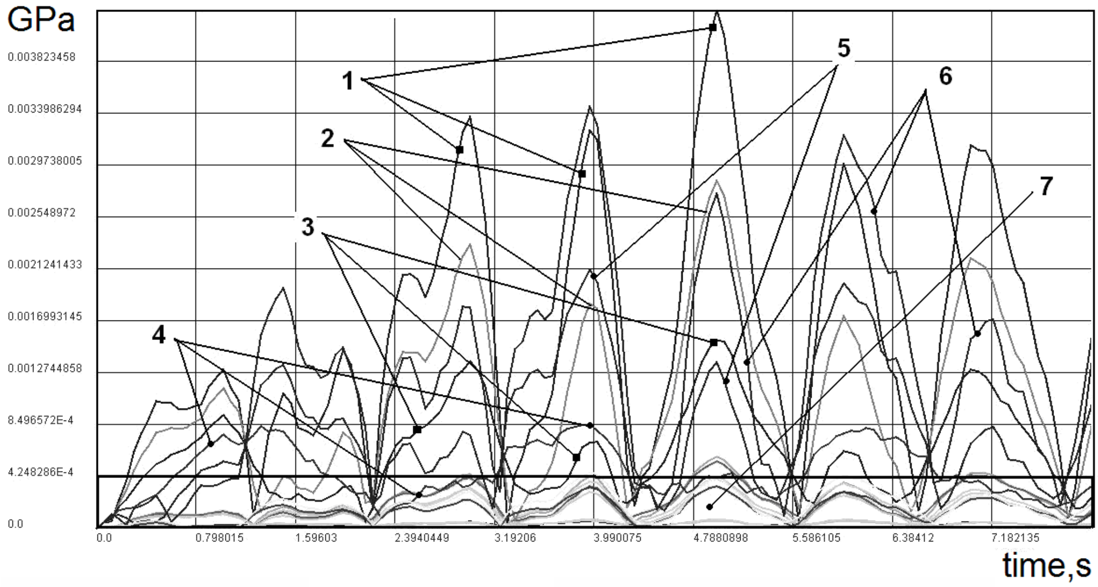

Fig. 3. The evolution of stress intensity by level B. The point 1, 2, 3, – elements of the steam, located to the left of the axis of symmetry. 4 – central element of the steam, 5,6 – tension steam of the right elements, 7 – region of stresses for bone and cement

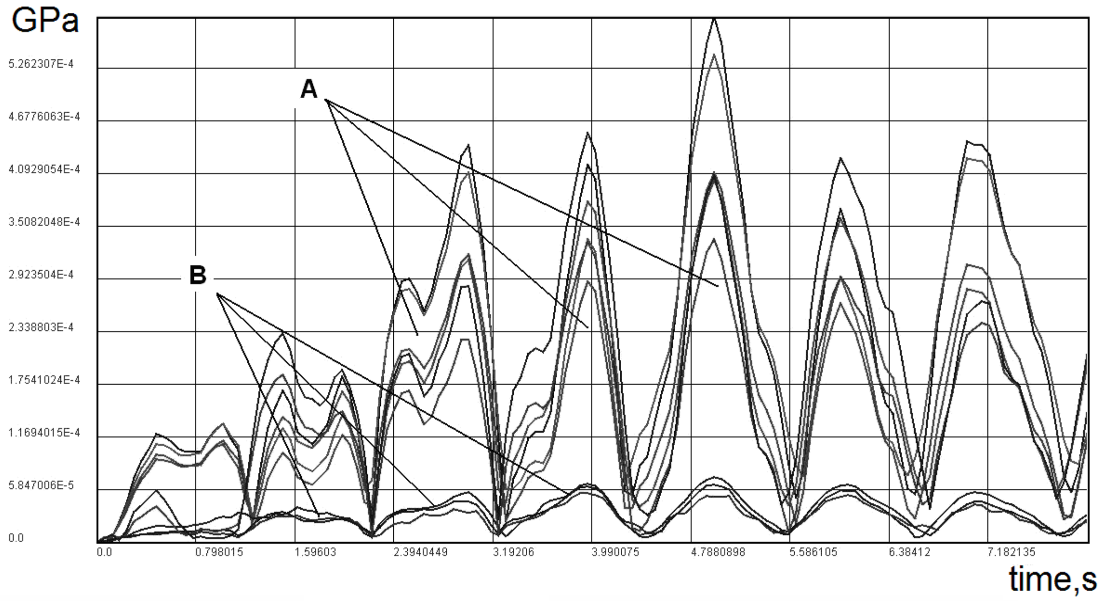

Fig. 4. Stress intensity ofor region 7 on fig.3.
A – level of stress bone, B – the level of stress in the cement mantle

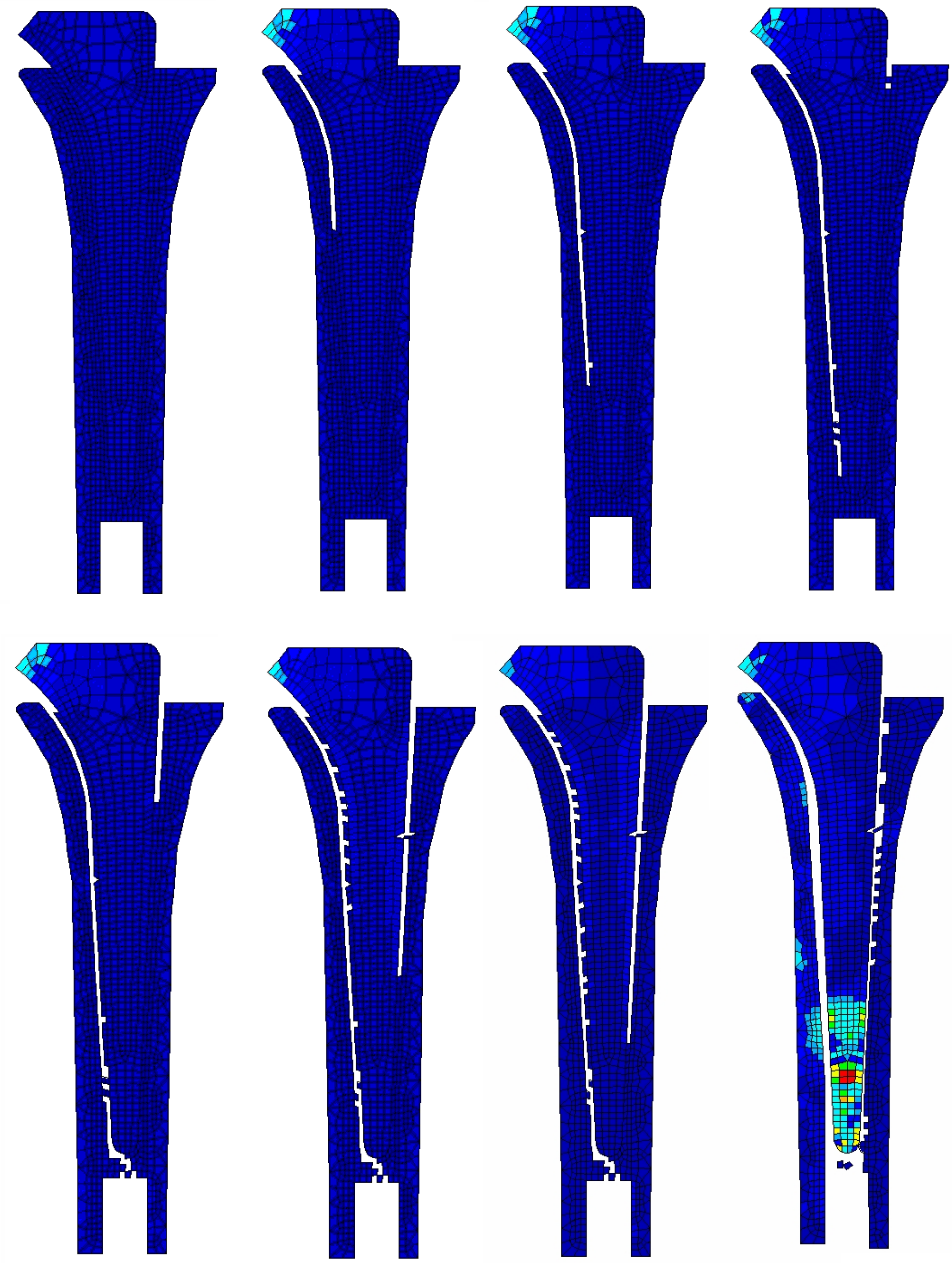

Fig. 5 Scenario loss of integrity of the interface components prosthesis depending on fatigue phenomena

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Надійшла 21.9.2010 р.