OWN SCIENTIFIC HIGHLIGHTS OBTAINED IN THE FIELD OF BIO AND MICRO-BEARINGS IN YEARS 2006-2008

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Abstract

Scientific problems considered in this paper presenting the achievements are mainly focused on comparisons of tribological processes which occur during flow of biological fluids around joint cartilage cells during lubrication of human joint surfaces as well as surfaces of micro- and nano-bearings used in micro-mechanisms.

The tissue growth presented in this paper is the process of change of mass of a biological system defined by genetic (congenital) factors and dependent on epigenetic (environmental) factors (temperature, mechanical stress and strain, internal and external physical fields, etc.).

This paper shows effects of influence of congenial growth and genetic code of bio-bearing or bio-joints material on the lubricant viscosity and lubricant process. In living tissues there is a growth strain defined by genetic code and depending on many other factors (such as temperature, force factors, chemical substances, etc.).

A general theory of materials with memory is the theory of simple fluid developed by Noll and Koleman. The simple fluid theory described in this paper is based on the assumption that stress is defined by a whole deformation history.

Keywords: *lubrication, rheological liquids, bio joints, micro-bearings*

1. Introduction

Research recapitulation presented in this paper show the general description of the human joint and micro-bearing lubrication caused by squeeze and rotation flow problem. Here are determined synovial liquid and ferrofluid velocity components, pressures, temperatures, friction forces and wear in analytical and numerical and experimental acoustic emission way in curvilinear coordinates for the laminar and turbulent lubrication flow which occurs in human joint and micro-bearing gap for the hyperbolic, parabolic and spherical rotational bone surfaces, under magnetic induction field. Analytical considerations are supported by the measurements of the cooperating surfaces performed by the mechanical and laser sensors and Atomic Force Microscope. Also, the use was made of the results of the measurements performed by means of the AFM (Atomic Forces Microscope) at the Research Institute, Belorussian Academy of Sciences, thanks to cooperation of Prof. D.Sc. S. Chizhik [1-3].

The authors would like to thank Dr. Med. J. Cwanek and Prof. Dr. Eng. W. Lubimow of Rzeszow University and Rzeszow University of Technology for their valuable medical comments as well as for their help in measuring the human joint cartilage surfaces, kindly offered during cooperation within the frame of the grant under way [6-7]. Also, some ways of application of the

results of the performed research to design and operation of bioreactors have been presented. Preparation of novel bio-lubricants was elaborated in Central Institute of Biomaterials of Ulm University (Germany) [4].

2. Achievements

- The obtained results reveal that the total apparent viscosity of synovial fluid depends on time and shear rates. The total apparent viscosity of synovial fluid changes periodically with time in periodic unsteady lubrication [6-7].
- During the human walk the head of human hip joint often moves simultaneously in more than one direction, with various amplitudes and frequencies. It has been proved, that the principle of superposition is not valid for the pressure and capacity values in the case of the motion of bone head of human hip joint in two directions simultaneously [7].
- With full particulars are performed the numerical calculations of pressure and capacity distributions after injury, with taking into account perturbations of the gap of human hip joint, resulting from impulsive motion [7].
- In described achievements are presented the influences of the visco-elastic properties of impulsive synovial fluid flow on the pressure and capacity distributions in human hip joint for stochastic changes of cartilage roughness with optimal standard deviation [7].
- From the numerical calculations we conclude that the pressure and capacity of the joint, obtained for the optimal standard deviation 0.375 by virtue of the measurements of roughness of normal cartilage surfaces of the human hip joint, decreases by about 30% in comparison with the pressure and capacity obtained for smooth cartilage surface without asperities and random effects [7].
- The numerical calculations show that the largest changes of pressure distribution and capacity in human joint arise within the time interval from 0.1 s to 30 s after impulse [7].
- From the numerical calculations and AFM measurements it follows, that viscoelastic properties of synovial fluid increases human hip joint capacities by 15% at least, and- in some cases- even by 60 %. If the angular velocity of perturbation periodicity is greater than 100 s^{-1}, then the influence of visco-elastic properties of synovial fluid on the joint capacity is of essential importance. If the angular velocity of perturbation periodicity is smaller than 100 s^{-1}, then the influence of the visco-elastic properties on the human hip joint capacity is negligibly small. From numerical calculations and AFM measurements it follows that stochastic description of roughness of bone surfaces and stochastic description of the film thickness of synovial fluid changes the hip joint capacity by about 11% [6], [7].
- If cartilage deformations are neglected and the stroke increases (decreases) the joint gap height, then the gap decreases (increases), i.e. it returns to its initial shape in the time interval from 0.000001 s to the 100.0 s [7].
- The greatest changes in the capacity of human hip joint are attained within the time interval from 0.1 s to 30 s after injury. In the time interval from 0.000001 s to the 0.1 s after injury, the capacities are not changed, irrespective of whether the gap height increases or decreases due to the stroke [7].
- On the ground of the performed investigations, it can be supposed, that the measurement by means of the acoustic emission of tribological parameters generated by two cooperating surfaces, is possible only if we deal with dry, mix or boundary friction. The method seems not to be applicable in the case of fluid friction. According to the Author knowledge the acoustic emission can be useful if direct contact between two cooperating surfaces takes place [4].
- The friction forces for steady motion increase if the velocity of synovial fluid and angular velocity of bone head increases [7].
- The friction force in unsteady motion of spherical bone head of human joint is greater in circumferential direction than in meridional direction [7].

- The friction coefficient in unsteady motion of spherical bone head of human joint is greater in circumferential direction than in meridional direction, and changes with time, both periodically and irregularly [7].
- The below presented conclusions will be mainly concern the hitherto existing methods for choosing proper flow parameters to obtain desirable features of cultivated cells and lubricated human joint or cooperating surfaces in machinery micro-bearings.
- Flow around the tissue of joint cartilage during the lubrication and cultivation can not generate the greater shear rates than those accepted by a given tissue [5, 8].
- As the dynamic viscosity of synovial liquid or lubricant for micro-bearing directly influences flow velocity and friction forces arising during the tissue lubrication therefore Young's modulus of elasticity of joint cartilage, shear rate of the liquid and structural geometry of the tissue surface become affecting the dynamic viscosity of the synovial liquid or lubricant [5, 8].
- Optimum cartilage cell body growth or optimum deformations of micro-bearing surfaces depends on properly generated and controlled friction forces which are affected by flow rate of the supplied liquid. Each cultivated tissue requires friction forces of an appropriate value to ensure its desired properties [5, 8].
- The friction forces arising over the cells surface area or over micro-bearing surfaces of about 10 μm^2 during its lubrication attain value of about 0.4 nN. The described contactless measurement methods and numerical calculation methods are here very desirable [5, 8].
- Preliminary applications of the elaborated methods to determine friction forces and friction coefficient directly in gap near the lubricated cells or lubricated bodies on the surface of the area of about 400 square micrometers, have been undertaken by using the atomic force microscope [5, 8].
- The initially performed analytical and numerical considerations in the area of tribological aspects of cell cultivation and joint cartilage lubrication in human joint, have made it possible to accumulate data and parameters which have influence on the micro-bearing regeneration process, moreover the investigations have enabled to constitute approximate relationships for determining values of the above mentioned parameters [5, 8].
- The performed numerical simulations indicate that it is possible to control the properties of lubricated and cultivated cells, lubricated joints and micro-bearings [5, 8].
- After Author's calculations and measurements, a magnetic induction field increases the load carrying capacity distributions in parabolic HDD micro-bearing by 6 percent at least, and -in some cases-even 10 percent and magnetic induction field decreases the values of friction coefficients [5].
- The journal bearing motion produces the periodic hydrodynamic forces resulting from the rotating grooves on the parabolic shaft with various diameter. Hence the periodic load carrying capacity fixes the capacity memory. We can simulate the increases of the capacity memory of fluid dynamic HDD micro-bearings not only by the herringbone or spiral grooves indicated in papers, but also by the various parabolic shapes of journal micro-bearings [5].
- The properties of the changes of memory capacity simulations in presented micro-bearing with parabolic journals are compared with the similar form for human bio-bearings with parabolic shapes of bone heads which are formed during the thousand years of evolution [5].

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