THE PROJECT OF MEMORY AND GENETIC CODE SIMULATIONS FOR JOINT LUBRICATION

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Abstract

This paper presents the optimization, simulation and practical application of operating parameters(load carrying capacity, friction forces, friction coefficient, wear) for hydrodynamic intelligent articular and artificial bio-bearing joints with curvilinear nano-shaped surfaces. One of the reason of such bone head and endoprosthese profile is that this profile contributes to the variation (an increase or decrease) the memory joint capacity. Such properties are very important and required in human joints.

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

The changes of bio-bearing superficial surfaces presented in this paper are described by the process of changes of mass of a body system defined by non-Newtonian synovial liquid properties and its genetic (congenital) factors which depends on epigenetic (environmental) factors (temperature, mechanical stress and strain, internal and external physical fields, etc.).

Scientific problems considered in the paper are mainly focused on comparisons and practical applications of tribological processes which occur during fluid flow around cells lubrication on the nano-surfaces in nano-bearings as well as surfaces of bio-bearings.

Keywords: *Curvilinear bone heads, capacity memory simulations, genetic code of biological liquids*

1. Introduction

The task of presented topic concerns the determining and practical applications of the operating parameters i.e., pressure distribution, load carrying capacity friction forces, coefficient and wear determination in a super thin layer of non-Newtonian, visco-elastic lubricant inside the slide living intelligent joints or endoprosthese between a cylindrical, conical, parabolic, hyperbolic shapes of cooperating surfaces [12-14]. The lubrication of living bio-bearing surfaces is characterized by various geometries form and non-Newtonian lubricants.

Non-isothermal, unsteady and random flow conditions and thermal deformations of the bio-bearing and its sleeve are taken into account in authors foregoing research [1-6]. This project considers the dynamic behavior of intelligent bio-bearing, and stress memory of the tissue and allows to compare obtained results with recently achievements of other authors. Moreover practical applications of a new obtained results are made.

Lack of knowledge

The application of theoretical and computational model for representing the behavior of cartilage and intelligent bio-joints surfaces with respecting the genetic code and load carrying capacity have not examined so far. Scientific effort of the proposed challenge shall contribute to improvement of this process by delivering the hydrodynamic flow characteristics of the considered media with the use of CFD tools. Up to now, only some parameters of human joints surfaces are kept under control (temperature, external and internal pressure values and flow rate) but without influences of genetic code and memory properties of course. For such investigation the lubrication of human joint for genetic code influences and stress-strain memory effects should be improved. Moreover, the engineering support for load carrying capacity development during the lubrication is to be delivered.

What should be done

- To describe the synovial fluid flow in human joint gap taking into account the congenial strain rate tensor of synovial fluid and growth strain rate tensor,
- to show the rheological properties of synovial liquids based on the assumptions that stress is defined by the whole deformation history and the following concepts: determinism, local action, fading memory,
- to determine growing cartilage deformations taking into account the congenial growth tensor of cartilage and tensor of stress influence on the cartilage growth,
- to determine the material coefficients on the experimental way, to describe the unknown congenial and growth tensors.

Goal definition

The social and ethical impacts of such a challenge are given at first through the following goals: improving the quality of life by increasing the success rate, as well as possible number of transplantations (~25%), social impact by enhancing the ability to recovery of patients suffering the problems with joints (~20%). The second order goal is financial impact by time and cost saving
(~2% and ~20% respectively).

To whom is it addressed?

Medical clinics as end-users, biological, biomaterials and biomechanical research parties, as well as computational fluid mechanics and control research are three main groups that the challenge is addressed to.

2. State of the art

On-going challenges

The comprehensive theoretical and computational model for joint lubrication under unsteady hydrodynamic conditions of fluid flow with memory, reflecting real human joint work with stochastic variations of surfaces has not been developed so far. It is possible to select a wide class of fluids which have the property of remembering their deformation history and exhibiting the elastic properties. To construct rheological equations for viscoelastic fluids, it is necessary to solve the problem of defining the elasticity of fluid. In the theory of elasticity, it is assumed that internal stresses are defined by deformations with respect to a reference configuration, the so called preferable configuration of material. On the contrary, liquid materials are those of no preferable configuration. This contradiction is resolved by determining deformation not with respect to preferable configuration but by the distinction between an actual configuration and preceding one. In other words, elastic solids have a permanent memory of preferable configuration. Ideally viscous fluids have no memory and are sensitive to instantaneous strain rate. The simple fluid theory is based on the assumption that stress is defined by a whole deformation history and the following four concepts [12-13]:

a) determinism - stresses are defined by the previous deformation history and do not depend on future deformations;
b) local action - stresses in a point are uniquely determined by the deformation history of the small neighborhood of the point;
c) non-existence of natural non-stressed state - fluid has not a preferable form and all possible forms are equivalent;
d) fading memory - influence of deformation is smaller at distant points of time than near ones.

Now we describe in detail the important property of living tissues − their capability of growing. We introduce the following definitions:

1) The growth 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, chemical substances, internal and external physical fields, *etc*.).
2) The remodeling (or adaptation) is the process of change of shape and properties of a biological system defined by change of internal and/or external conditions.
3) The external remodeling is the process of change of shape of the system.
3) The internal remodeling is the process of change of properties of the system (mechanical properties of trabeculae, their architecture, development of pores, *etc*.).

Sometimes the process of change of shape of the system is called the morphogenesis.

Characteristic strain rate tensor has the sum where first term denotes the scalar characteristic of hydrodynamic strain rate tensor of the liquid and second term denotes scalar characteristic of the growth strain rate tensor of the liquid.

Approaches for enhancing the state-of-the-art

The author suggest the following approaches to enhance the above described present situation:

1) More realistic description of properties and working conditions of human joints by acquiring the necessary real medical data on joint behaviour under load and parameters of synovial fluid to design a new endoprostheses with memory to be applied for human joint lubrication;
2) Making use of the recent developments of CFD computational tools and simulation techniques to optimize conditions for human joint lubrication and to increase its remodelling and adaptation possibilities and to decrease costs of the process;
3) To take into account new scientific knowledge on the human joint lubrication, as well as advanced mathematical description of hydrodynamic processes occurring in them.

These approaches will make possible to pass from extensive experimental research in the field of human joint lubrication and bioengineering technology to novel analytical and numerical investigations and vice versa.

Scientific effort should contribute to the development process by providing with the data on the hydrodynamic flow characteristic for the bio-bearing lubrication, obtained from computer optimization.

The lubricant velocity components and pressure values and load carrying capacities should be determined, calculated, simulated and then optimally controlled taking into account genetic code influences and stress-strain history. Boundary layer simplification has to be made for local flows. The unification of anticipated results by virtue of artificial neural network, random variables, stochastic methods and CFD tools are to be considered. The suggested approach also generalizes the obtained results by the virtue of random variables and stochastic methods for analysing the unsteady lubrication process of cartilage with stochastic changes of surface roughness.

The non - Newtonian viscoelastic fluid properties are to be taken into account to enhance the state of the present knowledge on the human joint lubrication because the friction forces which occur in the thin layer of liquids resting on the cartilage superficial layer will be taken into account, examined numerically and controlled. Moreover the hydrodynamic parameters during the lubrication process of a human joint will be described. Moreover, a novel lubricant with enhanced characteristics by application of viscosity control system and genetic code influences should be worked out.

The ultimate research and technological result of the proposed challenge is a prototype of intelligent bio-joint with strain-stress history able for repair and remodelling, together with analytical and computational tools for further development and optimization of lubrication technology and equipment.

3. Research areas

The objectives of the proposed challenge is mainly related to nanotechnologies and nano - sciences, knowledge-based functional materials, as well as new production processes and devices, but particularly intelligent tissue repair and regeneration with memory and genetic code influences should be considered [7], [8], [9]. In details, it addresses the following research domains:

1. Technologies associated with the joint lubrication and processing of knowledge-based multifunctional transplanted tissue:

Multifunctional biomaterial

Intelligent bio-bearing lubrication enables utilization of radically innovative technologies and can lead to enormous benefits caused by the multifunctional applications. The proposed topic will focus on technological novelties and methods applied during the human joint lubrication with relation to chemical and physical processes. To the innovative technologies is numbered a new biological fluid with ferrofluid additions and a new method of simultaneous control of the genetic code influence process. On their ground a new cartilage with better load carrying capacity to repair and regeneration and a new cartilage with higher hardness and durability and lower friction coefficient, can be obtained.

Cell surface

A new achievement of this project is accounting for the very thin multifunctional layer of the intelligent liquid lubricant in human joint with memory and genetic code influences. The multifunctional thin layer which arises in surrounding of the tissue surface during a new method lubrication, is of great importance for the proper human joint regeneration. The thickness of such film amounts from 10 to 100 nm. In such very thin layer boundary lubrication of the human joints surface occurs because the velocity of the fluid particles simultaneously attains the value of about 100 nm/s. Such thin film has a radically new nanostructure with chemical and physical properties that significantly differ from those of conventional lubrications occurring in classical technologies.

Tribology of biomaterials

The thin boundary layer of the fluid (produced by virtue of new technologies) cooperates with the thin superficial layer of lubricated tissue. These mutual tribological influences make it possible to obtain a greater strength and durability of lubricated cartilage.

Intelligent biomaterials

The intelligent biological lubricants contains enzymes, microcapsules with magnetic nano-particles, that have specific active behaviour and also improve the incorporation of substances providing the superficial layer of lubricated tissue with desired functionalities [9-11].

2. Engineering support for human joint lubrication

Nanoparticles in biomaterials

The magnetic nano-particles are novel multifunctional materials of wide applications. The magnetic nano-particles introduced at first into thin fluid layer and further into superficial layer of lubricated surface have two important aspects: miniaturisation - to include at least two functions in a small volume, and hybridisation - to gain from associating inorganic and organic components. Magnetic induction field in nano-scale at first improves lubrication and later increases the dynamic viscosity values of synovial fluid and increases load carrying capacity after lubrication of human joint.

Cognitive sciences

The proposed approach includes also introducing the intelligent bio-bearing, as well as related software generation by applying the optimal control theory and implementation of neuro-fuzzy methodology for creating the knowledge base of tissue lubrication.

4. Conclusions

- After Author's initial anticipations, a genetic code influences increases the load carrying capacity distributions in human joints by 6 percent at least, and–in some cases–even 10 percent and genetic code influences can be decrease the values of friction coefficients.
- We can simulate the increases of the load carrying capacity memory of human joint endoprostheses not only by the herringbone or spiral grooves, but also by the various parabolic shapes of endopostheses heads.
- Load carrying capacity with memory for various shapes of heads in endoprostheses are compared with the capacities obtained for similar but classical forms of endoprostheses.

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