Biomaterials characterization – parameters identification

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Abstract: Although the behavior of biomaterials is usually quite complex, modelling of their behavior, as well as that of conventional materials, can be based on the knowledge of their mechanical properties, such as the interdependence between the stress and elongation. These properties may be determined by experimental methods, some of them by tensile loading of the samples. In addition to knowledge of mathematical and material model which can be described by the aforementioned interdependence, a basic prerequisite for modeling the behavior of biological materials is the identification of their parameters, based on physical laws that apply to them. Due to the complexity of the model of biological materials and a large number of material parameters that appear in them, conventional calculation methods are not sufficient for their determination and it is advisable to apply the evolutionary methods, such as genetic algorithm.

Keywords: Biomaterials, Materials life, Parameters identification, Genetic algorithm

1. Introduction

Engineering design process consists of three main parts: material selection, components dimensioning and the choice of production technology. For optimization of this process, proper material selection is extremely important. The material selection relies strongly on the knowledge of material behavior in different loading conditions so that, in the field of materials research, modelling of complex material behavior receives a lot of attention nowadays. Although due to their wide application, majority of research analyses still deal with characterization of metallic materials, since innovative materials hold great potential and are being increasingly applied, research of their characterization and modelling of their behavior is increasingly getting into focus [1]. An example of such materials that exhibit a great potential in innovative materials research are soft tissues and within them human biomaterials.

2. Material behavior of the human cervical spine ligaments

In order to define the procedure for modelling of behavior of soft tissues within the framework of biological materials research, an experimental observation of biological material, in presented case, the ligaments of the human cervical spine was conducted. It was found that the maximum load capacity of the material is in the direction of their fibers. Also, it was observed that, while their tensile strength has very high values, compressive loading will quickly cause their buckling [2]. Since during movements of human body, these materials are experiencing complex loading states, caused by the applied forces and torques in different directions, their structure is by nature constituted to eventually develop resistance to the movements of the spine that could have an adverse effect on human posture. Ligaments are composed of collagen fibers organized uniformly in one direction and integrated together by intercellular material. Therefore, resulting mechanical behavior of ligaments depends on the behavior of individual ligaments' constituents as well as on their correlation and relative position.

Mathematical modeling of biological materials, especially with the presumption of modeling the said ligament material, is based upon the knowledge of the basic mechanical proper-

ties of materials. It is also necessary to know the type of interdependence of the stresses and strains. These characteristics can be determined by experimental procedures that include subjecting samples to tensile loading until their failure.

Hyperelastic material model that can be used for compressible and incompressible materials [3] is a good choice for the modeling of the biological material behavior in order to be applied to human spinal ligaments. This particular model is quite complex and requires several material parameters, which have to be identified on the basis of three separate physical relationships. These relationships correspond to three physically different regions in materials life???, from the physiologic phase, through traumatic phase to the post – traumatic phase. In order to simulate the behavior of said ligaments as accurately as possible, it is advisable to develop procedures for the parameter identification of biological materials.

3. Parameter identification

Parameter identification of biological materials for modeling their behavior would be well advised to be conducted by applying evolutionary methods, especially genetic algorithm, which has been recognized as a suitable tool to achieve this objective [4]. In order to more efficiently obtain the precise values of the parameters, a technique for determining the parameters of materials behavior needs to be developed for the proposed material model. For development of efficient operating procedures within genetic algorithm for a given material or group of materials, or the fastest achievement of desired solution, it is necessary to develop a procedure for a complex genetic algorithm and properly develop its operators as well as an adequate objective function optimization procedure, all based on inverse problem definition.

4. Conclusions

The proposed methodology of material characterization has so far proved to be applicable for parameters identification of materials with different microstructure and mechanical properties. It is expected that because of its flexibility and robustness, besides for the modeling of the biological materials it might also be applicable to behavior characterization of other non-conventional and innovative materials exhibiting complex behavior. Thus, it is assumed that with appropriate changes, additions and extensions it could be successfully adapted for behavior characterization of composites, polymers, rubber, ceramics, glass, metal foams, gels, implants materials, artificial tissues, fibers, etc. as well as for parameters identification of corresponding material models of varying complexity.

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