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Finite element analysis for biomedical engineering applications. (English) Zbl 1422.92001

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This textbook provides some simulations of various medical problems. It is focused on the establishment of finite element (FE) models in ANSYS 19.0. Although the book is intended to medical researchers with knowledge of ANSYS parametric design language, both undergraduate as well as beginning graduate students in biomedical engineering are able to understand the content. In detail, the book is divided into four main parts. The introduction that outlines the present book appears in Chapter 1. Each part consists of several chapters, who comprise the geometry and mesh, the material model, and results that are illustrated and discussed. Each chapter ends with a closing summary and a list of references.

Part I "Bone" introduces FE models for the bone. In Chapter 2 'Bone structure and material properties', some concepts are illustrated. For instance, the stress vs. strain is introduced under its graphical representation. Chapter 3 'Simulation of nonhomogeneous bone' begins by introducing an FE model of nonhomogeneous bone from the computed tomography data. To overcome two existent drawbacks, three multidimensional interpolation methods (radial-basis (RBAS), nearest-neighbor (NNEI), and linear-multivariate (LMUL)) are compared in the modelling of the cancellous (spongy) bone of the ankle (input file in Appendix 1). Chapter 4 'Simulation of anisotropic bone' explores a simulation for an anisotropic femur model (input file in Appendix 2), under vertical (axial) loading. Chapter 5 'Simulation of crack growth using the extended finite element method (XFEM)' explores a simulation for the microcrack growth of cortical (compact) bone by using XFEM (input file in Appendix 3).

In Part II "Soft tissues", Chapter 6 'Structure and material properties of soft tissues' describes the structure and material properties of the cartilage, the ligaments, and the intervertebral discs (IVD). Chapter 7 'Nonlinear behavior of soft tissues' begins by listing the characterization of the elastic potential for several hyperelastic materials. For a smooth, idealized geometry of an abdominal aortic aneurysm (AAA), a simulation of the wall stresses is developed under the Ogden hyperelastic model (input file in Appendix 4). Chapter 8 'Viscoelasticity of soft tissues' begins by introducing the Maxwell, the Kevin-Voigt, and the Burgers viscoelastic models. Then, the creep test is simulated for the tooth periodontal ligament (input file in Appendix 5). Chapter 9 'Fiber enhancement' begins by implementing the IVD model with fiber enhancement, using mesh-dependent and mesh-independent methods (input files, respectively, in Appendices 6 and 7). Then, the simulation is developed for both polynomial and exponential function based strain energy potential. Moreover, the anterior cruciate ligament with anisotropic material is modeled (input file in Appendix 8). Chapter 10 'USERMAT for simulation of soft tissues' rephrases the simulation of the wall stresses of AAA under a material model defined by UserHyper subroutine (input file in Appendix 9). Chapter 11 'Modeling soft tissues as porous media' begins by introducing the coupled pore-pressure thermal elements. Then, the head impact is simulated, in which the brain is regarded as a biphasic medium: the (solid) skull and (porous) brain tissue (input file in Appendix 10). Moreover, a poroelastic model of the IVD is created to simulate its creep response (input file in Appendix 11).

Part III "Joints" begins by describing the three types, immovable, slightly movable and movable, of joints in Chapter 12 'Structure and function of joints'. Chapter 13 'Modeling contact' begins by introducing the contact elements and their behavior. Then, a 3D knee contact model (input file in Appendix 12), and a 2D axisymmetrical poroelastic knee model (input file in Appendix 13) are analyzed. Chapter 14 'Application of the discrete element method for study of the knee joint' rephrases the contact pressures in the knee joint studied in Chapter 13, by using discrete element analysis. The procedure of building springs between bones by applying the line-plane intersection method is scheduled (input file in Appendix 14).

In Part IV "Simulation of implants", Chapter 15 'Study of contact in ankle replacement' deals with the contact between the talar component and the bone in the ankle replacement, in which the material of the cancellous bone is interpolated by using RBAS method (input file in Appendix 15). Chapter 16 'Simulation of shape memory alloy (SMA) cardiovascular stent' begins by modeling the SMA material as both superelastic and with shape memory effect. Then, the contact between the plaque of an artery and the stent implant is simulated (input file in Appendix 16). In Chapter 17 'Wear model of liner in hip replacement', the wear of the liner of a hip implant is simulated using the Archard wear model (input file in Appendix 17). Chapter 18 'Fatigue analysis of a mini dental implant (MDI)' uses separating, morphing, adaptive, and remeshing technology (SMART) in ANSYS to study the fatigue crack growth of a MDI (input file in Appendix 18).

Part V "Retrospective" closes the book by emphasizing the need of some factors in Chapter 19 'Retrospective', and it includes all appendices.

Reviewer: Luisa Consiglieri (Lisboa)

MSC:

92-01 Introductory exposition (textbooks, tutorial papers, etc.) pertaining to biology
92C50 Medical applications (general)
92C10 Biomechanics
74S05 Finite element methods applied to problems in solid mechanics

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