DOCTORAL PROGRAMME IN ENGINEERING AND APPLIED SCIENCES
UNIVERSITY OF BERGAMO, ENGINEERING CAMPUS (DALMINE)
viale G. Marconi 5, I-24044 Dalmine (BG), Italy

FINITE STRAIN MECHANICS OF SOFT TISSUES

prof. Fernando Simões (University of Lisbon)

Doctoral Course (20 h)

ABSTRACT

The course aims at providing a brief introduction to the broad field of physically and geometrically Nonlinear Solid Mechanics. Specific attention will be given to the nonlinear modelling and analysis, by the Finite Element Method (FEM), of soft tissues in the context of Biomechanics, including the presentation of several applications (like tendons and ligaments, articular cartilages, vertebral discs, cardiac muscle, bone, etc.)
Accordingly, the course is divided into two conceptual parts:

- Part I presents key foundamental concepts for the treatment of Finite Strain Mechanics. This could be taken as an introduction to the topic, also for attendees that do not have a specific background on mechanics, since presentation starts from the very basics.
- Part II presents several examples of mechanical behaviour of different materials, including applications at the material and at the structural levels via FEM, and with main reference to soft tissues modelling in biomedical, biomechanical and bioengineering contexts.

CALENDAR (11-17 February 2015)

+ Wed, 11 Feb, 15-19
+ Thu, 12 Feb, 15-19
+ Fri, 13 Feb, 15-19
+ Mon, 16 Feb, 15-19
+ Tue, 17 Feb, 15-19

BIOGRAPHICAL SKETCH

Fernando Simões received his Ph.D. degree in civil engineering from the Instituto Superior Técnico of the Technical University of Lisbon, Portugal, in 1997. Currently, he is Assistant Professor at the Department of Civil Engineering, Architecture and GeoResources of the Instituto Superior Técnico (University of Lisbon). His research interests include solid mechanics and biomechanics.

Ref. Prof. Egidio Rizzi (ICAR/08 – Scienza delle Costruzioni), egidio.rizzi@unibg.it

CONTENTS

1. Introduction to the course

PART I (8 h) Fundamentals on Finite Strain Mechanics

2. Strain measures
Material and spatial descriptions of motion. Displacement, velocity and acceleration. Material derivative.
Deformation gradient tensor. Right Cauchy-Green tensor. Left Cauchy-Green tensor. Green-Lagrange strain tensor. Euler-Almansi strain tensor. Transformation of an elementary volume. Transformation of an elementary area (Nanson´s formula). Polar decomposition of the deformation gradient tensor. Right stretch tensor. Left stretch tensor. Rotation tensor.
Strain rate measures: strain rate tensor, material gradient of the velocity and material derivative of the Green-Lagrange strain tensor.

3. Stress measures and laws of motion
Cauchy's traction vector. Cauchy's stress tensor. Linear momentum and angular momentum laws. Nominal traction vector and 2nd Piola-Kirchhoff traction vector. Nominal stress tensor and 2nd Piola-Kirchhoff stress tensor. Linear momentum and angular momentum laws in the reference configuration.

4. The principle of virtual power
Virtual power principle in the current and in the reference configuration.

PART II (12 h) Mechanical behavior of materials and soft tissues

5. Hyperelastic constitutive relations
Properties of the strain energy. Objectivity of the strain energy.
Incompressible materials. Isotropic materials. Incompressible and isotropic materials.
Neo-Hookean material and Mooney-Rivlin material.
Fung's exponential law for the behavior of tendons and ligaments.
Non-isotropic models: Humphrey's model for the passive behavior of the cardiac muscle.

6. Visco-hyperelastic constitutive relations
Creep and relaxation. Linear viscoelasticity. Fung's quasi-linear model of viscoelasticity.

7. The Finite Element Method for geometrical and physical 1-D non-linear problems
1D bar element - reference configuration. Virtual power principle in the static case applied to the 1D bar element. Linear and nonlinear problems. Newton-Raphson method for nonlinear problems. Tangent matrix.
FEM applications.