

CT4353

Continuum Mechanics

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Instructor	Frans Molenkamp
Education Period	1st Education Period, 2nd Education Period
Exam Period	1st Exam Period, 2nd Exam Period
Course Language	English
Course Contents	<p>The module starts with the solution of linear equations, matrix algebra, eigenvalues and eigenvectors and polar decomposition. Then vectors and Cartesian tensors are considered, including dyadic products, invariants, isotropic and deviatoric tensors, spectral representation of tensors, skew-symmetric and orthogonal tensors. Also tensor calculus is discussed and some common integral theorems are introduced. Next the kinematics of deformable bodies is considered, including the Lagrangian and Eulerian descriptions of the material time derivatives of material vectors and tensors. Particle paths, streamlines and streak lines are described as well. Then rigid body motion is considered.</p> <p>The larger topic concerns motion and deformation. This starts with the deformation and velocity gradient tensors and the deformation of material lines, surfaces and volumes and their rates of change. Then the polar decomposition of the large deformation tensor, the principal stretches and their direction and the large strain and material rotation tensors are discussed. Also the principal strain space is introduced to facilitate the illustration of the strain history. For small deformation the infinitesimal strain and rotation tensors, the conditions of strain compatibility and the displacement gradient circle are described. Finally the strain rate, spin and vorticity tensors are considered.</p> <p>Next the stress tensor is introduced, including traction and stress components, principal stresses and their directions, isotropic and deviatoric stress tensors, the principal stress space for the illustration of the stress history, the stress circle and various simple stress states. Additionally other stress tensors and their related strain measures are reviewed. Finally co-rotational material time derivatives of vector and tensor fields are described and their physical significance is clarified, including the Jaumann stress rate.</p> <p>Then the rates of change of integrals along material curves, surfaces and volumes are derived and applied to the conservation laws of mass, momentum and energy. Also flow of heat and the physical principle of non-negative internal dissipation are introduced. These laws are also expressed with respect to a general reference volume, thus facilitating application in analyses of large deformation and flow.</p> <p>Next some basic constitutive equations are considered, including isotropic linear and non-linear elasticity and visco-elasticity, Newtonian viscous fluids and some general aspects of material modelling, plasticity and visco-plasticity, including geomechanical constitutive concepts as stress-dilatancy and state of ultimate deviatoric deformation. Also transverse anisotropy is considered. The concepts of material instability and the controllability of constitutive models, the parameter range of uniqueness and the occurrence of bifurcations into localized deformation modes are described.</p> <p>Finally the basic laws of physics for two- and three-phase materials (a.o. saturated and unsaturated geomechanics) are formulated. The same physical laws are deployed for each phase of the multi-phase continuum, inclusive of interaction terms. Then constitutive laws for each of the phases and their interactions are discussed. Finally the stiffness and strength of the solid phase, the interaction with the liquid and air phases and the flow of the pore fluid, the pore air and the heat are formulated in general terms.</p> <p>Assignments hands-on fortran95 eigenvalue analysis of 3*3 symmetric matrix polar decomposition of 3*3 non-symmetric matrix stress-strain paths (in the principal spaces)</p>
Study Goals	<p>Understanding and usage of tensor calculus</p> <p>Calculation and interpretation of both large deformation and rotation of materials and stress in materials</p>

Understanding of the combined application of the laws of physics and constitutive relations in order to:

- measure, interpret and formulate the properties of continuum materials
- formulate engineering problems in continuum mechanics

Understanding of the background of the mechanics and physics of multi-phase continuum materials in large deformation and flow, a.o. as applied for saturated and unsaturated geomechanics

Education Method Lectures, exercise

Course Relations CT4352 uses CT1021
CT4352 uses CT1121
CT4352 uses CT2022
CT4352 uses CT2090
CT4352 uses CT2100
CT4352 uses CT3320
CT4352 uses CT3330
CT4352 uses WI1316CT
CT4352 uses WI1317CT
CT4352 uses WI2253CT
CT4352 uses WI3097TU

Literature and Study Materials Eglit, M.E., Hodges, D.H., "Continuum Mechanics via problems and exercises", Part 1: Theory and Problems, World Scientific Publishing Co. Pte. Ltd, 1996, ISBN: 981-02-2962-3. Part 2: Answer and Solutions, World Scientific Publishing Co. Pte. Ltd, 1996, ISBN: 981-02-2963-1.

Haupt, P., "Continuum Mechanics and theory of materials", Springer-Verlag, 2000, ISBN: 3-540-66114-x.

Assessment Written exam (open questions)
Assignments

Judgement Final mark consists 70% of mark of examination and 30% of mark of assignments