Module level Master	Credit points 6 ECTS	Language English	Return annual
Module designation Nonlinear Computational Structural Mechanics			
Course Nonlinear Computational Structural Mechanics			
Code	**Subtitle**		
Person responsible for the module	Prof. Dr.-Ing. Detlef Kuhl		
Lecturer	Prof. Dr.-Ing.. Detlef Kuhl		
Workload	180 h (30h contact time, 90h private study, 60h homework)		
Relation to curriculum	Specialist studies, Simulation and Structural Technology, elective		
Type of teaching, contact hours	Chapter-Checks, virtual classroom, online scripts, digital communication		
Requirements according to examination regulations	Modules Mathematics, Solid Mechanics		

Recommended prerequisites

Modules Application of Software Tools, Linear Computational Structural Mechanics

Module objective / intended learning outcomes

This course provides a brief introduction to geometrically nonlinear continuum mechanics and subsequently an intensive study of nonlinear computational structural mechanics using the finite element method and solution procedures for nonlinear structural statics and dynamics. The present course is continuing Linear Computational Structural Mechanics. At the end of the course, the students should:

- Understand the basic theory of the geometrically non-linear finite element method including the initial boundary value problem, the weak formulation and the discretization in space and time
- Understanding the necessity and the procedure of linearization in the continuum mechanics, element, structural and algorithmic levels
- Interpreting the linear finite element method as special case of the nonlinear finite element method
- Understand the static solution process using load and arc-length controlled Newton-Raphson and their control parameters iteration schemes
- Knowing the methods of computational stability analysis and their control parameters
- Knowing different types of time integrations schemes and their properties with regard to nonlinear dynamics
- Be able to develop a basic nonlinear finite element program using MATLAB
- Be familiar with the application of nonlinear finite element programs to the static and dynamic analysis of wind power plant components

Content

The course Nonlinear Computational Structural Mechanics provides the theoretical basis, the development and the application of the geometrically non-linear finite element method. Special attention is taken to the requirements for the static and dynamic analysis of wind power plants undergoing large deformations and rotations.

- Geometrically nonlinear continuum mechanics - Weak formulation of nonlinear elastostatics and elastodynamics - Consistent linearization - Development of nonlinear 1d, 2d, and 3d-finite-element-methods - Development of Crisfield 3d-truss element - Development of 2d- and 3d-beam elements - Static load and arc-length controlled Newton-Raphson solution procedures - Explicit and implicit solution of nonlinear dynamics - Nonlinear finite element program development - Nonlinear numerical analyses of components of wind power plants using a MATLAB finite element code	
Study and examination requirements and forms of examination	Written exam (120 min) or online oral examination (30 min) or written homework (25 pages) with presentation of the homework (30 min). The examinations are going to 75% (written homework) of the shares and 25% (presentation) in the final grade of the module.
Media employed	Online materials as lecture notes, presentations, interactive learning modules and chapter checks. Online class room

Reading list

Textbooks on the nonlinear finite element method, e.g.

Zienkiewicz & Taylor (2000): The Finite Element Method. Volume 2. Solid Mechanics

Crisfield (1993, 1997): Non-Linear Finite Element Analysis of Solids and Structures. Volume 1: Essentials. Volume 2: Advanced Topics

Belytschko, Liu & Moran (2000): Nonlinear Finite Elements for Continua and Structures

Wriggers (2008): Nonlinear Finite Element Methods

Particular journal papers as basis of homeworks , e.g.

Geers (1999): Enhanced Solution Control for Physically and Geometrically Non-Linear Problems. Part I – The Subplane Control Approach. Part II – Comparative Performance Analysis. International Journal for Numerical Methods in Engineering, (46), 177-230

Betsch & Steinmann (2001): Conservation Properties of a Time FE Method – Part II: Time-Stepping Schemes for Non-Linear Elastodynamics. International Journal for Numerical Methods in Engineering, (50), 1931-1955

Ibrahimbegovic & Mamouri (2002): Energy Conserving/Decaying Implicit Time-Stepping Scheme for Non-linear Dynamics of Three-Dimensional Beams Undergoing Finite Rotations. Computer Methods in Applied Mechanics and Engineering, (191), 4241-4258