An ECCOMAS Advanced Course on Computational Structural Dynamics

Institute of Thermomechanics
Czech Academy of Sciences

and

Faculty of Civil Engineering,
Czech Technical University
in Prague

Prague
Czech Republic

June 4-8, 2018

Lecturers

Prof. K.C. Park
University of Colorado,
Boulder, USA
Prof. Alain Combescure
Institut National des Sciences
Appliquées, Lyon, France
Dr. Jiří Plešek
Institute of Thermomechanics,
Prague, Czech Republic
Prof. Jaroslav Kruis
Czech Technical University in Prague,
Czech Republic
Prof. José González
Universidad de Sevilla, Spain
Prof. Alexander Popp
Bundeswehr University Munich,
Germany
Dr. Jin-Gyun Kim
Institute of Machinery and Materials,
Korea
Dr. Anton Tkachuk
University of Stuttgart, Germany
Dr. Radek Kolman
Institute of Thermomechanics,
Prague, Czech Republic

Topics:

The course covers topics relating to modern and recent numerical methods in *computational structural dynamics*, finite element method in linear and nonlinear dynamic cases, wave propagation in solids and its numerical solution, numerical methods in dynamic contact problems, buckling analysis, modern methods for direct time integration and partitioned analysis, modal and spectral analysis, coupled problems (e.g. fluid-structure interaction), reduction modelling in dynamics and many others.

The short course is organized under

European Community on Computational Methods in Applied Sciences

Central European Association for Computational Mechanics

- Czech Society for Mechanics
- Academy of Sciences of the Czech Republic
- Institute of Thermomechanics, CAS
- Centre of Excellence for Nonlinear Dynamic Behaviour of Advanced Materials in Engineering
- Faculty of Civil Engineering, Czech Technical University in Prague

Course schedule:

9.00 -10.00	Lecture
10.00-10.20	Coffee break
10.20-11.20	Lecture
11.20-11.40	Coffee break
11.40-12.40	Lecture
12.40-14.30	Lunch
14.30-15.30	Lecture
15.30-15.50	Coffee break
15.50-16.50	Lecture
16.50-17.15	Open discussion

Venue: Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29 Prague 6

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Course fee: Early payment up to March 15, 2018:

300 €	for 30 students and Ph.D. students from abroad (confirmation needed, contact of organizers is needed)
500 €	for students and Ph.D. students
600 €	for post-docs and junior and senior researchers
700€	for industry and private sector

Short Course Program:

Monday

1. Basics of dynamics and introduction with motivation (K.C. Park)
- Introduction of the course
- Historical background of dynamics
- Newtonian, Lagrangian and Hamiltonian mechanics

2. Continuum mechanics I (J. Plešek)
- Kinematics of deformation
- Strains and stresses
- Governing equations, Strong form

3. Continuum mechanics II (J. Plešek)
- Constitutive equations for small strains - elasticity, hyper-elasticity, plasticity
- Numerical integration of constitutive equations

4. Continuum mechanics III (A. Tkachuk)
- Variational formulations in dynamics
- Mixed formulations, Tonti diagram, Hamilton's principle, Weak forms

5. Dynamics of multibody systems (J. Kim)
- Governing equations, Constrains
- Lagrange equations and Lagrange multipliers
- Numerical methods in multibody dynamics

Tuesday

6. Finite element method I - Basics (J. Gonzalez)
- Principle of virtual work
- Finite Element Formulation
- Assembly of global matrices
- Convergence properties

7. Finite element method II (J. Gonzalez)
- Shape functions and higher order FEM
- Isoparametric formulation
- Numerical integration
- Hybrid and mixed formulation, inf-sup condition

8. Finite element method III - Mass matrices (A. Tkachuk)
- Properties of mass matrix
- Consistent and lumped mass matrices
- Higher-order mass matrix
- Direct inversion of mass matrix

9. Finite element method IV (J. Gonzalez)
- Implementation of FE codes for linear dynamics (Matlab)

10. Poster section of participants

Wednesday

11. Finite element method V – Beams and Plates (A. Combescure)
- Basics of beam theory – Euler-Bernoulli and Timoshenko theory
- Basics of plate theory - Kirchoff-Love and Mindlin theory
- FEM for beams and plates
- Free vibration of beams and plates

12. Finite element method VI – Shells (A. Combescure)
- Basics of shell theory
- FEM shell models
- Shells in dynamics

13. Finite element method VII (A. Tkachuk)
- Locking phenomena and hourglass effect
- Assumed strain, enhanced strain FEM, B-bar formulation
- Reduced integration and stabilization

14. Finite element method VIII– Linear Solvers (J. Kruis)
- Linear solvers in FEM
- Matrix factorization
- Sparse solvers, Krylov methods (especially conjugate gradient method)

15. Finite element method IX (J. Kruis)
- FEM in vibration problems
- Spectral and modal analysis
- Numerical methods for eigen-value problem (subspace iteration, etc)
- Convergence of FEM in eigen-value problem
- Dynamic steady state response

Thuersday

16. Finite element method X (A. Popp)
- Basics of nonlinear continuum mechanics, FEM for nonlinear problems, Total Lagrangian formulation, Nonlinear solvers - Newton-Raphson method

17. Finite element method XI - Direct time integration in dynamics (R. Kolman)
- FEM in dynamics, formulation of dynamic problems
- Introduction into direct time integration
- Basic methods (Newmark method and central difference method)
- Solving of nonlinear time-depend problems
- Time step size estimates, mass scaling

18. Buckling phenomena (A. Combescure)
- Linear theory of stability
- Solution methods, path following techniques
- Identification of critical points
- Pre-buckling analysis and nonlinear stability analysis

19. Wave propagation (R. Kolman)
- Theory of wave propagation in elastic solids, Wave speeds in solids
- Dispersion and frequency analysis of FEM,

20. Partitioned analysis (K.C. Park)
- Theory of Lagrange multipliers
- Basic theory of partitioned analysis
- Equations of motion for partitioned systems, Domain decomposition methods and FETI

Friday

21. Model reduction in dynamics (J. Kim)
- Variational analysis of dynamic sub-structuring, Hurty and Craig-Bampton methods, dynamic reduction, mode selection, error estimation,

22. Contact problems I (A. Popp)
- Basics of contact mechanics, FEM for contact problems
- Penalty, Lagrange multiplier and Augmented Lagrangian methods

23. Contact problems II (A. Popp)
- Modeling of friction
- Advanced discretization techniques and solution algorithms
- Mortar methods, Semi-smooth Newton methods

24. Coupled problems – Fluid-structures interactions (K.C. Park)
- Variational formulation
- Methods of discretizations
- Staggered analysis

25. Closing and discussion