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COMPUTATIONAL MECHANICS IN FINLAND

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Finland is known as a land of ice and snow. Thus good knowledge of arctic technology is very important for us. When constructing in arctic conditions, unusually large stresses are often caused by large temperature variations and by ice and snow loads.

The analysis in fracture mechanics was first developed mainly because of the safety analysis required in nuclear power plants, but later the methods were applied increasingly in other fields of industry as well.

The departments at the technical universities have pioneered the research and the training of specialists in steel structures and welding technology in Finland. Because of robot and laser technology the latter field is of governing interest.

In this description some of today's activities in the sphere of computational mechanics in Finland have been collected. It consists of a short list of research interests and projects, finite element and computer-aided engineering software at five universities and at the technical research centre of the state. In the section on recent research reports a list of some recent publications from these institutions is given.

At *Helsinki University of Technology* the research activity in computational mechanics concentrates mainly on four departments. The research topics at the *Department of Civil Engineering* (M. J. Mikkola) are

(a) Non-linear problems of structural mechanics:
  (i) geometrical and material non-linearities
  (ii) static and transient dynamic problems
  (iii) beams, frames, plates and shells
  (iv) metal and reinforced concrete structures.
(b) Constitutive equations and concrete based on continuous damage theory.
(c) Numerical analysis of box girders.
(d) Structural analysis of fire-exposed steel structures.

The research projects at the *Department of Mechanics* (E.-M. Salonen) are

(a) Applications of the finite element method:
  (i) free surface flows in hydraulics
  (ii) plate bending with non-conforming elements.
(b) Non-linear phenomena and chaos:
  (i) chaos in an impact oscillator
  (ii) chaos in Duffing's oscillator.

At the *Institute of Strength of Materials* (E. Pennala) problems regarding the state of stress and deformations of structures of various materials are investigated by means of mathematical models, finite element methods and experiments. Research is carried out in the following areas:

(a) Fatigue of materials and structures.
(b) Basic strength properties of Finnish structural plywoods.
(c) Vibrations of structures (theoretically: FEM; experimentally: single and multiple exciter techniques).

At the *Institute of Mathematics* (J. Pitkäranta) the research in computational mechanics is devoted to the theoretical aspects of the finite element method, especially to

(a) Mixed finite element methods.
(b) Multigrid methods.

The commercial FEM computer programs used at Helsinki University of Technology are ADINA, ADINAT, PAFEC, PIGS and SAPIV. CAE software: CADAM, CATIA, SUPERTAB and SUPERB. Moreover, several programs have been developed for special methods of FEM and especially in CAE.

At *Tampere University of Technology* the research related to computational mechanics is carried out in the *Institution of Applied Mechanics* (A. Pramila). The research projects are

(a) Surface and curve creation methods for CAD using variational principles and FEM. Applications in the ship, boat and aeroplane industries.
(b) Vibration and stability of axially moving material. Applications to sheet flutter control in paper mills and printing machines.
(c) Statistics of thin shells of revolution employing FEM based on analytical solutions. Applications to pressure vessels and storage tanks etc.
(d) Force methods in the analysis of geometrically non-linear structures. Applications to bridges.
(e) Multicriterion optimization of structures. Applications to every kind of load carrying structure.
(f) Mechanics of curved beams. Applications to stairs, bridges etc.
(g) Unilateral contact problems. Applications to railway wheels etc.
(h) Numerical methods in fracture mechanics.

The FEM programs used are: ABACUS, ADINA, ANSYS, GAFEP, SAP VI, SAP VII, and STAFRA. CAE-systems: Gen Rad 2515, Computervisions and CADAM.

At the *University of Oulu* the research in computational mechanics is taking place mainly at two departments. At the *Laboratory of Technical Mechanics* (M. Määttänen) the research projects are

(a) Ice–structure dynamic interaction.
(b) Ice forces against offshore structures.
(c) Mechanical vibrations, e.g. applied to paper machines.
(d) Large displacement material non-linear (including viscosity) FEM analysis.
(e) Post-buckling behaviour of plates on elastic foundations.

At the *Department of Mathematics* (J. Saranen) theoretical aspects of FEM, the boundary element method and the collocation method are studied. The research projects are

(a) FEM solution of compressible and incompressible flows.

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(b) BEM solution of non-smooth potentials.
(c) Fast solvers of BEM.
(d) FEM analysis of high-speed elevator vibration.

The FEM/CAE programs used are ADINA, FINEL, NASTRAN, NONSAP, STRUOL, and CAODS 4. The Department of Mathematics uses mainly its own program development.

Lappeenranta University of Technology is the youngest technical university in Finland (opened in 1969). In computational mechanics the research is being done at the *Department of Mechanical Engineering* (H. Martikka and M. Suviolahti). The main research interests are

(a) In design of machine elements:
  (i) CAD
  (ii) optimization of machine elements and mechanisms.
(b) Steel structures:
  (i) plastic capacity of joints
  (ii) weld fatigue, residual stresses due to welding
  (iii) elastic-plastic fracture mechanics
  (iv) optimization of structures.
(c) Workshop engineering research.
(d) Practical applications of photoelasticity.
(e) Secondary stresses of structures.
(f) FE software for microcomputers.
(g) Thermal stresses in continuous casting of steel.

The FEM programs used are ADINA, ANSYS, NASTRAN, SAP IV, SAP VI, and TWODEPEP. CAE software: I-DEAS included GEOMOD, MODAL PLUS, SUPERTAB, SUPERB and SYSTAN. Moreover, the structural optimization program STARS is used.

At the *University of Jyväskylä* the research in the sphere of computational mechanics is being carried out at the *Department of Applied Mathematics* (P. Neittaanmäki). The research projects in this field are

(a) FEM in contact problems.
(b) Optimum structural design in contact problems.
(c) Computation of stresses and strains by post-processing techniques with linear elements.
(d) Optimization of the water spray cooling in continuous casting of steel.
(e) Multigrid methods.
(f) FEM in microcomputers.

The FEM programs used are: ANSYS, INTERLIB (developed by INRIA, France), ELLPACK, and TWODEPEP. Because the research is focused on new methods or special problems locally developed programs have been used.

The *Technical Research Centre* of Finland (VTT) is a polytechnical consultative research establishment dealing with almost all areas of technology. In structural mechanics there are activities altogether at nine laboratories covering different fields of technology such as mechanical and civil engineering, naval architecture, geotechnics and nuclear engineering; both experimental and theoretical work is widely carried out. In addition to the conventional calculations, measurements and testing, VTT has developed advanced methods in several areas, some of which are

(a) Arctic technology
(b) Fracture mechanics and fatigue
(c) Dynamic measurements

General purpose finite element programs are used in VTT. We mention ADINA, ADINAT, PFEC, SAP VI, PIPEBREAK, JTROCK, CRACK, FEFLOW, MAGENON, COUPLE, STRUDL-II, and FLUSH. For further information contact J. Vanne.

The *Finnish State Computer Centre* (VTKK) at Espoo supports the software development of universities. Moreover, though the computer net, FUNET, the universities can use the software and computers of VTKK. The engineering software of VTKK includes, among others, ADINA, ELLPACK, BASPL, NAGFEM, NASTRAN, PHOENICS, PIGS, SPICE 2, SUPERTAB, and TWODEPEP. For further information contact M. Käpyaho.

RECENT RESEARCH REPORTS

(1) Helsinki University of Technology, SF 02150 Espoo, Finland

(a) Department of Civil Engineering

M. Mikkola, and M. Tuomala, 'Comparative study of the nonlinear response of plane and arches'.

M. Mikkola, M. Tuomala, and K. Wolf, 'Nonlinear transient response of beams and frames'.

M. J. Mikkola, and P. Piila, 'Nonlinear response of concrete by use of continuous damage theory'.

M. J. Mikkola, 'Uber die nichtlineare Berechnung von Tragwerken unter statischer und dynamischer Belastung'.

(b) Institute of Mechanics

E. M. Salonen and J. Paavola, 'The principle of virtual work with discontinuous virtual displacements'.

H. M. Isomäki, J. von Boehm and R. Räty, 'Devil's attractor and chaos of a driven impact oscillator'. H. M. Isomäki, J. von Boehm and R. Räty, 'Chaotic motion of an impact oscillator'.

R. Räty, H. M. Isomäki and J. von Boehm, 'Chaotic motion of a classical anharmonie oscillator'.

R. Räty, J. von Boehm and H. M. Isomäki, 'Absence of inversion-symmetric limit cycles of even periods and the chaotic notion of Duffing's oscillator'.

(c) Department of General Sciences

(c1) Institute of Strength of Materials

Matti K. Hakala, 'Numerical modelling of fluid-structure and structure–structure interaction in ship vibration'.

Erkki Pennala, Mika Nieminen and Sami Saarinen, 'Report of racking tests carried out on timber framed wall panels sheeted with 6.5 mm Finnish conifer plywood'.

(c2) Department of Mathematics

J. Pitkäranta and T. Saarinen, 'A multigrid version of a simple finite element method for the Stokes problem'.
R. Stenberg, 'Analysis of mixed finite element methods for the Stokes problem: a unified approach'.
R. Stenberg, 'Analysis of the convergence of mixed finite element methods'.
C. Johnson, U. Nävert and J. Pitkäranta, 'Finite element methods for linear hyperbolic problems'.
J. Pitkäranta and R. Stenberg, 'Analysis of some mixed finite element methods for plane elasticity equations'.
C. Johnson and J. Pitkäranta, 'Analysis of some mixed finite element methods related to reduced integration'.
J. Pitkäranta, 'On a mixed finite element method for the Stokes problem in R3'.
J. Pitkäranta, 'On multigrid methods'.

(2) Tampere University of Technology, Institution of Applied Mechanics, Box 527, SF-33101 Tampere 10, Finland
A. Pramila, (ed.), *Proceedings of the 2nd Finnish Mechanics Days.*
J. Koski, 'Bicriterion optimum design method for elastic trusses'.

(3) University of Oulu, Linnanmaa, SF 90570 Oulu, Finland
(a) Laboratory of Technical Mechanics
Mauri Määttänen, 'The effect of structural properties on ice-induced self-excited vibrations'.
Mauri Määttänen, (ed.), 'Ice forces, state of the art report'.
J. Hoikkanen, T. Krankkala, M. Määttänen and E. Pulkkinen, Calculation methods for loads against offshore structures'.
S.-G. Sjölind, 'Visco-elastic buckling as a load-limiting factor on rigid structures in ice'.
T. Krankkala, 'Methods for determining ice impact loads against offshore structures'.
J. Hoikkanen, 'Measurement and analysis of ice force against a conical offshore structure'.
E. Pulkkinen, 'The creep analysis of ice forces by the finite element method'.
(b) Department of Mathematics
J. Saranen, and W. Wendland, 'On the asymptotic convergence of collocation methods with spline functions of even degree'.
C. Johnson and J. Saranen, 'Streamline diffusion methods for the incompressible Euler and Navier–Stokes equations'.

(4) Lappeenranta University of Technology, Box 20, SF 53851 Lappeenranta, Finland
(a) Department of Mechanical Engineering
Matti Suviolahti, 'The use of layered photoelastic coatings in the determination of stress concentrations on pressure vessels and on related structures and components'.
M. Suviolahti, 'Collection of practical examples in structural analysis solved using the MSC Nastran I'.
M. Suviolahti, 'Error in the conventional eccentric stiffening beam formulation in connection with shell structures'.
M. Suviolahti, 'Practical examples solved using the STARDYNE I'.
M. Suviolahti, 'FEM analysis with codings of practical structural problems and the idealizations and modellings necessary in their solutions 3'.
(b) Department of Physics and Mathematics
J. Haslinger, P. Neittaanmäki and T. Tiihonen, 'Shape optimization of an elastic body in contact based on penalization of the state inequality'.
J. Haslinger, V. Horák and P. Neittaanmäki, 'Shape optimization in contact problems with friction'.
J. Haslinger and P. Neittaanmäki, 'Shape optimization in contact problems'.
P. Neittaanmäki and E. Laitinen, 'Optimization of cooling conditions in continuous casting'.
P. Neittaanmäki, P. Koikkalainen and C. A. Marinov, 'On the computation of the delay time in some parabolic problems'.
A. Kaarna and P. Neittaanmäki, 'CAE/FEM'.
J. Haslinger, P. Neittaanmäki, A. Kaarna and T. Tiihonen, 'Optimization of the domain in unilateral boundary value problems, Part I'.

(5) University Jyväskylä, Department of Mathematics, Seminaarinkatu 15, SF 40100 Jyväskylä, Finland.
P. Neittaanmäki and T. Tiihonen, 'Sensitivity analysis for a class of optimal shape design problems'.
P. Neittaanmäki (ed.), *Proceedings of the Numerical Analysis, Summer School at Jyväskylä.*
J. Haslinger and P. Neittaanmäki, 'On the existence of optimal shapes in contact problems —perfectly plastic bodies'.

(6) Technical Research Centre of Finland (VTT), SF 02150 Espoo, Finland
Pekka Oksanen, 'Friction and adhesion of ice'.
Matti K. Hakala, 'Numerical modelling of fluid-structure and structure–structure interaction in ship vibration'.
The Seventh International Conference on Port and Ocean Engineering under Arctic Conditions, Volumes 1–4, Helsinki, Finland.
'Corrosion and stress corrosion of steel pressure boundary components and steam turbines', International Atomic Energy Agency, Specialists' meeting, Espoo.