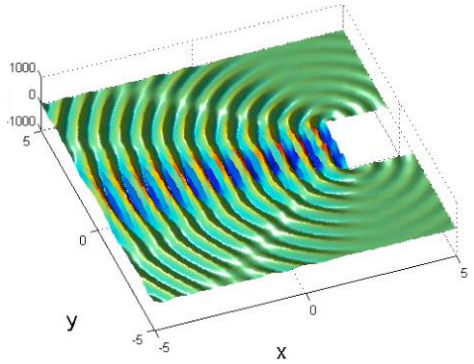
TU Delft

Delft University of Technology

Boundary Element Method (BEM)



Short course
June 14-15-16, 2011

given by

Prof. Lothar Gaul
Institute of Applied and Experimental Mechanics
University of Stuttgart

Co-organized by the **Koiter Institute**

with the support of
Delft Center for Engineering Science and Engineering
www.cse.tudeflt.nl

DCSE
Delft Centre for Computational Science and Engineering

The Boundary Element Method is one of the essential tools for the modern engineer, but is only rarely included in the MSc curriculum of our Universities. This short course is organized for academic and industrial attendees and will be given by Prof. **Lothar Gaul**, an enthusiastic lecturer whose expertise stretches from experimental dynamics to advanced computational methods. He is the co-author of the book **Boundary Element Methods for Engineers and Scientists** (Springer, 2003).

Lecture Cost:

- Staff and students from TU Delft: **free**
- Academic from outside TU Delft: **€ 150**
- Industrial attendees: **€ 300**

Location and dates

The lectures (3 days) will be on June 14-15-16, 2011
at the Faculty 3mE, TU Delft, The Netherlands
Further details sent after registration

Contact and registration

To register, contact Ms. Corinne du Burck (faculty 3mE, TU Delft):
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Local organiser: Prof. Daniel J. Rixen

Registration DEADLINE: June 7, 2011

NOTE:
PhD students from the Dutch Engineering Mechanics Graduate School can report this course for their curriculum. It will count for 1,5 ECTS.

Description and detailed content: *see next pages*

Course summary

The course introduces engineering problems described by physical models, mathematical models and numerical models such as FEM, BEM, FDM leading to engineering solutions.

The historic development of the BEM is briefly reviewed. Methods of Weighted Residuals are recalled to obtain approximate solutions of Differential Equations. Finite Element (FE) and Boundary Element (BE) Formulations are compared. The Boundary Integral Method is explained by an introductory problem.

Continuum Physics is summarized for Acoustics, Heat Conduction and Electrostatics.

Source terms are treated by Cell Integration and Domain Integral Transformation to a Boundary Integral. Techniques of Subdomain Coupling are discussed.

Examples of single Domains and coupled Subdomains are solved by BEM and compared to Analytical Solutions.

Fast Boundary Element Methods using the Multipole Method and Hierarchical Matrices are compared and applied for the simulation of Vibro-Acoustic Behavior of Ship Structures.

Literature

- L. Gaul, M. Kögl, M. Wagner: Boundary Element Methods for Engineers and Scientists. Springer Verlag Berlin, ISBN 3-540-00463-7, 2003
- D. Brunner, M. Junge, P. Rapp, M. Bebendorf and L. Gaul: Comparison of the Fast Multipole Method with Hierarchical Matrices for the Helmholtz-BEM. CMES, vol. 58, no. 2, pp 131 – 158, 2010

Content of the course

Introduction

- Numerical Solution of Engineering Problems
- Historic Development of Boundary Element method
- The Method of Weighted Residuals
  - Collocation Method
  - Method of Moments
  - Galerkin's Method
  - Collocation by Subregions
  - Least Squares
- Boundary Elements vs. Finite Elements
  - General Features
  - Comparison of FE and BE Formulations
- Boundary Integral Method for 1-D Differential Equation
- General Boundary Element Approach

Continuum Physics

- Acoustics
  - The Acoustic Wave Equation
  - Constitutive Equations
  - The Velocity Potential
  - Boundary Conditions in Acoustics

  - Radiation Condition in Infinite Domains
- Heat Conduction
  - First Law of Thermodynamics
  - Second Law of Thermodynamics
  - Field Equation of Heat Conduction
  - Boundary and Initial Conditions
- Electrodynamics
  - Maxwell's Equations in Vacuum
  - Electromagnetic Wave Equations
  - Electrostatic Field in Macroscopic Media

Boundary Element Method for Potential Problems

- Introduction
- BE Formulation of Laplace's Equation
  - Inverse Formulation of Differential Equation
  - Green's Representation Formula
  - Fundamental Solutions
  - Boundary Integral Equation of the 2-D Problem
  - Discretization of the Boundary
  - The Collocation Method
  - Modelling of Discontinuous Fluxes
- Example: Steady-State Heat Conduction
  - Calculation of System Matrices
  - Assembly and Solution of Equations
  - The Analytical Solution
- Calculation of Solution in the Domain
  - Potential in the Domain
  - Flux in the Domain
- Poisson's Equation – Treatment of Source Terms
  - Calculation of Domain Integral by Cell Integration
  - Calculation of Domain Integral by Transformation to a Boundary Integral
  - Calculation of the Unknown Boundary Variables
- Indirect Calculation of Diagonal Entries of
- Concentrated Sources
- Subdomains
- Orthotropic Heat Conduction
- Example: Coupling of Orthotropic and Isotropic Subdomains

Comparison of the Multipole BEM with BEM using Hierarchical Matrices for the simulation of the Vibro-Acoustic Behavior of Ship Structures

- Motivation
- Boundary Element Method (Water) treated by Galerkin Method
  - Half Space formulation (Burton-Miller)
  - Mixed formulation
- Fast Boundary Element Methods
  - Diagonal form of fast multipole method
  - Hierarchical matrices
- Fluid-Structure Coupling
  - FE-formulation
  - Direct coupling
  - Coupling with Lagrange multipliers
- Examples: Submarine and Container Ship