Simulation Methods in Acoustics

Exam Topics

December 2017

1. The direct stiffness method.

   Linear spring element. Element degrees of freedom. Element stiffness matrix in local and global coordinates. Connectivity constraints. Structure of the global stiffness matrix. Properties of the stiffness matrix (symmetry, definiteness) and their physical interpretation.

2. Linear constraints

   Formulation of linear multiple degree of freedom constraints. Canocical form and matrix notation. The master–slave method. The penalty method. The method of Lagrange multipliers.

   Special cases: Clamped DOF and rigid body constraints.

3. Solution of linear systems of algebraic equations

   Forward and backward substitution. Gaussian elimination and LU-decomposition. Pivoting: Problem definition and possible solutions. LDLT and Cholesky decompositions. Sparse systems. The Cuthill–McKee algorithm for bandwidth reduction.

4. Dynamic Systems

   Mass element and mass matrix. Damping elements and damping matrix. Properties of the mass and damping matrices. The equation of motion and its analytical solution.

5. Time stepping methods

   Construction of numerical derivative schemes. Forward and backward Euler method. Definition of stability and accuracy. Determining the range of stability and order of accuracy of a time stepping method. Runge-Kutta methods.

6. The modal solution

   Definition of modes. Obtaining the normal modes of the equation of motion. The equation of motion in modal coordinates. Properties of the generalized system matrices. Proportional damping models. Rayleigh damping.

7. Vibroacoustic modal analysis

   Vibroacoustic reciprocity and its application in modal testing. Vibroacoustic transfer functions and transfer matrices.

8. Finite dimensional approximation of functions

   Finite dimensional function representations. Methods for obtaining the coordinates: Collocation and Galerkin methods.

9. The weak form of boundary value problems

   Construction steps of the weak form. Interpretation of "weakness". Methods for discretizing and solving the weak form. Test and trial functions.

   Derive the weak form of the Poisson's equation in higher dimensions.

10. The Finite Element Method

    Discretization of the weak form: Finite elements and geometrical mappings. Shape functions.

    The acoustic finite element method. Mass and stiffness matrices.

    Boundary conditions in acoustic FEM.

11. Vibroacoustic FEM-FEM coupling

    The weak form of a coupled vibroacoustic system. Vibroacoustic coupling matrices. Projection of the coupled system to normal (mechanical/acoustical) modes.

12. Fundamental solutions and Green's functions

    Definitions. Convolution property of fundamental solutions. Time and space domain analogies. Fundamental solutions of the Poisson equation in 1D and 2D. Construction Green's functions using the method of mirror images.

13. Boundary element methods

    Motivation. General procedure for obtainig a boundary integral representation (BIR). The boundary integral equation (BIE). Discretizaion and solution of the BIE. Properties of the BIE system matrices.

14. Acoustic boundary elements

    Green's functions of the Helmholtz equation in 1D, 2D, 3D. Properties of the Green's functions. The Kirchhoff–Helmholtz integral equation (KHIE). The Sommerfeld radiation condition. Acoustic BEM system matrices (definition, properties). Solution steps of a radiation problem.

15. Numerical integration over standard domains

    Quadratures for regular functions. Newton–Cotes and Gaussian quadratures. Tensor product quadrartures. Duffy transform. Methods for singular integrals with integrable singularities.

16. Vibroacoustic FEM/BEM coupling

    Problem definition. The effect of air loading on structural vibrations. Formulation of the coupled problem. Structure and properties of the coupled system matrices.