

1. Record Nr.	UNINA9910830035403321
Autore	Peiffer Alexander
Titolo	Vibroacoustic simulation : an introduction to statistical energy analysis and hybrid methods / / Alexander Peiffer
Pubbl/distr/stampa	Hoboken, New Jersey : , : John Wiley & Sons, Inc., , [2022] ©2022
ISBN	1-119-84987-X 1-119-84985-3
Descrizione fisica	1 online resource (474 pages)
Disciplina	620.3
Soggetti	Vibration - Mathematical models Acoustical engineering - Mathematics
Lingua di pubblicazione	Inglese
Formato	Materiale a stampa
Livello bibliografico	Monografia
Nota di bibliografia	Includes bibliographical references and index.
Nota di contenuto	Intro -- Vibroacoustic Simulation -- Contents -- Preface -- Acknowledgments -- Acronyms -- 1 Linear Systems, Random Process and Signals -- 1.1 The Damped Harmonic Oscillator -- 1.1.1 Homogeneous Solutions -- 1.1.2 The Overdamped Oscillator (> 1) -- 1.1.3 The Underdamped Oscillator (< 1) -- 1.1.4 The Critically Damped Oscillator ($= 1$) -- 1.2 Forced Harmonic Oscillator -- 1.2.1 Frequency Response -- 1.2.2 Energy, Power and Impedance -- 1.2.3 Impedance and Response Functions -- 1.2.4 Damping -- 1.2.5 Damping in Real Systems -- 1.3 Two Degrees of Freedom Systems (2DOF) -- 1.3.1 Natural Frequencies of the 2DOF System -- 1.4 Multiple Degrees of Freedom Systems MDOF -- 1.4.1 Assembling the Mass Matrix -- 1.4.2 Assembling the Stiffness Matrix -- 1.4.3 Power Input into MDOF Systems -- 1.4.4 Normal Modes -- 1.5 Random Process -- 1.5.1 Probability Function -- 1.5.2 Correlation Coefficient -- 1.5.3 Correlation Functions for Random Time Signals -- 1.5.4 Fourier Analysis of Random Signals -- 1.5.5 Estimation of Power and Cross Spectra -- 1.6 Systems -- 1.6.1 SISO-System Response in Frequency Domain -- 1.6.2 System Response in Time Domain -- 1.6.3 Systems Excited by Random Signals -- 1.7 Multiple-input-multiple-output Systems -- 1.7.1 Multiple Random Inputs -- 1.7.2 Response of MIMO Systems to Random Load -- Bibliography -- 2 Waves in Fluids --

2.1 Introduction -- 2.2 Wave Equation for Fluids -- 2.2.1 Conservation of Mass -- 2.2.2 Newton's law - Conservation of Momentum -- 2.2.3 Equation of State -- 2.2.4 Linearized Equations -- 2.2.5 Acoustic Wave Equation -- 2.3 Solutions of the Wave Equation -- 2.3.1 Harmonic Waves -- 2.3.2 Helmholtz equation -- 2.3.3 Field Quantities: Sound Intensity, Energy Density and Sound Power -- 2.3.4 Damping in Waves -- 2.4 Fundamental Acoustic Sources -- 2.4.1 Monopoles - Spherical Sources.

2.5 Reflection of Plane Waves -- 2.6 Reflection and Transmission of Plane Waves -- 2.7 Inhomogeneous Wave Equation -- 2.7.1 Acoustic Green's Functions -- 2.7.2 Rayleigh integral -- 2.7.3 Piston in a Wall -- 2.7.4 Power Radiation -- 2.8 Units, Measures, and levels -- Bibliography -- 3 Wave Propagation in Structures -- 3.1 Introduction -- 3.2 Basic Equations and Definitions -- 3.2.1 Mechanical Strain -- 3.2.2 Mechanical Stress -- 3.2.3 Material Laws -- 3.3 Wave Equation -- 3.3.1 The One-dimensional Wave Equation -- 3.3.2 The Three-dimensional Wave Equation -- 3.4 Waves in Infinite Solids -- 3.4.1 Longitudinal Waves -- 3.4.2 Shear waves -- 3.5 Beams -- 3.5.1 Longitudinal Waves -- 3.5.2 Power, Energy, and Impedance -- 3.5.3 Bending Waves -- 3.5.4 Power, Energy, and Impedance -- 3.6 Membranes -- 3.7 Plates -- 3.7.1 Strain-displacement Relations -- 3.7.2 In-plane Wave Equation -- 3.7.3 Longitudinal Waves -- 3.7.4 Shear Waves -- 3.7.5 Combination of Longitudinal and Shear Waves -- 3.7.6 Bending Wave Equation -- 3.8 Propagation of Energy in Dispersive Waves -- 3.9 Findings -- Bibliography -- 4 Fluid Systems -- 4.1 One-dimensional Systems -- 4.1.1 System Response -- 4.1.2 Power Input -- 4.1.3 Pressure Field -- 4.1.4 Modes -- 4.2 Three-dimensional Systems -- 4.2.1 Modes -- 4.2.2 Modal Frequency Response -- 4.2.3 System Responses -- 4.3 Numerical Solutions -- 4.3.1 Acoustic Finite Element Methods -- 4.3.2 Deterministic Acoustic Elements -- 4.4 Reciprocity -- Bibliography -- 5 Structure Systems -- 5.1 Introduction -- 5.2 One-dimensional Systems -- 5.2.1 Longitudinal Waves in Finite Beams -- 5.2.2 Bending Wave in Finite Beams -- 5.3 Two-dimensional Systems -- 5.3.1 Bending Waves in Flat Plates -- 5.4 Reciprocity -- 5.5 Numerical Solutions -- 5.5.1 Normal Modes in Discrete Form -- Bibliography -- 6 Random Description of Systems -- 6.1 Diffuse Wave Field.

6.1.1 Wave-Energy Relationships -- 6.1.2 Diffuse Field Parameter of One-Dimensional Systems -- 6.1.3 Diffuse Field Parameter of Two-Dimensional Systems -- 6.1.4 Diffuse Field Parameter of Three-Dimensional Systems -- 6.1.5 Topology Conclusions -- 6.1.6 Auto Correlation and Boundary Effects -- 6.1.7 Sources in the Diffuse Acoustic Field - the Direct Field -- 6.1.8 Some Comments on the Diffuse Field Approach -- 6.2 Ensemble Averaging of Deterministic Systems -- 6.3 One-Dimensional Systems -- 6.3.1 Fluid Tubes -- 6.4 Two-Dimensional Systems -- 6.4.1 Plates -- 6.4.2 Monte Carlo Simulation -- 6.5 Three-Dimensional Systems - Cavities -- 6.5.1 Energy and Intensity -- 6.5.2 Power Input to the Reverberant Field -- 6.5.3 Dissipation -- 6.5.4 Power Balance -- 6.5.5 Monte Carlo Simulation -- 6.6 Surface Load of Diffuse Acoustic Fields -- 6.7 Mode Wave Duality -- 6.7.1 Diffuse Field Energy -- 6.7.2 Free Field Power Input -- 6.8 SEA System Description -- 6.8.1 Power Balance in Diffuse Fields -- 6.8.2 Reciprocity Relationships -- 6.8.3 Fluid Analogy -- 6.8.4 Power Input -- 6.8.5 Engineering Units -- 6.8.6 Multiple Wave Fields -- Bibliography -- 7 Coupled Systems -- 7.1 Deterministic Subsystems and their Degrees of Freedom -- 7.2 Coupling Deterministic Systems -- 7.2.1 Fluid Subsystems -- 7.2.2 Fluid Structure Coupling -- 7.2.3 Deterministic Systems Coupled to the Free

Field -- 7.3 Coupling Random Systems -- 7.3.1 Power Input to System (m) from the nth Reverberant Field -- 7.3.2 Power Leaving the (m)th Subsystem -- 7.3.3 Some Remarks on SEA Modelling -- 7.4 Hybrid FEM/SEA Method -- 7.4.1 Combining SEA and FEM Subsystems -- 7.4.2 Work Flow of Hybrid Simulation -- 7.5 Hybrid Modelling in Modal Coordinates -- Bibliography -- 8 Coupling Loss Factors -- 8.1 Transmission Coefficients and Coupling Loss Factors -- 8.1.1 - Relationship from Diffuse Field Assumptions. 8.1.2 Angular Averaging -- 8.2 Radiation Stiffness and Coupling Loss Factors -- 8.2.1 Point Radiation Stiffness -- 8.2.2 Point Junctions -- 8.2.3 Area Radiation Stiffness -- 8.2.4 Area Junctions -- 8.2.5 Line Radiation Stiffness -- 8.2.6 Line Junctions -- 8.2.7 Summary -- Bibliography -- 9 Deterministic Applications -- 9.1 Acoustic One-Dimensional Elements -- 9.1.1 Transfer Matrix and Finite Element Convention -- 9.1.2 Acoustic One-Dimensional Networks -- 9.1.3 The Acoustic Pipe -- 9.1.4 Volumes and Closed Pipes -- 9.1.5 Limp Layer -- 9.1.6 Membranes -- 9.1.7 Perforated Sheets -- 9.1.8 Branch Lumped Elements -- 9.1.9 Boundary Conditions -- 9.1.10 Performance Indicators -- 9.2 Coupled One-Dimensional Systems -- 9.2.1 Change in Cross Section -- 9.2.2 Impedance Tube -- 9.2.3 Helmholtz Resonator -- 9.2.4 Quarter Wave Resonator -- 9.2.5 Muffler System -- 9.2.6 T-Joint -- 9.2.7 Conclusions of 1D-Systems -- 9.3 Infinite Layers -- 9.3.1 Plate Layer -- 9.3.2 Lumped Elements Layers -- 9.3.3 Fluid Layer -- 9.3.4 Equivalent Fluid - Fiber Material -- 9.3.5 Performance Indicators -- 9.3.6 Conclusions on Layer Formulation -- 9.4 Acoustic Absorber -- 9.4.1 Single Fiber Layer -- 9.4.2 Multiple Layer Absorbers -- 9.4.3 Absorber with Perforate -- 9.4.4 Single Degree of Freedom Liner -- 9.5 Acoustic Wall Constructions -- 9.5.1 Double Walls -- 9.5.2 Limp Double Walls with Fiber -- 9.5.3 Two Plates with Fiber -- 9.5.4 Conclusion on Double Walls -- Bibliography -- 10 Application of Random systems -- 10.1 Frequency Bands for SEA Simulation -- 10.2 Fluid Systems -- 10.2.1 Twin Chamber -- 10.3 Algorithms of SEA -- 10.4 Coupled Plate Systems -- 10.4.1 Two Coupled Plates -- 10.5 Fluid-Structure Coupled Systems -- 10.5.1 Twin Chamber -- 10.5.2 Noise Control Treatments -- 10.5.3 Transmission Loss of Trimmed Plate -- 10.5.4 Free Field Radiation into Half Space. 10.5.5 Isolating Box -- 10.5.6 Rules of Noise Control -- Bibliography -- 11 Hybrid Systems -- 11.1 Hybrid SEA Matrix -- 11.2 Twin Chamber -- 11.2.1 Step 1 - Setting up System Configurations -- 11.2.2 Step 2 - Setting up System Matrices and Coupling Loss Factors -- 11.2.3 Step 3 - External Loads -- 11.2.4 Step 4 - Solving System Matrices -- 11.2.5 Step 5 - Adding the Results -- 11.3 Trim in Hybrid Theory -- 11.3.1 The Trim Stiffness Matrix -- 11.3.2 Hybrid Modal Formulation of Trim and Plate -- 11.3.3 Modal Space -- 11.3.4 Plate Example with Trim -- Bibliography -- 12 Industrial Cases -- 12.1 Simulation Strategy -- 12.1.1 Motivation -- 12.1.2 Choice of Simulation Method -- 12.2 Aircraft -- 12.2.1 Excitation -- 12.2.2 Simulation Strategy -- 12.2.3 Fuselage Sidewall -- 12.2.4 SEA Model of a Fuselage Section -- 12.3 Automotive -- 12.3.1 Simulation Strategy -- 12.3.2 Excitation -- 12.3.3 Rear Carbody -- 12.3.4 Full Scale SEA Models -- 12.4 Trains -- 12.4.1 Structural Design -- 12.4.2 Interior Design -- 12.4.3 Excitation and Transmission Paths -- 12.4.4 Simulation Strategy -- 12.4.5 Applications to Rail Structures - Double Walls -- 12.4.6 Carbody Sections - High Speed Applications -- 12.5 Summary -- Bibliography -- 13 Conclusions and Outlook -- 13.1 Conclusions -- 13.2 What Comes Next? -- 13.3 Experimental Methods -- 13.3.1 Transfer Path Analysis -- 13.3.2 Experimental Modal Analysis -- 13.3.3 Correlation Between Test and Simulation -- 13.3.4 Experimental or Virtual SEA --

13.4 Further Reading on Simulation -- 13.4.1 Advances in SEA and Hybrid FEM/SEA Methods -- 13.5 Energy Flow Method and Influence Coefficient -- 13.5.1 More Realistic Systems -- 13.5.2 Anisotropic Material -- 13.5.3 Porous Elastic Material -- 13.5.4 Composite Material -- 13.5.5 Sandwich -- 13.5.6 Shell Theory -- 13.5.7 Wave Finite Element Method (WFE) -- 13.5.8 The High Frequency Limit. 13.6 Vibroacoustics Simulation Software.

Sommario/riassunto

VIBROACOUSTIC SIMULATION Learn to master the full range of vibroacoustic simulation using both SEA and hybrid FEM/SEA methods. Vibroacoustic simulation is the discipline of modelling and predicting the acoustic waves and vibration of particular objects, systems, or structures. This is done through finite element methods (FEM) or statistical energy analysis (SEA) to cover the full frequency range. In the mid-frequency range, both methods must be combined into a hybrid FEM/SEA approach. By doing so, engineers can model full frequency vibroacoustic simulations in complex technical systems used in aircraft, trains, cars, ships, and satellites. Indeed, hybrid approaches are increasingly used in the automotive, aerospace, and rail industries. Previously covered primarily in scientific journals, Vibroacoustic Simulation provides a practical approach that helps readers master the full frequency range of vibroacoustic simulation. Through a systematic approach, the book illustrates why both FEM and SEA are necessary in acoustic engineering and how both can be used in combination through hybrid methodologies. Striking a crucial balance between complex theories and practical applications, the text provides real-world examples of vibroacoustic simulation, such as fuselage simulation, interior-noise prediction for electric and combustion vehicles, train profiles, and more, to help elucidate the concepts described within. Vibroacoustic Simulation also features: A balance of complex theories with the nuts and bolts of real-world applications Detailed worked examples of junction equations Case studies from companies like Audi and Airbus that illustrate how the methods discussed have been applied in real-world projects A companion website that provides corresponding Python codes for all examples, allowing readers to work through the examples on their own Vibroacoustic Simulation is a useful reference for acoustic and mechanical engineers working in the automotive, aerospace, defense, or rail industries, as well as researchers and graduate students studying acoustics.
