

# Vibrations of Shells and Plates

Soedel, Werner

ISBN-13: 9780824756291

## Table of Contents

### **Preface to the Third Edition**

### **Preface to the Second Edition**

### **Preface to the First Edition**

Historical Development of Vibration Analysis of Continuous Structural Elements

References

### **Deep Shell Equations**

Shell Coordinates and Infinitesimal Distances in Shell Layers

Stress-Strain Relationships

Strain-Displacement Relationships

Love Simplifications

Membrane Forces and Bending Moments

Energy Expressions

Love's Equations by Way of Hamilton's Principle

Boundary Conditions

Hamilton's Principle

Other Deep Shell Theories

Shells of Nonuniform Thickness References

Radii of Curvature

References

### **Equations of Motion for Commonly Occurring Geometries**

Shells of Revolution

Circular Conical Shell

Circular Cylindrical Shell

Spherical Shell

Other Geometries

References

### **Nonshell Structures**

Arch

Beam and Rod

Circular Ring

Plate

Torsional Vibration of Circular Cylindrical Shell and Reduction to a Torsion Bar

References

### **Natural Frequencies and Modes**

General Approach

Transversely Vibrating Beams

Circular Ring

Rectangular Plates That are Simply Supported Along Two Opposing Edges

Circular Cylindrical Shell Simply Supported

Circular Plates Vibrating Transversely

Examples: Plate Clamped at Boundary

Orthogonality Property of Natural Modes

Superposition Modes

Orthogonal Modes from Nonorthogonal Superposition Modes

Distortion of Experimental Modes Because of Damping

Separating Time Formally

Uncoupling of Equations of Motion

In-Plane Vibrations of Rectangular Plates

In-Plane Vibration of Circular Plates

Deep Circular Cylindrical Panel Simply Supported at All Edges

Natural Mode Solutions by Power Series

On Regularities Concerning Nodelines

References

### **Simplified Shell Equations**

Membrane Approximations

Axisymmetric Eigenvalues of a Spherical Shell

Bending Approximation

Circular Cylindrical Shell

Zero In-Plane Deflection Approximation

Example: Curved Fan Blade  
Donnell-Mushtari-Vlasov Equations  
Natural Frequencies and Modes  
Circular Cylindrical Shell  
Circular Duct Clamped at Both Ends  
Vibrations of a Freestanding Smokestack  
Special Cases of the Simply Supported Closed Shell and Curved Panel  
Barrel-Shaped Shell  
Spherical Cap  
Inextensional Approximation: Ring  
Toroidal Shell  
The Barrel-Shaped Shell Using Modified Love Equations  
Doubly Curved Rectangular Plate  
References

### **Approximate Solution Techniques**

Approximate Solutions by Way of the Variational Integral  
Use of Beam Functions  
Galerkin's Method Applied to Shell Equations  
Rayleigh-Ritz Method  
Southwell's Principle  
Dunkerley's Principle  
Strain Energy Expressions  
References

### **Forced Vibrations of Shells by Modal Expansion**

Modal Participation Factor  
Initial Conditions  
Solution of the Modal Participation Factor Equation  
Reduced Systems  
Steady-State Harmonic Response  
Step and Impulse Response  
Influence of Load Distribution  
Point Loads  
Line Loads  
Point Impact  
Impulsive Forces and Point Forces Described by Dirac Delta Functions  
Definitions and Integration Property of the Dirac Delta Function  
Selection of Mode Phase Angles for Shells of Revolution  
Steady-State Circular Cylindrical Shell Response to Harmonic Point Load with All Mode Components Considered  
Initial Velocity Excitation of a Simply Supported Cylindrical Shell  
Static Deflections  
Rectangular Plate Response to Initial Displacement Caused by Static Sag  
The Concept of Modal Mass, Stiffness Damping, and Forcing  
Steady State Response of Shells to Periodic Forcing  
Plate Response to a Periodic Square Wave Forcing  
Beating Response to Steady State Harmonic Forcing  
References

### **Dynamic Influence (Green's Function)**

Formulation of the Influence Function  
Solution to General Forcing Using the Dynamic Influence Function  
Reduced Systems  
Dynamic Influence Function for the Simply Supported Shell  
Dynamic Influence Function for the Closed Circular Ring  
Traveling Point Load on a Simply Supported Cylindrical Shell  
Point Load Traveling Around a Closed Circular Cylindrical Shell in Circumferential Direction  
Steady-State Harmonic Green's Function  
Rectangular Plate Examples  
Floating Ring Impacted by a Point Mass  
References

### **Moment Loading**

Formulation of Shell Equations That Include Moment Loading  
Modal Expansion Solution  
Rotating Point Moment on a Plate  
Rotating Point Moment on a Shell  
Rectangular Plate Excited by a Line Moment  
Response of a Ring on an Elastic Foundation to a Harmonic Point Moment  
Moment Green's Function  
References

### **Vibration of Shells and Membranes Under the Influence of Initial Stresses**

Strain-Displacement Relationships  
Equations of Motion  
Pure Membranes

Example: The Circular Membrane

Spinning Saw Blade

Donnell-Mushtari-Vlasov Equations Extended to Include Initial Stresses

References

### **Shell Equations with Shear Deformation and Rotary Inertia**

Equations of Motion

Beams with Shear Deflection and Rotary Inertia

Plates with Transverse Shear Deflection and Rotary Inertia

Circular Cylindrical Shells with Transverse Shear Deflection and Rotary Inertia

References

### **Combinations of Structures**

Receptance Method

Mass Attached to Cylindrical Panel

Spring Attached to Shallow Cylindrical Panel

Harmonic Response of a System in Terms of Its Component Receptances

Dynamic Absorber

Harmonic Force Applied Through a Spring

Steady-State Response to Harmonic Displacement Excitation

Complex Receptances

Stiffening of Shells

Two Systems Joined by Two or More Displacement

Suspension of an Instrument Package in a Shell

Subtracting Structural Subsystems

Three and More Systems Connected

Examples of Three Systems Connected to Each Other

References

### **Hysteresis Damping**

Equivalent Viscous Damping Coefficient

Hysteresis Damping

Direct Utilization of Hysteresis Model in Analysis

Hysteretically Damped Plate Excited by Shaker

Steady State Response to Periodic Forcing

References

### **Shells Made of Composite Material**

Nature of Composites

Lamina-Constitutive Relationship

Laminated Composite

Equation of Motion

Orthotropic Plate

Circular Cylindrical Shell

Orthotropic Nets or Textiles Under Tension

Hanging Net or Curtain

Shells Made of Homogeneous and Isotropic Lamina

Simply Supported Sandwich Plates and Beams Composed of Three Homogeneous and Isotropic Lamina

References

### **Rotating Structures**

String Parallel to Axis of Rotation

Beam Parallel to Axis of Rotation

Rotating Ring

Rotating Ring Using Inextensional Approximation

Cylindrical Shell Rotating with Constant Spin About Its Axis

General Rotations of Elastic Systems

Shells of Revolution with Constant Spin About Their Axes of Rotation

Spinning Disk

References

### **Thermal Effects**

Stress Resultants

Equations of Motion

Plate

Arch, Ring, Beam, and Rod

Limitations

### **Elastic Foundations**

Equations of Motion for Shells on Elastic Foundations

Natural Frequencies and Modes

Plates on Elastic Foundations

Ring on Elastic Foundation

Donnell-Mushtari-Vlasov Equations with Transverse Elastic Foundation

Forces Transmitted Into the Base of the Elastic Foundation

Vertical Force Transmission Through the Elastic Foundation of a Ring on a Rigid Wheel

Response of a Shell on an Elastic Foundation to Base Excitation

Plate Examples of Base Excitation and Force Transmission

Natural Frequencies and Modes of a Ring on an Elastic Foundation in Ground Contact at a Point  
Response of a Ring on an Elastic Foundation to a Harmonic Point Displacement

References

### **Similitude**

General Similitude

Derivation of Exact Similitude Relationships for Natural Frequencies of Thin Shells

Plates

Shallow Spherical Panels of Arbitrary Contours (Influence of Curvature)

Forced Response

Approximate Scaling of Shells Controlled by Membrane Stiffness

Approximate Scaling of Shells Controlled by Bending Stiffness

References

### **Interactions with Liquids and Gases**

Fundamental Form in Three-Dimensional Curvilinear Coordinates

Stress-Strain-Displacement Relationships

Energy Expressions

Equations of Motion of Vibroelasticity with Shear

Example: Cylindrical Coordinates

Example: Cartesian Coordinates

One-Dimensional Wave Equations for Solids

Three-Dimensional Wave Equations for Solids

Three-Dimensional Wave Equations for Inviscid Compressible Liquids and Gases (Acoustics)

Interface Boundary Conditions

Example: Acoustic Radiation

Incompressible Liquids

Example: Liquid on a Plate

Orthogonality of Natural Modes for Three-Dimensional Solids, Liquids, and Gases

References

### **Discretizing Approaches**

Finite Differences

Finite Elements

Free and Forced Vibration Solutions

References

### **Index**