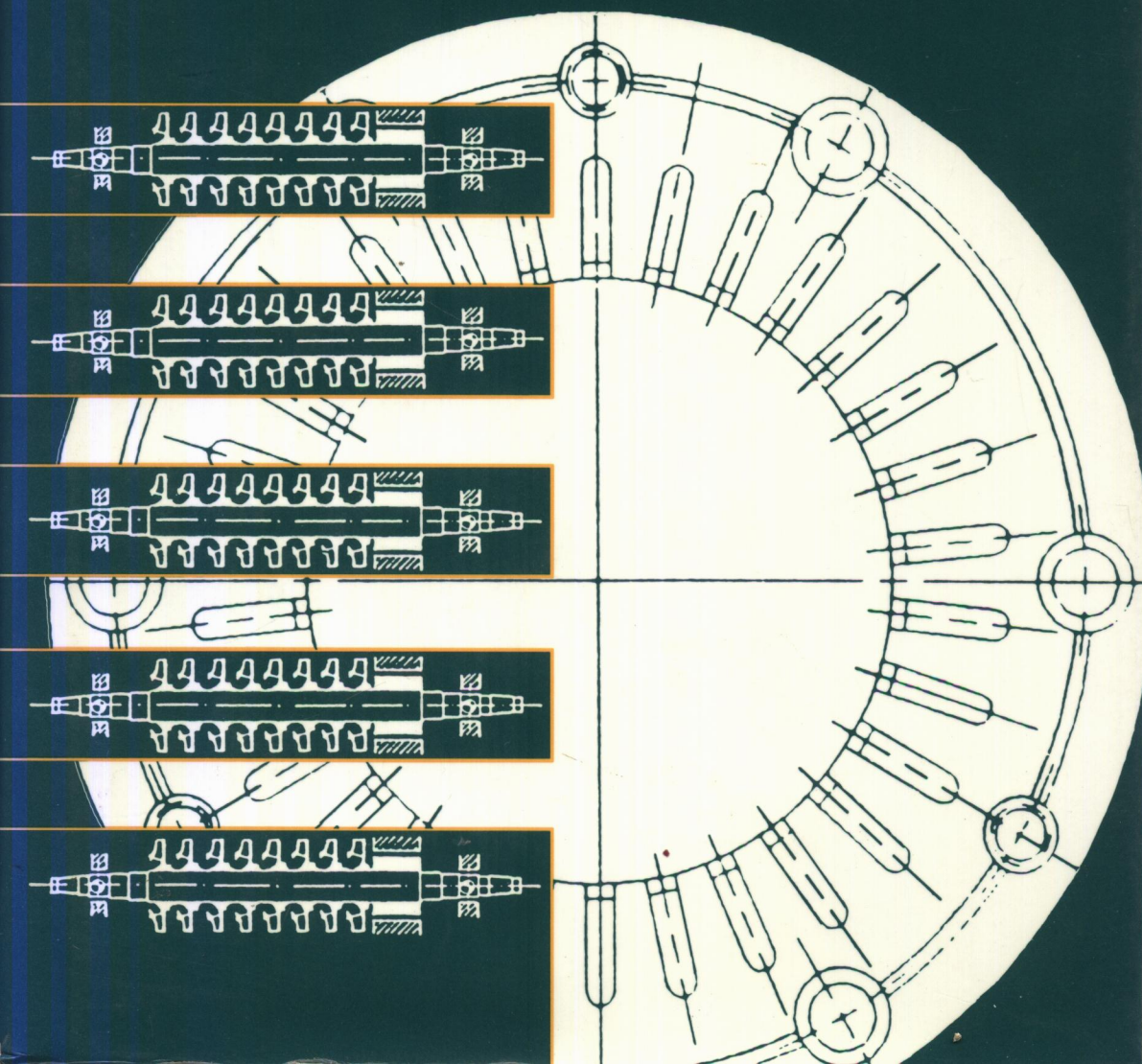


DARA CHILDS

TURBOMACHINERY ROTORDYNAMICS

**Phenomena,
Modeling, &
Analysis**



CONTENTS

Preface	xi
Acknowledgment	xv
1 Introduction to Rotordynamic Phenomena	1
1.1 Introduction, 1	
1.2 The Jeffcott Model: Critical Speeds and Synchronous Imbalance Response, 2	
1.3 The Jeffcott Model: Response to Gravity Loading and Shaft "Bow", 8	
1.4 The Stodola-Green (Rigid Body) Model for Rotordynamics: Effects of Rotary Inertia and Gyroscopic Coupling, 13	
1.5 Rotor Stability: Effects of Internal and External Damping, 23	
1.6 Influence of Bearings and Bearing Supports on Stability and Response, 28	
1.7 Parametric Instability: Shaft-Stiffness Orthotropy, 35	
1.8 Fractional-Frequency Rotor Motion due to Nonsymmetric Clearance Effects, 40	
1.9 Synchronous Motion with Bearing Clearances, 55	
1.10 Rotor-Housing Response Across an Annular Clearance, 61	
1.11 Transient Response: Critical-Speed Transitions, 77	
1.12 Summary and Extensions, 81	
Chapter 1 References, 83	
2 Structural-Dynamic Models and Eigenanalysis for Undamped Flexible Rotors	86
2.1 Introduction, 86	
2.2 Lumped-Parameter Vibration Models, 87	

- 2.3 Matrix Stiffness Methods for Rotordynamics Analysis, 92
 - 2.4 Myklestad-Prohl Transfer-Matrix Approach for Flexible-Rotor Models, 104
 - 2.5 Finite-Element Models for (Slender) Flexible Rotors, 111
 - 2.6 Finite-Element Models for Slender Beams Including Rotary Inertia and Gyroscopic Effects, 118
 - 2.7 Numerical Examples, 122
 - 2.8 Summary and Extensions, 127
 - Chapter 2 References, 131
- 3 Rotordynamic Introduction to Hydrodynamic Bearings and Squeeze-Film Dampers 132**
- 3.1 Introduction, 132
 - 3.2 Reynolds Equation, 134
 - 3.3 Impedance Descriptions for Plain Journal Bearings, 142
 - 3.4 Static Characteristics, and Stiffness and Damping Coefficients for Plain Journal Bearings, 150
 - 3.5 Synchronous Response, Stability, and Transient-Analysis Results for Simple Rotor Models Supported by Plain Journal Bearings, 161
 - 3.6 "Oil Whip" and "Oil Whirl", 177
 - 3.7 Additional Bearing Configurations, 183
 - 3.8 Modeling Complications in Bearing Analysis, 193
 - 3.9 Finite-Difference and Finite-Element Solutions for the Reynolds Equation, 198
 - 3.10 Squeeze-Film Dampers, 214
 - 3.11 Summary and Extension, 221
 - Chapter 3 References, 223
- 4 Rotordynamic Models for Liquid Annular Seals 227**
- 4.1 Introduction, 227
 - 4.2 Governing Equations for Plain (Ungrooved) Turbulent Annular Seals, Bulk-Flow Models, 229
 - 4.3 Perturbation Equations, 238
 - 4.4 Solution for Flow and Pressure in a Plain Centered Annular Seal, 239
 - 4.5 Solution of the First-Order Equations for Rotordynamic Force Coefficients, 243
 - 4.6 Rotordynamic Force Coefficients and Their Dependence on Physical Parameters, 248
 - 4.7 Tilt and Moment Coefficients, 274
 - 4.8 Summary, Conclusions, and Discussion, 280
 - Chapter 4 References, 284

5	Rotordynamic Models for Annular Gas Seals	290
5.1	Introduction, 290	
5.2	Initial Test and Analysis of Annular Labyrinth Seals, 295	
5.3	Additional Measurements and Two-Control-Volume Models for Labyrinth Seals, 306	
5.4	Dependence of K , k , C , and $k/C\omega$ on Physical Parameters, 319	
5.5	Bulk-Flow Model Predictions Versus Experiment for Labyrinth Seals and Alternative Analysis Procedures, 326	
5.6	Bulk-Flow Models for Plain Annular Gas Seals with Smooth or Honeycomb Stators, 331	
5.7	Theory Versus Experiments and Comparative Performance of Plain Annular Gas Seals, 335	
5.8	Brush Seals, 341	
5.9	Summary, Conclusions, and Discussion, 343	
	Chapter 5 References, 350	
6	Rotordynamic Models for Turbines and Pump Impellers	355
6.1	Introduction, 355	
6.2	Models and Measurements for Axial Turbine Stages, 355	
6.3	Rotordynamic Coefficient Test Results for Centrifugal Pump Impellers, 364	
6.4	Analytical Models for Rotordynamic Coefficients for Pump Impellers, 374	
6.5	Bulk-Flow Analysis for Shroud Forces, 376	
6.6	Hydraulic Imbalance, 389	
6.7	Conclusions, 390	
	Chapter 6 References, 392	
7	Developing and Analyzing a System Rotordynamics Model	395
7.1	Introduction, 395	
7.2	Combining a Structural-Dynamics Model with Component Force Models to Obtain a Complete Matrix Rotordynamics Model, 396	
7.3	Analysis for a Complete Matrix Rotordynamic Model, 399	
7.4	Approaches for Dimensional Reduction of Matrix Rotordynamic Models, 403	
7.5	Transfer-Matrix Methods for Synchronous Response and Stability Calculations, 421	
7.6	Closing Comments, 429	
	Chapter 7 References, 430	

8 Example Rotor Analysis	432
8.1 Introduction, 432	
8.2 Elements of the ATD-HPFTP Rotordynamic Model, 434	
8.3 Linear-Rotordynamic-Analysis Predictions, 443	
8.4 Nonlinear-Rotordynamic-Analysis Predictions, 446	
8.5 Summary and Conclusions, 452	
Chapter 8 References, 457	
Appendix A: Solution for Elliptic Orbit Parameters	458
Appendix B: Finite-element Models for Slender Beams	461
Appendix C: Fluidity Matrix for a Two-Dimensional Three-Node Triangular Element	464
Appendix D: Seal-Perturbation Coefficients	465
Appendix E: Impeller Perturbation Coefficients	468
Index	471