
Contents

Preface	V
1 Chemical Equilibrium Detonation	1
<i>Sorin Bastea and Laurence E. Fried</i>	1
1.1 Introduction	1
1.2 Chemical Equilibrium States	2
1.3 Equations of State	10
1.4 Fluid Phase Separations	17
1.5 Ionic Dissociation at High Pressures and Temperatures	21
1.6 Nonideal Explosives	23
1.7 Concluding Remarks	26
References	27
2 Steady One-Dimensional Detonations	33
<i>Andrew Higgins</i>	33
2.1 Introduction	33
2.2 ZND Model for Perfect Gas	36
2.3 Pathological Detonations	41
2.4 Detonations with Source Terms	46
2.4.1 Source Terms	48
2.4.2 Work Done by Friction	49
2.4.3 Effect of Friction	51
2.4.4 Effect of Heat Loss	55
2.4.5 Experiments with Losses	57
2.5 Systems with Real Chemistry	59
2.5.1 Chemical Reaction Rates	62
2.5.2 Carbon Monoxide/Oxygen System	65
2.5.3 Hydrogen/Chlorine System	69
2.5.4 Frozen and Equilibrium Sound Speed	75
2.6 Detonations with Divergent Flow	77
2.6.1 Stream Tube Divergence	79
2.6.2 Radial Flow Derivative	80

2.6.3	Shock Front Curvature	82
2.6.4	Confinement Interaction via Newtonian Theory	83
2.6.5	Comparisons to Experiment	88
2.7	Concluding Remarks	90
A.1	Appendix A: Gasdynamics of Detonation Products	92
A.1.1	Planar Detonation	92
A.1.2	Matching Expansion to Detonation Exit State	95
A.1.3	Cylindrical and Spherical Detonations	96
A.2	Appendix B: Critical Sonic Point with Friction	99
	References	100
3	Detonation Instability	107
	<i>Hoi Dick Ng and Fan Zhang</i>	<i>107</i>
3.1	Introduction	107
3.1.1	Linear Stability Analysis	109
3.1.2	Asymptotic Theory and Modeling	109
3.1.3	Numerical Simulation	111
3.2	Basic Formulation for Linear Stability Analysis	114
3.2.1	Governing Equations	114
3.2.2	Shock Relations	115
3.2.3	Steady Planar ZND Detonation Solution	116
3.2.4	Non-dimensionalization	117
3.2.5	Linear Stability Analysis Formulation	118
3.2.6	Radiation Boundary Condition	121
3.2.7	Numerical Examples	122
3.3	Nonlinear Instability Simulation and Analysis	124
3.3.1	Mathematical Model	125
3.3.2	Numerical Methods and Validations	127
3.3.3	Nonlinear Dynamics of One-Dimensional Unstable Detonations	133
3.3.4	Nonlinear One-Dimensional Oscillator Model	143
3.3.5	Two-Dimensional Unstable Detonation	151
3.3.6	Detonation Structure Using a Binary Mixture Model	155
3.4	The Effect of Chemistry on Detonation Instability	162
3.4.1	Simplified Chain-Branching Kinetic Model	166
3.4.2	Neutral Stability Boundaries	171
3.4.3	Relation Between One- and Two-Dimensional Detonation Instability	173
3.5	Instability of Nonideal Detonations	180
3.5.1	Nonideal Detonation with Losses	180
3.5.2	Pathological Detonation	185
3.5.3	Diverging Detonation	187
3.5.4	Transverse Wave Generation of Diverging Detonation	196
3.6	Concluding Remarks	200
	References	203

4 Dynamic Parameters of Detonation	213
<i>Anatoly A. Vasil'ev</i>	213
4.1 Introduction	213
4.2 Detonation Cell Size	216
4.2.1 Local Induction Time	216
4.2.2 Cell Size Models	217
4.2.3 Influence Factors of Cell Size	222
4.3 Direct Initiation of Detonation	228
4.3.1 Measurement of Critical Initiation Energy	229
4.3.2 Peculiar Properties of Initiation Process	232
4.3.3 Critical Initiation Energy Models	235
4.3.4 Data of Critical Initiation Energy	239
4.3.5 Supersonic Bullet Initiation	242
4.4 Diffraction Initiation of Detonation	245
4.4.1 Critical Scales for Diffraction Initiation	245
4.4.2 Diffraction Initiation in Other Divergent Geometries	251
4.5 Advanced Initiations	255
4.6 Critical Sizes for Limiting Detonations	261
4.7 Concluding Remarks	264
Appendix A: Explosion Parameters	266
References	268
5 Multi-Scaled Cellular Detonation	281
<i>Daniel Desbordes and Henri-Noël Presles</i>	281
5.1 Introduction	281
5.2 Detonation Front Structure	283
5.2.1 Macroscopic Aspect	283
5.2.2 Structure Details	288
5.2.3 Two-Cell Structure	300
5.3 Detonation Heat Release Mechanisms	306
5.3.1 One-Step Heat Release	306
5.3.2 Two-Step Heat Release	307
5.3.3 Two-Step Hybrid Heat Release	308
5.4 Direct Numerical Simulation	314
5.4.1 Simulation of One-Step/One-Cell Detonation	314
5.4.2 Simulation of Two-Step/One or Two-Cell Detonation	316
5.5 Limits of Multi-Scaled Cellular Detonation	320
5.5.1 Limits of Expanding Detonation	320
5.5.2 Detonation Propagation Limits in Tubes	328
5.6 Concluding Remarks	330
References	332

6 Condensed Matter Detonation: Theory and Practice	339
<i>Craig M. Tarver</i>	339
6.1 Introduction	339
6.2 Condensed-Phase Detonation Theory	340
6.3 Practical Modeling of Detonation: Ignition and Growth	347
6.4 Concluding Remarks	364
References	366
7 Theory of Detonation Shock Dynamics	373
<i>John B. Bdzil and D. Scott Stewart</i>	373
7.1 Introduction	373
7.2 Overview of DSD Theory	374
7.2.1 Detonation Dynamics	374
7.2.2 Weak-Curvature Limit	377
7.2.3 Boundary Conditions	379
7.3 Basic 1D ZND Model of Detonation	379
7.3.1 Ideal EOS Model and Reaction Rate Laws	380
7.3.2 ZND Spatial Structure	382
7.4 Detonation Front Propagation Laws	383
7.4.1 Characteristic Analysis and DSD Theory	383
7.4.2 DSD: Quasi-Steady Limit Using the Master Equation Formulation	396
7.4.3 Time-Dependent Solutions	404
7.4.4 Flux Formulation: Numerics and Asymptotics	408
7.5 Interaction of Detonation with Explosive/Inert Material Boundaries	415
7.6 Detonation Shock-Polar Analysis	417
7.6.1 Reflected Shock Simple Wave Solution	418
7.6.2 Reflected Rarefaction Simple Wave Solution	421
7.7 Shock Polars for the ZND Model of Detonating Explosive	424
7.7.1 Regime I: Supersonic Interaction	424
7.7.2 Regime II: Interaction of the Detonation's Reaction Zone with the Adjacent Inert Material	425
7.7.3 Regime III: Subsonic Transition to Sonic Flow in the HE Reaction Zone at the Edge of Confinement	425
7.7.4 Regular Shock Reflection	426
7.7.5 Mach-Stem Solution	429
7.7.6 Direct Numerical Simulation of Mach-Style Reflection	433
7.8 DSD Boundary Conditions	435
7.8.1 Summary of Oblique Detonation Interaction Study	435
7.8.2 Statement of DSD Boundary Conditions	437
7.8.3 Comparison of DSD Boundary Conditions with DNS Predictions	439

7.9	Examples of DSD Front Propagation: Application of the $D_n(\kappa)$	
	Relation with Boundary Conditions	441
7.9.1	DSD Level-Set Method	442
7.9.2	DSD Solution Examples	443
7.9.3	Application of DSD to Detonation Diffraction Past a Disk	445
7.10	Concluding Remarks	449
	References	451
Index	455

Shock Waves Science and Technology Library, Vol. 6

Detonation Dynamics

Zhang, F. (Ed.)

2012, XVIII, 470 p., Hardcover

ISBN: 978-3-642-22966-4