

Contents

Preface to the Second Edition	v
Preface to the First Edition	vii
1 Introduction	1
1.1 Preliminary Remarks	1
1.2 Flat Plate Turbulent Boundary Layers	4
1.3 Propagation of Pressure Fluctuations	13
1.4 Mixing Layers	15
1.5 Shock-Turbulence Interaction	18
1.6 Shock Wave-Boundary Layer Interaction	21
1.7 Measurement Techniques	25
1.7.1 Hot Wire Anemometry	25
1.7.2 Laser-Doppler Velocimetry	32
1.7.3 Fluctuating Wall Pressure Measurements	35
1.7.4 Flow Imaging	37
1.8 Summary	41
2 Equations of Motion	43
2.1 Continuity	44
2.2 Momentum	44
2.3 Energy	48
2.4 Summary	51
2.5 Compressible Couette Flow	52
2.6 Vorticity	55
3 Equations for Turbulent Flow	61
3.1 Definition of Averages	61
3.1.1 Turbulent Averages	63
3.2 Equations for the Mean Flow	65
3.2.1 Continuity	65
3.2.2 Momentum	66
3.2.3 Energy	67
3.2.4 Turbulent Kinetic Energy	68

3.3	Thin Shear Layer Equations	69
3.3.1	Characteristic Scales	70
3.3.2	Continuity	71
3.3.3	Momentum	72
3.3.4	Total Enthalpy	77
3.4	Summary	78
4	Fundamental Concepts	79
4.1	Kovaszny's Modes	80
4.2	Velocity Divergence in Shear Flows	85
4.3	Velocity Induced by a Vortex Field	93
4.4	Rapid Distortion Concepts	94
4.4.1	Linearizing the Equations for the Fluctuations	96
4.4.2	Application to Supersonic Flows	98
4.4.3	Rapid Distortion Approximations	99
4.4.4	Application to Shock-Free Flows	102
4.4.5	Shock Relations for the Turbulent Stresses	103
4.5	Mach Numbers for Turbulence	105
4.6	DNS and LES	108
4.6.1	Homogeneous Decaying Turbulence	109
4.6.2	Turbulence Subjected to Constant Shear	110
4.6.3	Spectra for Compressible Turbulence	111
4.6.4	Shear Flows	112
4.7	Modeling Issues	114
5	Morkovin's hypothesis	119
5.1	Space, Time, and Velocity Scales	119
5.2	Temperature-Velocity Relationships	122
5.3	Experimental Results	123
5.4	Analytical Results for $P_m = 1$	127
5.5	Analytical Results for $P_m \neq 1$	130
5.6	Reynolds Analogy for Mixing Layers	134
6	Mixing Layers	139
6.1	Introduction	139
6.2	Incompressible Mixing Layer Scaling	141
6.3	Compressible Mixing Layers	144
6.4	Classification of Compressibility Effects	148
6.4.1	Convective Mach Number	148
6.4.2	Similarity Considerations	151
6.5	Mean Flow Scaling	153
6.6	Turbulent Shear Stress Scaling	160
6.7	Self-Preservation Conditions	162
6.8	Turbulent Normal Stresses	166

6.9	Space-Time Characteristics	167
6.10	Compressibility and Mixing	171
6.11	Final Remarks	177
7	Boundary Layer Mean-Flow Behavior	179
7.1	Introduction	179
7.2	Viscous Sublayer	182
7.3	Logarithmic Region	185
7.3.1	Incompressible Flow	185
7.3.2	Compressible Flow	192
7.4	Law-of-the-Wake	202
7.5	Skin-Friction Relationships	208
7.6	Power Laws	212
7.7	Summary	215
8	Boundary Layer Turbulence Behavior	217
8.1	Introduction	217
8.2	Scaling Laws	218
8.2.1	Spectral Scaling for Incompressible Flow	219
8.2.2	Spectral Scaling for Compressible Flow	224
8.3	Turbulence Data	229
8.3.1	Incompressible Flow	230
8.3.2	Compressible Flow	237
8.4	Organized Motions	243
8.4.1	Inner Layer Structure	244
8.4.2	Outer Layer Structure	248
8.5	Correlations and Ensemble Averages	252
8.5.1	Structure Angle	257
8.6	Integral Scales	261
8.7	Eddy Models of Turbulence	270
8.7.1	Inner-Outer Interactions	274
8.7.2	Summary of Boundary Layer Eddy Structure	276
8.8	Final Remarks	281
9	Perturbed Boundary Layers	285
9.1	Introduction	285
9.2	Perturbation Strength	288
9.3	A Step Change in Wall Temperature	290
9.4	Adverse Pressure Gradients	298
9.4.1	Flow over Concavely Curved Walls	300
9.4.2	Reflected Wave Flows	308
9.4.3	Taylor-Görtler Vortices	309
9.5	Favorable Pressure Gradients	312
9.6	Successive Distortions	313

9.7 Summary	317
10 Shock Boundary Layer Interactions	319
10.1 Introduction	319
10.2 Compression Corner Interactions	321
10.2.1 Skin Friction	323
10.2.2 Separation	323
10.2.3 Upstream Influence	325
10.2.4 Shock Motion	326
10.2.5 Turbulence Amplification	334
10.2.6 Three-Dimensionality	337
10.3 Rapid Distortion and Linear Methods	338
10.4 Incident Shock Interactions	345
10.5 Isentropic Three-Dimensional Flows	346
10.6 Three-Dimensional Interactions	348
10.6.1 Flow Field Topology	350
10.6.2 Swept Compression Corner Interactions	354
10.6.3 Sharp-Fin Interactions	356
10.6.4 Blunt-Fin Interactions	360
10.7 Crossing-Shock Interactions	361
10.8 Concluding Remarks	362
References	365
Index	401

Turbulent Shear Layers in Supersonic Flow

Smits, A.J.; Dussauge, J.-P.

2006, XIV, 410 p. 171 illus., Hardcover

ISBN: 978-0-387-26140-9