

Springer Handbook of Experimental Fluid Mechanics

TU Darmstadt
FB Maschinenbau



60014086

Contents

The authors of the different Sections can be identified by consulting the *Detailed Contents* or the *About the Authors* part.

List of Abbreviations	XXI
Nomenclature	XXV

Part A Experiments in Fluid Mechanics

1 Experiment as a Boundary-Value Problem

<i>Ronald L. Panton, Saeid Kheirandish, Manfred H. Wagner</i>	3
1.1 Thermodynamic Equations.....	3
1.2 Kinematic Equations	5
1.3 Balance Laws and Local Governing Equations	6
1.4 Balance Laws and Global Governing Equations	8
1.5 Constitutive Equations.....	10
1.6 Navier–Stokes Equations	11
1.7 Discontinuities in Density	11
1.8 Constitutive Equations and Nonlinear Rheology of Polymer Melts	13
References	30

2 Nondimensional Representation of the Boundary-Value Problem

<i>John F. Foss, Ronald L. Panton, Alexander L. Yarin</i>	33
2.1 Similitude, the Nondimensional Prototype and Model Flow Fields...	34
2.2 Dimensional Analysis and Data Organization	42
2.3 Self-Similarity.....	57
References	82

Part B Measurement of Primary Quantities

3 Material Properties: Measurement and Data

<i>William A. Wakeham, Marc J. Assael, Abraham Marmur, Joël De Coninck, Terry D. Blake, Stephanus A. Theron, Eyal Zussman</i>	85
3.1 Density.....	85
3.2 Surface Tension and Interfacial Tension of Liquids	96
3.3 Contact Angle	106
3.4 Viscosity.....	119
3.5 Thermal Conductivity and Thermal Diffusivity	133
3.6 Diffusion.....	147
3.7 Electric and Magnetic Parameters of Liquids and Gases	158
References	169

4	Pressure Measurement Systems	
	<i>Beverley J. McKeon, Rolf H. Engler</i>	179
4.1	Measurement of Pressure with Wall Tappings	180
4.2	Measurement of Pressure with Static Tubes	185
4.3	Hardware and Other Considerations	187
4.4	Pressure-Sensitive Paint (PSP)	188
	References	209
5	Velocity, Vorticity, and Mach Number	
	<i>Beverley J. McKeon, Geneviève Comte-Bellot, John F. Foss, Jerry Westerweel, Fulvio Scarano, Cameron Tropea, James F. Meyers, Joseph W. Lee, Angelo A. Cavone, Richard Schodl, Manoochehr M. Koochesfahani, Daniel G. Nocera, Yiannis Andreopoulos, Werner J.A. Dahm, John A. Mullin, James M. Wallace, Petar V. Vukoslavčević, Scott C. Morris, Eric R. Pardyjak, Alvaro Cuerva</i>	215
5.1	Pressure-Based Velocity Measurements	216
5.2	Thermal Anemometry	229
5.3	Particle-Based Techniques	287
5.4	Molecular Tagging Velocimetry (MTV)	362
5.5	Vorticity	382
5.6	Thermal Transient Anemometer (TTA)	434
5.7	Sonic Anemometry/Thermometry	436
	References	446
6	Density-Based Techniques	
	<i>Wolfgang Merzkirch</i>	473
6.1	Density, Refractive Index, and Optical Flow Visualization	473
6.2	Shadowgraphy	474
6.3	Schlieren Method	476
6.4	Moiré Deflectometry	478
6.5	Interferometry	480
6.6	Optical Tomography	485
	References	485
7	Temperature and Heat Flux	
	<i>Tomasz A. Kowalewski, Phillip Ligrani, Andreas Dreizler, Christof Schulz, Uwe Fey, Yasuhiro Egami</i>	487
7.1	Thermochromic Liquid Crystals	488
7.2	Measurements of Surface Heat Transfer Characteristics Using Infrared Imaging	500
7.3	Temperature Measurement via Absorption, Light Scattering and Laser-Induced Fluorescence	515
7.4	Transition Detection by Temperature-Sensitive Paint	537
	References	553

8 Force and Moment Measurement	
<i>Klaus Hufnagel, Günter Schewe</i>	563
8.1 Steady and Quasi-Steady Measurement.....	564
8.2 Force and Moment Measurements in Aerodynamics and Aeroelasticity Using Piezoelectric Transducers.....	596
References	615

Part C Specific Experimental Environments and Techniques

9 Non-Newtonian Flows	
<i>Klaas te Nijenhuis, Gareth H. McKinley, Stephen Spiegelberg, Howard A. Barnes, Nuri Aksel, Lutz Heymann, Jeffrey A. Odell</i>	619
9.1 Viscoelastic Polymeric Fluids	619
9.2 Thixotropy, Rheopexy, Yield Stress	661
9.3 Rheology of Suspensions and Emulsions.....	680
9.4 Entrance Correction and Extrudate Swell	720
9.5 Birefringence in Non-Newtonian Flows	724
References	732
10 Measurements of Turbulent Flows	
<i>Giovanni Paolo Romano, Nicholas T. Ouellette, Haitao Xu, Eberhard Bodenschatz, Victor Steinberg, Charles Meneveau, Joseph Katz</i>	745
10.1 Statistical Eulerian Description of Turbulent Flows	746
10.2 Measuring Lagrangian Statistics in Intense Turbulence	789
10.3 Elastic Turbulence in Viscoelastic Flows	799
10.4 Measurements for Large-Eddy Simulations	830
References	849
11 Flow Visualization	
<i>Wolfgang Merzkirch</i>	857
11.1 Aims and Principles of Flow Visualization	857
11.2 Visualizations of Flow Structures and Flow Direction	859
11.3 Visualization of Free Surface Flows	868
References	869
12 Wall-Bounded Flows	
<i>Joseph C. Klewicki, William S. Saric, Ivan Marusic, John K. Eaton</i>	871
12.1 Introductory Concepts.....	871
12.2 Measurement of Wall Shear Stress	875
12.3 Boundary-Layer Stability and Transition.....	886
12.4 Measurements Considerations in Non-Canonical Flows	896
References	902

13 Topological Considerations in Fluid Mechanics Measurements	
<i>John F. Foss</i>	909
13.1 A Companion Document	909
13.2 Utilization of Topological Considerations for Flow Field Analyses.....	910
References	918
14 Flow Measurement Techniques in Turbomachinery	
<i>Oğuz Uzol, Joseph Katz</i>	919
14.1 Background On Turbomachinery Flows	919
14.2 Non-Optical Measurement Techniques	921
14.3 Optical Measurement Techniques	933
14.4 Concluding Remarks	950
References	951
15 Hydraulics	
<i>Roger E.A. Arndt, Damien Kawakami, Martin Wosnik, Marc Perlin, James H. Duncan, David M. Admiraal, Marcelo H. García</i>	959
15.1 Measurements in Cavitating Flows	959
15.2 Wave Height and Slope.....	1009
15.3 Sediment Transport Measurements	1020
References	1033
16 Aerodynamics	
<i>Wolf-H. Hucho, Klaus Hannemann, Jan Martinez Schramm, Charles H.K. Williamson</i>	1043
16.1 Ground Vehicle Aerodynamics	1043
16.2 Short-Duration Testing of High Enthalpy, High Pressure, Hypersonic Flows	1081
16.3 Bluff Body Aerodynamics	1125
References	1146
17 Atmospheric Measurements	
<i>Harindra J.S. Fernando, Marko Princevac, Ronald J. Calhoun</i>	1157
17.1 Point Measurements.....	1159
17.2 Dispersion Measurements	1167
17.3 Remote Sensing	1169
17.4 Satellite Measurements	1175
References	1178
18 Oceanographic Measurements	
<i>Bruce Howe, Teresa K. Chereskin</i>	1179
18.1 Oceanography	1179
18.2 Point Measurements.....	1182
18.3 Lagrangian Techniques	1188
18.4 Remote Sensing	1192

18.5	Measurement Systems	1203
18.6	Experiment Case Studies	1208
	References	1214
19	Microfluidics: The No-Slip Boundary Condition	
	<i>Eric Lauga, Michael P. Brenner, Howard A. Stone</i>	1219
19.1	History of the No-Slip Condition.....	1220
19.2	Experimental Methods.....	1222
19.3	Molecular Dynamics Simulations	1226
19.4	Discussion: Dependence on Physical Parameters.....	1228
19.5	Perspective	1234
	References	1235
20	Combustion Diagnostics	
	<i>Christof Schulz, Andreas Dreizler, Volker Ebert, Jürgen Wolfrum</i>	1241
20.1	Basics	1242
20.2	Laser-Based Combustion Diagnostics.....	1243
20.3	Experimental Data Devoted to Validation of Numerical Simulations and Modeling	1244
20.4	Application of Laser-Based Techniques	1247
20.5	Conclusions.....	1299
	References	1300
21	Electrohydrodynamic Systems	
	<i>Antonio Castellanos, Alberto T. Pérez</i>	1317
21.1	Equations	1318
21.2	Fluid Statics and Dynamics in EHD	1320
21.3	Experimental Methods in EHD	1322
21.4	Conductivity	1323
21.5	Mobility	1327
21.6	Electric Field Measurement: Kerr Effect	1328
21.7	Velocity.....	1329
21.8	Visualization	1330
	References	1331

Part D Analysis and Post-Processing of Data

22	Review of Some Fundamentals of Data Processing	
	<i>Holger Nobach, Cameron Tropea, Laurent Cordier, Jean-Paul Bonnet, Joël Delville, Jacques Lewalle, Marie Farge, Kai Schneider, Ronald J. Adrian</i>	1337
22.1	Fourier Transform	1337
22.2	Correlation Function	1342
22.3	Hilbert Transform	1344
22.4	Proper Orthogonal Decomposition: POD	1346

22.5	Conditional Averages and Stochastic Estimation	1370
22.6	Wavelet Transforms	1378
	References	1395
23	Fundamentals of Data Processing	
	<i>Holger Nobach, Cameron Tropea</i>	1399
23.1	Statistical Principles	1399
23.2	Stationary Random Processes.....	1401
23.3	Estimator Expectation and Variance	1402
23.4	Signal Noise	1406
23.5	Cramér–Rao Lower Bound (CRLB).....	1408
23.6	Propagation of Errors.....	1416
	References	1417
24	Data Acquisition by Imaging Detectors	
	<i>Bernd Jähne</i>	1419
24.1	Definitions.....	1419
24.2	Types of Detectors	1420
24.3	Imaging Detectors	1421
24.4	Performance of Imaging Sensors	1426
24.5	Camera Selection.....	1435
	References	1436
25	Data Analysis	
	<i>Bernd Jähne, Michael Klar, Markus Jehle</i>	1437
25.1	Image Processing	1437
25.2	Motion Analysis.....	1464
	References	1488
	Acknowledgements	1493
	About the Authors	1495
	Detailed Contents	1513
	Subject Index	1531