

Contents

Part I Taylor–Couette flow

Pitchfork bifurcations in small aspect ratio

Taylor–Couette flow

| | |
|--|----|
| <i>Tom Mullin, Doug Satchwell, Yorinobu Toya</i> | 3 |
| 1 Introduction | 3 |
| 2 A numerical bifurcation method | 7 |
| 2.1 Governing equations | 7 |
| 2.2 The finite element technique | 9 |
| 2.3 Spatial discretisation and symmetry | 11 |
| 2.4 Stability | 13 |
| 2.5 Bifurcation points and extended systems | 15 |
| 3 Results | 16 |
| 3.1 Experimental apparatus | 16 |
| 3.2 Numerical and experimental bifurcation set | 17 |
| 4 Discussion | 18 |
| References | 19 |

Taylor–Couette system with asymmetric boundary conditions

| | |
|---|----|
| <i>Oliver Meincke, Christoph Egbers, Nicoleta Scurtu, Eberhard Bänsch</i> | 22 |
| 1 Introduction | 22 |
| 2 Experimental setup | 23 |
| 3 Measurement techniques | 23 |
| 3.1 PIV | 23 |
| 3.2 LDV | 25 |
| 4 Numerical method | 26 |
| 5 Results | 27 |
| 5.1 Symmetric system | 27 |
| 5.2 Asymmetric system | 30 |
| 6 Conclusions | 34 |
| References | 35 |

Bifurcation and structure of flow between counter-rotating cylinders

| | |
|--|----|
| <i>Arne Schulz, Gerd Pfister</i> | 37 |
| 1 Introduction | 37 |

| | | |
|-----|--|----|
| 2 | Experimental setup | 37 |
| 3 | Stability diagram | 39 |
| 4 | Primary instabilities | 40 |
| 4.1 | Transition to Taylor vortex flow (TVF) | 40 |
| 4.2 | Transition to time-dependent flow states | 42 |
| 5 | Transition from Spirals to TVF | 45 |
| 6 | Wavy-vortex flow | 46 |
| 7 | Observation of propagating Taylor vortices | 50 |
| 8 | Comparison to theoretical investigations | 51 |
| 9 | Conclusion | 53 |
| | References | 53 |

**Spiral vortices and Taylor vortices in the annulus
between counter-rotating cylinders**

| | | |
|---|---|----|
| | <i>Christian Hoffmann, Manfred Lücke</i> | 55 |
| 1 | Introduction | 55 |
| 2 | System | 56 |
| 3 | Linear stability analysis of CCF | 57 |
| 4 | Bifurcation properties of Taylor vortex and spiral flow | 58 |
| 5 | Structure of Taylor vortex and spiral flow | 64 |
| 6 | Summary | 64 |
| | References | 66 |

Stability of time-periodic flows in a Taylor–Couette geometry

| | | |
|-----|---------------------------|----|
| | <i>Christiane Normand</i> | 67 |
| 1 | Introduction | 67 |
| 2 | Modulated base flow | 71 |
| 2.1 | Narrow gap approximation | 73 |
| 3 | Stability problem | 74 |
| 3.1 | Perturbative analysis | 76 |
| 4 | Nonlinear models | 77 |
| 4.1 | Amplitude equations | 77 |
| 4.2 | Lorenz model | 79 |
| 5 | Conclusions | 81 |
| | References | 82 |

**Low-dimensional dynamics of axisymmetric modes
in wavy Taylor vortex flow**

| | | |
|-----|-------------------------------------|----|
| | <i>Jan Abshagen, Gerd Pfister</i> | 84 |
| 1 | Introduction | 84 |
| 2 | Experimental setup | 86 |
| 3 | An intermittency route to chaos | 86 |
| 3.1 | Onset of ‘symmetric’ chaos | 87 |
| 3.2 | Type of intermittency | 90 |
| 3.3 | Observation of Shil’nikov attractor | 92 |
| 3.4 | Transition to Hopf regime | 94 |

4 A T^3 -torus in spatial inhomogeneous flow 96
 4.1 Axially localised Large-jet mode 96
 4.2 Onset of VLF mode and transition to chaos 98
 5 Discussion 100
 References 100

**Spatiotemporal intermittency
 in Taylor–Dean and Couette–Taylor systems**

Innocent Mutabazi, Afshin Goharzadeh and Patrice Laure 102
 1 Introduction 102
 2 Pomeau model of spatiotemporal intermittency 103
 2.1 Analogy with the directed percolation 104
 2.2 Ginzburg–Landau amplitude equation 106
 3 STI in the Taylor–Dean system 107
 3.1 Main results on critical properties 107
 3.2 STI in other extended systems 108
 4 STI in the Couette–Taylor system 109
 4.1 Experimental setup 109
 4.2 Results 111
 4.3 Physical origin of turbulent bursts 112
 4.4 Kinematics of turbulent spiral 113
 4.5 Hayot–Pomeau model for spiral turbulence 115
 5 Conclusion 116
 6 Acknowledgments 116
 References 116

**Axial effects in the Taylor–Couette problem:
 Spiral–Couette and Spiral–Poiseuille flows**

Álvaro Mesequer, Francesc Marquès 118
 1 Introduction 118
 2 Spiral–Couette flow 119
 2.1 Linear stability of the SCF 121
 2.2 Computation of the neutral stability curves 122
 2.3 Stability analysis for $\eta = 0.5$ 122
 2.4 Comparison with experimental results ($\eta = 0.8$) 127
 3 Spiral–Poiseuille flow 130
 3.1 Linear stability results ($\eta = 0.5$) 131
 4 Conclusions 133
 References 135

**Stability and experimental velocity field
 in Taylor–Couette flow with an axial and radial flow**

Richard M. Lueptow 137
 1 Introduction 137
 2 Cylindrical Couette flow with an imposed axial flow 139
 2.1 Stability 139

| | | |
|-----|--|-----|
| 2.2 | Velocity field | 143 |
| 3 | Cylindrical Couette flow with an imposed radial flow | 148 |
| 4 | Combined radial and axial flow | 150 |
| 5 | Summary | 153 |
| | References | 154 |

Transport phenomena in magnetic fluids in cylindrical geometry

| | | |
|-----|--|-----|
| | <i>Stefan Odenbach</i> | 156 |
| 1 | Introduction | 156 |
| 1.1 | Magnetic fluids | 157 |
| 1.2 | Magnetic properties of ferrofluids | 158 |
| 1.3 | Viscous properties of ferrofluids | 160 |
| 2 | Taylor vortex flow in magnetic fluids | 163 |
| 2.1 | Taylor vortex flow as a tool for magnetic fluid characterization | 163 |
| 2.2 | Changes of the flow profile in magnetic fields | 167 |
| 3 | Taylor vortex flow in magnetic fluids with radial heat gradient | 169 |
| 4 | Conclusion and outlook | 169 |
| | References | 170 |

Secondary bifurcations of stationary flows

| | | |
|-----|--|-----|
| | <i>Rita Meyer-Spasche, John H. Bolstad, Frank Pohl</i> | 171 |
| 1 | Stationary Taylor-vortex flows | 171 |
| 2 | Convection rolls with stress-free boundaries | 172 |
| 2.1 | Critical curves of the primary solution | 174 |
| 2.2 | Pure-mode solutions | 175 |
| 3 | Secondary bifurcations on pure mode solutions | 177 |
| 3.1 | The 2-roll,4-roll interaction in a model problem | 177 |
| 3.2 | The perturbation approach | 179 |
| 3.3 | A Hopf curve | 180 |
| 3.4 | The 2-roll, 6-roll interaction in a model problem | 181 |
| 3.5 | Other interactions | 183 |
| 4 | Numerical investigations | 184 |
| 4.1 | The Rayleigh–Bénard code used | 184 |
| 4.2 | Convection rolls with rigid boundaries on top and bottom | 187 |
| 4.3 | Secondary bifurcations in the Taylor problem revisited | 191 |
| | References | 193 |

Taylor vortices at different geometries

| | | |
|-----|---|-----|
| | <i>Manfred Wimmer</i> | 194 |
| 1 | Introduction | 194 |
| 2 | Flow between cones with a constant width of the gap | 195 |
| 2.1 | Experimental set-up | 195 |
| 2.2 | Flow field and Taylor vortices | 195 |
| 2.3 | Influence of initial and boundary conditions | 198 |
| 3 | Combinations of circular and conical cylinders | 200 |

| | | |
|-----|---|-----|
| 3.1 | Rotating cylinder in a cone | 201 |
| 3.2 | Rotating cone in a cylinder | 201 |
| 4 | Flow between cones with different apex angles | 203 |
| 5 | Flow between rotating ellipsoids | 206 |
| 5.1 | Oblate rotating ellipsoids | 209 |
| 5.2 | Prolate rotating ellipsoids | 210 |
| 6 | Conclusions | 211 |
| | References | 212 |

Part II Spherical Couette flow

Isothermal spherical Couette flow

| | | |
|-----|--|-----|
| | <i>Markus Junk, Christoph Egbers</i> | 215 |
| 1 | Introduction | 215 |
| 2 | Summary of previous investigations | 218 |
| 3 | Experimental methods | 220 |
| 3.1 | Spherical Couette flow apparatus | 220 |
| 3.2 | LDV measuring system and visualisation methods | 222 |
| 4 | Transitions | 224 |
| 4.1 | Small and medium gap instabilities | 224 |
| 4.2 | Bifurcation behaviour | 227 |
| 4.3 | Wide gap instabilities | 228 |
| 5 | Conclusion | 231 |

Vortical structures and velocity fluctuations of spiral and wavy vortices in the spherical Couette Flow

| | | |
|---|---|-----|
| | <i>Koichi Nakabayashi, Weiming Sha</i> | 234 |
| 1 | Introduction | 234 |
| 2 | Onset Reynolds numbers of various disturbances | 235 |
| 3 | Structure and formation of the spiral TG vortices | 236 |
| 4 | Motion of the azimuthally travelling waves | 241 |
| 5 | Spectral analysis of velocity fluctuations | 244 |
| 6 | Relaminarization | 247 |
| 7 | Concluding remarks | 254 |
| | References | 254 |

Spherical Couette flow with superimposed throughflow

| | | |
|---|-----------------------------|-----|
| | <i>Karl Bühler</i> | 256 |
| 1 | Introduction | 256 |
| 2 | Numerical simulations | 260 |
| 3 | Experiments | 260 |
| 4 | Conclusion | 267 |
| | References | 267 |

Three-dimensional natural convection in a narrow spherical shell
Ming Liu, Christoph Egbers 269

1 Introduction 269

2 Mathematical formulation 270

3 Results and discussion 273

 3.1 Axisymmetric basic flow 273

 3.2 Three-dimensional convective motions 274

 3.3 Transient evolution 287

4 Concluding remarks 291

References 292

Magnetohydrodynamic flows in spherical shells
Rainer Hollerbach 295

1 Introduction 295

2 The induction equation 296

3 Kinematic dynamo action 301

4 The Lorentz force 304

5 Magnetic Couette flow 306

References 314

Intermittency at onset of convection in a slowly rotating, self-gravitating spherical shell
Pascal Chossat 317

1 Introduction 317

2 Heteroclinic cycles in systems with $O(3)$ symmetry and the spherical Bénard problem 318

3 Perturbation induced by a slow rotation of the domain 322

References 324

Part III Goertler vortices and curved surfaces

Control of secondary instability of the crossflow and Görtler-like vortices (Success and problems)
Viktor V. Kozlov, Genrich R. Grek 327

Part I. Active control over secondary instability in a swept wing boundary layer 327

Part II. Transition and control experiments in a boundary layer with Görtler-like vortices 336

PART III. Influence of riblets on a boundary layer with Görtler-like vortices 346

References 349

Part IV Rotating annulus

Higher order dynamics of baroclinic waves

| | |
|---|-----|
| <i>Bernd Sitte, Christoph Egbers</i> | 355 |
| 1 Introduction | 355 |
| 2 The rotating annulus experiment | 357 |
| 3 Stability | 359 |
| 4 Nonlinear dynamics | 362 |
| 4.1 Measurement technique | 362 |
| 4.2 Flow characterization | 364 |
| 4.3 Bifurcation scenario | 371 |
| 4.4 Comparison to Taylor–Couette flow | 374 |
| 5 Conclusions | 374 |
| References | 375 |

Part V Plane Couette flow

Superfluid Couette flow

| | |
|--|-----|
| <i>Carlo F. Barenghi</i> | 379 |
| 1 Liquid helium | 379 |
| 2 Helium II and Landau’s two-fluid model | 379 |
| 3 Vortex lines and the breakdown of Landau’s model | 381 |
| 4 The generalized Landau equations | 383 |
| 5 The basic state | 386 |
| 6 Rotations of the inner cylinder: absolute zero | 389 |
| 7 Rotations of the inner cylinder: finite temperatures | 390 |
| 8 Rotations of the inner cylinder: nonlinear effects | 394 |
| 9 Rotations of the outer cylinder | 394 |
| 10 Co-rotations and counter-rotations of the cylinders | 396 |
| 11 Finite aspect ratios and end effects | 396 |
| 12 Discussion and outlook | 397 |
| References | 398 |

Tertiary and quaternary solutions for plane Couette flow with thermal stratification

| | |
|--|-----|
| <i>R.M. Clever, Friedrich H. Busse</i> | 399 |
| 1 Introduction | 399 |
| 2 Mathematical formulation of the problem | 401 |
| 3 Steady three-dimensional wavy roll solutions in an air layer | 404 |
| 4 Wavy roll solutions in dependence on the Grashof number | 408 |
| 5 Transition to quaternary states of fluid flow | 413 |
| 6 Concluding remarks | 414 |
| References | 416 |

**On the rotationally symmetric laminar flow
of Newtonian fluids induced by rotating disks**

Antonio Delgado 417

1 Introduction 417

2 Isotherm, steady flow of a Newtonian fluid 419

 2.1 Governing equations 419

 2.2 Von Kármán's solution for a single rotating disk 420

 2.3 Flow between co-rotating disks 422

3 Conclusions and future investigations 437

References 438