

Contents

1	General Characteristic of Rotating-Disk Systems	1
1.1	Industrial Applications of Rotating-Disk Systems	1
1.2	Acting Forces	2
1.3	Differential Equations of Continuity, Momentum and Heat Transfer	4
1.4	Differential Equation of Convective Diffusion	9
2	Modelling of Fluid Flow and Heat Transfer in Rotating-Disk Systems	11
2.1	Differential and Integral Equations	11
2.1.1	Differential Navier–Stokes and Energy Equations	11
2.1.2	Differential Boundary Layer Equations	13
2.1.3	Integral Boundary Layer Equations	14
2.2	Differential Methods of Solution	15
2.2.1	Self-Similar Solution	15
2.2.2	Approximate Analytical Methods for Laminar Flow Based on Approximations of Velocity Profiles	17
2.2.3	Numerical Methods	17
2.3	Integral Methods of Solution	18
2.3.1	Momentum Boundary Layer	18
2.3.2	Thermal Boundary Layer	22
2.4	Integral Method for Modelling Fluid Flow and Heat Transfer in Rotating-Disk Systems	23
2.4.1	Structure of the Method	23
2.4.2	Turbulent Flow: Improved Approximations of the Velocity and Temperature Profiles	24
2.4.3	Models of Surface Friction and Heat Transfer	25
2.4.4	Integral Equations with Account for the Models for the Velocity and Temperature Profiles	27
2.5	General Solution for the Cases of Disk Rotation in a Fluid Rotating as a Solid Body and Simultaneous Accelerating Imposed Radial Flow	29
3	Free Rotating Disk	33
3.1	Laminar Flow	33
3.2	Transition to Turbulent Flow and Effect of Surface Roughness	37

3.3	Turbulent Flow	41
3.3.1	Parameters of the Turbulent Boundary Layer	41
3.3.2	Surface Heat Transfer: Experimental and Theoretical Data of Different Authors	45
3.3.3	Effect of Approximation of the Radial Velocity Profile on Parameters of Momentum and Thermal Boundary Layers	48
3.3.4	Numerical Computation of Turbulent Flow and Heat Transfer for an Arbitrary Distribution of the Wall Temperature	54
3.4	Generalized Analytical Solution for Laminar and Turbulent Regimes Based on the Novel Model for the Enthalpy Thickness ...	58
3.5	Inverse Problem of Restoration of the Wall Temperature Distribution at a Specified Arbitrary Power Law for the Nusselt Number	61
3.5.1	Solution of the Problem	61
3.5.2	Limiting Case of the Solution	64
3.5.3	Properties of the Solution for Temperature Head	65
3.5.4	Analysis of the Solution	66
3.6	Theory of Local Modelling	72
3.6.1	Solution of the Problem	72
3.6.2	Other Interpretations	74
4	Unsteady Laminar Heat Transfer of a Free Rotating Disk	77
4.1	Transient Experimental Technique for Measuring Heat Transfer over Rotating Disks	77
4.2	Self-Similar Navier–Stokes and Energy Equations	79
4.3	Exact Solution for Surface Heat Transfer of an Isothermal Rotating Disk	82
4.4	Numerical Solution of an Unsteady Conjugate Problem of Hydrodynamics and Heat Transfer of an Initially Isothermal Disk	85
4.4.1	Computational Domain and Grid	85
4.4.2	Validation for Steady-State Fluid Flow and Heat Transfer ...	86
4.4.3	Unsteady Fluid Flow and Heat Transfer	88
4.5	Unsteady Conjugate Laminar Heat Transfer of a Rotating Non-uniformly Heated Disk	91
4.5.1	Problem Statement	91
4.5.2	Self-Similar Solution of the Transient Laminar Convective Heat Transfer Problem	92
4.5.3	Solution of the Unsteady Two-Dimensional Problem of Heat Conduction in a Disk	93
4.5.4	Analysis of the Solutions for Unsteady Heat Conduction in a Disk	94

5	External Flow Imposed over a Rotating Disk	101
5.1	Rotation of a Disk in a Fluid Rotating as a Solid Body Without Imposed Radial Flow	101
5.1.1	Turbulent Flow	101
5.1.2	Laminar Flow	106
5.2	Accelerating Radial Flow Without Imposed External Rotation	118
5.2.1	Flow Impingement onto an Orthogonal Rotating Disk: Experimental and Computational Data of Different Authors	118
5.2.2	Turbulent Flow	123
5.2.3	Laminar Flow	125
5.3	Non-symmetric Flow over a Parallel Rotating Disk	143
6	Outward Underswirled and Overswirled Radial Flow Between Parallel Co-rotating Disks	147
6.1	Flow in the Ekman Layers	147
6.2	Radial Outflow Between Parallel Co-rotating Disks	148
6.2.1	Flow Structure, Experiments and Computations of Different Authors	148
6.2.2	Computation of the Radial Variation of the Swirl Parameter Using the Integral Method	152
6.2.3	Local Nusselt Numbers	157
6.2.4	Effect of the Radial Distribution of the Disk Surface Temperature	161
6.3	Effect of the Flow Overswirl	164
6.4	Aerodynamics and Heat Transfer in a Rotating-Disk Air Cleaner	168
6.4.1	General Characteristics of the Problem	168
6.4.2	Geometrical and Regime Parameters of the Air Cleaner	169
6.4.3	Parameters of the Computational Scheme	171
6.4.4	Results of Simulations	171
7	Laminar Fluid Flow and Heat Transfer in a Gap Between a Disk and a Cone that Touches the Disk with Its Apex	179
7.1	General Characterization of the Problem	179
7.2	Navier–Stokes and Energy Equations in the Self-similar Form	181
7.3	Rotating Disk and/or Cone	184
7.3.1	Numerical Values of Parameters in the Computations	184
7.3.2	Cone Rotation at a Stationary Disk	185
7.3.3	Disk Rotation at a Stationary Cone	187
7.3.4	Co-rotating Disk and Cone	188
7.3.5	Counter-Rotating Disk and Cone	188
7.4	Radially Outward Swirling Flow in a Stationary Conical Diffuser	189
8	Heat and Mass Transfer of a Free Rotating Disk for the Prandtl and Schmidt Numbers Larger than Unity	193
8.1	Laminar Flow	193

8.2	Transitional and Turbulent Flows for the Prandtl or Schmidt Numbers Moderately Different from Unity	201
8.3	Transitional and Turbulent Flows at High Prandtl and Schmidt Numbers	208
8.4	An Integral Method for Modelling Heat and Mass Transfer in Turbulent Flow for the Prandtl and Schmidt Numbers Larger than Unity	214
8.4.1	Prandtl and Schmidt Numbers Moderately Different from Unity	214
8.4.2	High Prandtl and Schmidt Numbers	217
References		225
Index		235

Convective Heat and Mass Transfer in Rotating Disk
Systems

Shevchuk, I.V.

2009, XIX, 236 p. 116 illus., Hardcover

ISBN: 978-3-642-00717-0