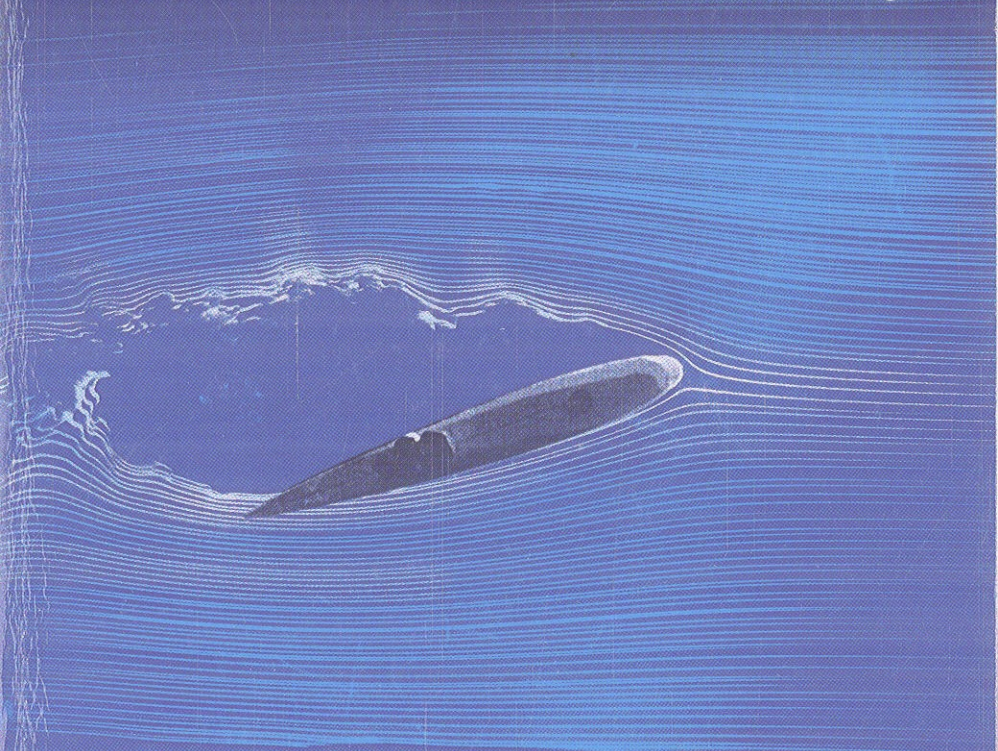


Basic Wing and Airfoil Theory



Alan Pope

CONTENTS

PREFACE	vii
LIST OF SYMBOLS	xv

CHAPTER 1. VECTOR ANALYSIS

1.1 Vectors	1
1.2 Components of a Vector	1
1.3 Addition of Vectors	2
1.4 Subtraction of Vectors	2
1.5 Vector Cross Product	3
1.6 Cross-product Significance	4
1.7 Dot, or Scalar, Product	5
1.8 Division of Vectors	6
1.9 Triple Product, $\mathbf{A} \cdot \mathbf{B} \times \mathbf{C}$	6
1.10 Triple Vector Product, $\mathbf{A} \times (\mathbf{B} \times \mathbf{C})$	7
1.11 Direction Cosines	7
1.12 Angle between Vectors	7
1.13 Vector Derivatives	8
1.14 Derivative of the Cross Product	8
1.15 Derivative of the Dot Product	8
1.16 Fields	8
1.17 The Gradient, Del	9
1.18 Applications of the Gradient	10
1.19 Successive Applications of the Gradient; the Laplacian	10

CHAPTER 2. COMPLEX VARIABLES AND FOURIER SERIES

2.1 Complex Variables	12
2.2 Properties of Complex Variables	13
2.3 Properties of ϕ and ψ	14
2.4 Cauchy's Second Theorem	15
2.5 The Laplacian	16
2.6 Matching Empirical Curves by Simultaneous Power Equations	17
2.7 Matching Empirical Curves by Simultaneous Fourier Series	19
2.8 Hyperbolic Functions	20
2.9 Determinants	21
2.10 The Binomial Expansion	22
2.11 Axes	22

CHAPTER 3. THE STREAM FUNCTION

3.1 Fluids; Perfect Fluids	24
3.2 The Equation of Continuity (Conservation of Mass)	25
3.3 Euler's Equations of Motion	26
3.4 Bernoulli's Equation	27

3.5	Boundary Conditions	28
3.6	The Stream Function and Streamlines	29
3.7	ψ in Rectilinear Coordinates	29
3.8	ψ in Polar Coordinates.	30
3.9	Stream Functions for Uniform Flow	31
3.10	The Stream Function for a Source.	32
3.11	Plotting by Using	33
3.12	Source in a Uniform Stream.	34
3.13	Practical Source Applications.	39
3.14	Source and Sink in a Uniform Stream; the Rankine Oval.	41
3.15	Doublet in a Uniform Stream: the Circular Cylinder.	46

CHAPTER 4. OTHER FLOW FUNCTIONS

4.1	Vortex Motion	51
4.2	Circulation.	52
4.3	Circular Cylinder with Circulation in a Uniform Stream	58
4.4	Pressures over a Cylinder with Circulation	59
4.5	Further Discussion of $\rho V \Gamma$	61
4.6	The Velocity Potential.	62
4.7	Tests for Rotation and Compressibility	64
4.8	Determining ϕ if ψ Is Known	64
4.9	Plotting Equipotential Lines	66
4.10	The Potential Function.	67
4.11	The Blasius Equations.	68
4.12	General Formula for Lift.	70
4.13	General Formula for Moment.	71
4.14	Summary of Important Relations	72

CHAPTER 5. THE JOUKOWSKI TRANSFORMATION

5.1	Conformal Transformation	75
5.2	The Joukowski Transformation	76
5.3	Transformation of the Velocity	78
5.4	Lift of a Joukowski Airfoil	79
5.5	Moment of a Joukowski Airfoil	84
5.6	General Lift and Moment Coefficients	85
5.7	General Center-of-pressure Equation.	86
5.8	The General Airfoil Equation.	87
5.9	The Flat-plate Airfoil	87
5.10	The Circular-arc Airfoil	88
5.11	The Symmetrical Airfoil	91
5.12	The Cambered Airfoil	97

CHAPTER 6. AIRFOIL CONSTRUCTION AND PRESSURE DISTRIBUTION

6.1	Trefftz Graphical Construction	100
6.2	Pressure Distributions	104
6.3	Pressure Distribution over a Symmetrical Joukowski Airfoil	106
6.4	Pressure-distribution Discussion.	110
6.5	Pressure Distribution by the Trefftz Method	112
6.6	Kármán-Trefftz Airfoils	114
6.7	Pressure Distribution over a Kármán-Trefftz Airfoil	119

CHAPTER 7. THIN-AIRFOIL THEORY

7.1	The Thin Airfoil.	120
7.2	Lift of a Thin Airfoil.	122
7.3	Velocity over a Thin Airfoil.	122
7.4	Pressure over a Thin Airfoil.	124
7.5	Lift and Moment Coefficients.	124
7.6	The Ideal Angle of Attack	132
7.7	Thin Airfoils with Trailing-edge Flaps	133
7.8	Total Pressure Distribution over a Thin Airfoil	134
7.9	Upper- and Lower-surface Pressure Distribution.	144
7.10	Rapid Estimation of Pressure Distribution	149
7.11	Summary of Thin-airfoil Theories	152

CHAPTER 8. THICK-AIRFOIL THEORIES

8.1	Theodorsen's Theory.	155
8.2	Pinkerton's Addition to Theodorsen's Theory.	171
8.3	Airfoils with Specified Pressure Distributions	176
8.4	Estimation of Airfoil Drag	178

CHAPTER 9. THE FINITE WING

9.1	The Finite Wing.	181
9.2	The Trailing Vortices	181
9.3	The Biot-Savart Law.	186
9.4	Downwash at the Wing for Any Spanwise Distribution of Circulation	193
9.5	Downwash at the Wing for Elliptic Distribution of Circulation	194
9.6	Downwash at the Wing for Uniform Distribution of Circulation.	195
9.7	Induced Drag Coefficient.	197

CHAPTER 10. THE MONOPLANE WING

10.1	The Fundamental Wing Equation.	200
10.2	Lift and Drag.	202
10.3	Minimum Induced Drag	202
10.4	Aspect-ratio Corrections for Induced Flow: Angle of Attack.	203
10.5	Aspect-ratio Corrections for Induced Flow: Drag	205
10.6	Corrections for Change of Aspect Ratio	206
10.7	Slope of a Three-dimensional Elliptic-wing Lift Curve	206
10.8	The Edge Correction.	207
10.9	Rectangular Wings	209
10.10	Slope of Rectangular-wing Lift Curve	212
10.11	Rectangular-wing Pitching Moments.	212
10.12	Tapered Wings	214

CHAPTER 11. THE FIELD ABOUT THE WING

11.1	The Field near the Horseshoe Vortex.	217
11.2	Uniform Loading	218
11.3	The Lateral Plane (Uniform Loading)	220
11.4	The Normal Axis (Uniform Loading).	223
11.5	The Longitudinal Axis (Uniform Loading)	224
11.6	The Vortex Span (Rectangular and Elliptic Wings)	227
11.7	The Normal Axis (Elliptic Loading)	230

11.8	The Lateral Plane (Elliptic Loading)	233
11.9	The Longitudinal Axis (Elliptic Loading)	237
11.10	Sweepback (Uniform Loading)	240
11.11	Dihedral (Uniform Loading)	243

CHAPTER 12. SPANWISE LOAD DISTRIBUTION FOR ARBITRARY WINGS

12.1	Multhopp's Spanwise Load Distribution Theory	246
12.2	Schrenk's Method	255
12.3	Determination of the Stall Pattern	260

CHAPTER 13. MISCELLANEOUS APPLICATIONS OF PERFECT FLUID THEORY

13.1	Types of Applications	265
13.2	Single Boundaries	265
13.3	Solid Round Boundaries	266
13.4	Open Round Boundaries	268
13.5	Flat Boundaries	269
13.6	Rectangular Boundaries	272
13.7	Apparent Additional Mass	276

APPENDIX 1	279
----------------------	-----

APPENDIX 2	281
----------------------	-----

APPENDIX 3	286
----------------------	-----

INDEX	291
-----------------	-----