
Contents

Foreword	xii
Serge ZANINOTTI	
Introduction	xiii
Chapter 1. Use of Aerodynamic Forces to Control the Trajectory of an Aircraft	1
1.1. Definitions	1
1.1.1. Lift	3
1.1.2. Drag	4
1.1.3. Equilibrium in horizontal flight	7
1.1.4. Aerodynamic moments	8
1.1.5. Center of gravity	8
1.1.6. Aerodynamic center	9
1.1.7. Center of thrust	10
1.1.8. Centering and stability	10
1.1.9. Lateral stability	11
1.1.10. Turn and roll	11
1.1.11. Load factor	12
1.2. Pitch control	13
1.3. Yaw control	15
1.4. Roll control	17
1.5. The Mach: subsonic, transonic and supersonic speeds	18

Chapter 2. Aerodynamic Forces and Moments and their Derivatives	21
2.1. Definitions	21
2.2. Aerodynamic forces	22
2.2.1. Drag expression	22
2.2.2. Expression of lateral lift	24
2.2.3. Expression of lift	25
2.3. Aerodynamic moments	25
2.4. Major aerodynamic derivatives	26
Chapter 3. Wind Tunnel	27
3.1. Description of wind tunnel tests	27
3.2. Stall	28
3.3. Calculation of the maximum stress applied to an aircraft wing in a wind tunnel	30
3.3.1. Definition of the drag coefficient from the flow tables	30
3.3.2. Calculation of the maximum stress applied to an aircraft wing in a wind tunnel	31
Chapter 4. Trihedron	33
4.1. Writing convention	33
4.2. Definitions of trihedrons	33
4.2.1. Definition of a trihedron or frame of reference	33
4.2.2. Galilean trihedron	34
4.2.3. Absolute trihedron	34
4.2.4. Local geographic trihedron	35
4.2.5. Terrestrial trihedron	35
4.2.6. Aircraft trihedron	35
4.2.7. Aircraft aerodynamic speed trihedron ($G, X_{vae}, Y_{vae}, Z_{vae}$)	36
4.2.8. Balance trihedron	36
4.3. Change of reference	36
4.4. Relation between trihedra	39
4.4.1. Aircraft trihedron (G, X_1, Y_1, Z_1) with respect to the reference trihedron (G, X_0, Y_0, Z_0)	39
4.4.2. Aerodynamic trihedron of the aircraft ($G, X_{va}, Y_{va}, Z_{va}$) with respect to the aircraft trihedron (G, X_e, Y_e, Z_e)	40
4.5. Relative positions of the various trihedra	40
4.5.1. Position of the aircraft trihedron with respect to the local geographical trihedron	40
4.5.2. Position of the aerodynamic trihedron with respect to the terrestrial trihedron	43

4.5.3. Position of the aircraft trihedron in relation to the aerodynamic speed trihedron	46
4.5.4. Position of the aircraft trihedron in relation to the balance trihedron	48
4.5.5. Position of the terrestrial trihedron in relation to the local geographic trihedron	50
Chapter 5. Movement of a Solid	53
5.1. Rotation of a solid around a fixed point	53
5.2. Kinematics of a solid	57
5.3. Reference framework	60
5.3.1. Absolute reference	60
5.3.2. Relative reference	60
5.3.3. Drive movement	61
5.3.4. Goal	61
5.3.5. Change of reference framework	61
5.3.6. Change of reference: conclusion and summary	67
5.4. Components of the instantaneous velocity vector of the aircraft reference $(O, i_e, j_e, k_e)_E$ with respect to the local geographic reference $(O, i_{lg}, j_{lg}, k_{lg})_{LGT}$ in the aircraft reference	70
5.5. Equations of accelerations and forces in the aircraft frame $(O, i_e, j_e, k_e)_E$	74
5.6. Determination of load factors in the aircraft reference $(O, i_e, j_e, k_e)_E$	77
5.7. Case where the speeds and accelerations are provided at a point other than G	77
5.8. Coordinates of the aerodynamic speed in aircraft axes	79
5.9. Equations of moments in the aircraft frame $(O, i_e, j_e, k_e)_E$	80
5.10. Forces and moments applied to the aircraft	85
5.10.1. Force of gravity	85
5.10.2. Forces and moments of propulsion	86
5.10.3. Aerodynamic forces and moments	86
5.10.4. Forces and inertia torques	86
Chapter 6. Aircraft Characteristics	87
6.1. Aerodynamics problems posed by aircraft	87
6.1.1. Drag	87
6.1.2. Lift	89
6.1.3. Reynolds number	90
6.1.4. Flow velocity	90
6.1.5. Stability of an aircraft	91
6.1.6. Resistance of structures	92

6.1.7. Sizing of an aircraft	93
6.2. Load factor	93
6.2.1. Definition of the load factor.	93
6.2.2. Definition of load factor requirements	93
Chapter 7. Aircraft Simulation Model.	95
7.1. Simulation model of the atmosphere	96
7.2. Propulsive coefficients	96
7.3. Mass coefficients	96
7.4. Aerodynamic coefficients	97
7.5. Equations of motion.	98
7.6. Introduction of wind	104
Chapter 8. Processing of Trajectography Information.	107
8.1. Telemeasured parameters	107
8.2. Smoothing, first derivation and second derivation	107
8.3. Performance calculation	108
8.3.1. Change of coordinates to move from the trihedron (O, X_c, Y_c, Z_c) to the trihedron (O, X_0, Y_0, Z_0).	108
8.3.2. Aircraft speed relative to the ground	109
8.3.3. Aerodynamic speed and Mach number	109
8.4. Aerodynamic route and slope	111
8.5. Determination of the angle ψ	114
8.6. Load factors in the aerodynamic trihedron (O, X_a, Y_{af}, Z_r)	114
8.7. Processing of data from the inertial unit (in the aircraft frame)	115
8.7.1. Load factor conversion.	116
8.7.2. Calculation of accelerations at the center of gravity	118
8.7.3. Speed conversion	118
8.7.4. Calculation of Ψ	120
8.7.5. Recomposition of the trajectory	120
8.8. Determination of some aerodynamic parameters.	120
8.8.1. Determination of the incidence α and sideslip β	120
8.8.2. Determination of ψ_{ac}	121
8.8.3. Determination of θ	128
8.9. Determination of load factors (n_{x1}, n_{y1}, n_{z1}) in the aircraft trihedron	129
8.10. Determination of C_Y and C_z	131
8.11. Determination of the total incidence	132
8.12. Determination of the longitudinal attitude compared to the local horizontal plane.	132
8.13. Determination of drag coefficients	136
8.14. Determination of the pushing force	137

Chapter 9. Quaternion Methods	139
9.1. Goal	139
9.2. Reminder of the axis change formulas using Euler angles	140
9.3. Olinde-Rodrigues's formulas: definition of quaternions	140
Glossary	161
List of Abbreviations	165
References	169
Index	171