

AERODYNAMICS FOR NAVAL AVIATORS

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TABLE OF CONTENTS

	Page
PREFACE.....	iii
CHAPTER I: BASIC AERODYNAMICS	
WING AND AIRFOIL FORCES	
PROPERTIES OF THE ATMOSPHERE.....	1
Static pressure	
Temperature	
Density	
Viscosity	
Standard atmosphere	
Pressure altitude	
Density altitude	
BERNOULLI'S PRINCIPLE AND SUBSONIC AIRFLOW.....	4
Bernoulli's equation.....	6
Incompressible flow	
Variation of static pressure and velocity	
Kinetic and potential energy of flow	
Static and dynamic pressure, q	
Factors affecting dynamic pressure	
Airspeed measurement.....	9
Stagnation pressure	
Measurement of dynamic pressure	
Pitot and static sources	
Indicated airspeed	
Calibrated airspeed	
Equivalent airspeed	
True airspeed	
DEVELOPMENT OF AERODYNAMIC FORCES.....	14
Streamline pattern and pressure distribution.....	14
Generation of lift.....	16
Circulation	
Pressure distribution	
Airfoil terminology.....	20
Aerodynamic force coefficient.....	22
Basic lift equation.....	23
Lift coefficient	
Dynamic pressure and surface area	

	Page
Interpretation of the lift equation	23
Lift coefficient versus angle of attack	
Stall speed and angle of attack	
Angle of attack versus velocity	
Primary control of airspeed	
Airfoil lift characteristics	27
Section angle of attack and lift coefficient	
Typical section characteristics	
Effect of thickness and camber	
Drag characteristics	29
Drag equation	
Drag coefficient versus angle of attack	
Lift-drag ratio	
Power-off glide performance	
Airfoil drag characteristics	33
Section drag coefficient	
Typical section characteristics	
Effect of thickness and camber	
Low drag sections	
FLIGHT AT HIGH LIFT CONDITIONS	35
Stall speeds	35
Maximum lift coefficient	
Stall angle of attack	
Effect of weight	35
Effect of maneuvering flight	35
Load factor versus bank angle	
Stall speed versus load factor	
Effect of high lift devices	37
Effect on stall speed	
Stall angle of attack and stall recovery	39
HIGH LIFT DEVICES	39
Types of high lift devices	41
Plain flap	
Split flap	
Slotted flap	
Fowler flap	
Slots and slats	
Boundary layer control	
Operation of high lift devices	43
Flap retraction and extension	
Changes in lift, drag, and trim	
Effect of power	
DEVELOPMENT OF AERODYNAMIC PITCHING MOMENTS	
Pressure distribution	47
Center of pressure and aerodynamic center	47
Pitching moment coefficient	49
Effect of camber	
Effect of flaps	
Relationship between center of pressure, aerodynamic center, and moment coefficient	
Application to longitudinal stability	51
Stability and trim	
Effect of supersonic flow	

	Page
FRICITION EFFECTS	52
Viscous flow	52
Boundary layers	52
Laminar flow	
Transition	
Turbulent flow	
Reynolds Number	54
Definition	
Skin friction versus Reynolds Number	
Airflow separation	56
Pressure distribution	
Pressure gradient and boundary layer energy	
Factors affecting separation	
Scale effect	59
Effect on aerodynamic characteristics	
Reynolds Number correlation	

PLANFORM EFFECTS AND AIRPLANE DRAG

EFFECT OF WING PLANFORM	61
Description of planform	61
Area, span, and chord	
Aspect ratio and taper	
Sweepback	
Mean aerodynamic chord	
Development of lift by a wing	63
Vortex system	
Tip and bound vortices	
Induced flow and downwash	
Section angle of attack	
Induced angle of attack	
INDUCED DRAG	66
Induced angle of attack and inclined lift	66
Induced drag coefficient	68
Effect of lift coefficient	
Effect of aspect ratio	
Effect of lift	68
Effect of altitude	69
Effect of speed	69
Effect of aspect ratio	71
Lift and drag characteristics	
Influence of low aspect ratio configurations	
EFFECT OF TAPER AND SWEEPBACK	74
Spanwise lift distribution	74
Local induced flow	76
Effect on lift and drag characteristics	76
STALL PATTERNS	77
Favorable stall pattern	77
Effect of planform	77
Taper	
Sweepback	
Modifications for stall characteristics	86

	Page
PARASITE DRAG	87
Sources of parasite drag	87
Parasite drag coefficient.....	87
Parasite and induced drag	89
Minimum parasite drag coefficient	
Airplane efficiency factor	
Equivalent parasite area	
Effect of configuration	91
Effect of altitude.....	91
Effect of speed.....	91
AIRPLANE TOTAL DRAG	92
Drag variation with speed	
Induced and parasite drag	
Stall speed	
Minimum drag	
Specific performance conditions	
Compressibility drag rise	

CHAPTER 2. AIRPLANE PERFORMANCE

REQUIRED THRUST AND POWER

DEFINITIONS	96
Parasite and induced drag	96
Thrust and power required	97

VARIATION OF THRUST AND POWER REQUIRED

Effect of gross weight	99
Effect of configuration	101
Effect of altitude	101

AVAILABLE THRUST AND POWER

PRINCIPLES OF PROPULSION	104
Mass flow, velocity change, momentum change	104
Newton's laws	104
Wasted power	104
Power available	106
Propulsion efficiency	106

TURBOJET ENGINES

Operating cycle	107
Function of the components	109

Inlet or diffuser
 Compressor
 Combustion chamber
 Turbine
 Exhaust nozzle

Turbojet operating characteristics.....	116
---	-----

Thrust and power available
 Effect of velocity
 Effect of engine speed
 Specific fuel consumption
 Effect of altitude
 Governing apparatus
 Steady state, acceleration, deceleration
 Instrumentation

	Page
Turbojet operating limitations	124
Exhaust gas temperature	
Compressor stall or surge	
Flameout	
Compressor inlet air temperature	
Engine speed	
Time limitations	
Thrust augmentation	129
Afterburner	
Water injection	
The gas turbine-propeller combination	132
Equivalent shaft horsepower	
Governing requirements	
Operating limitations	
Performance characteristics	
THE RECIPROCATING ENGINE	135
Operating characteristics	135
Operating cycle	
Brake horsepower	
Torque, RPM, and BMEP	
Normal combustion	
Preignition and detonation	
Fuel qualities	
Specific fuel consumption	
Effect of altitude and supercharging	
Effect of humidity	
Operating limitations	144
Detonation and preignition	
Water injection	
Time limitations	
Reciprocating loads	
AIRCRAFT PROPELLERS	
Operating characteristics	145
Flow patterns	
Propulsive efficiency	
Powerplant matching	
Governing and feathering	
Operating limitations	148
ITEMS OF AIRPLANE PERFORMANCE	
STRAIGHT AND LEVEL FLIGHT	150
Equilibrium conditions	
Thrust and power required	
Thrust and power available	
Maximum and minimum speed	
CLIMB PERFORMANCE	150
Steady and transient climb	150
Forces acting on the airplane	
Climb angle and obstacle clearance	
Rate of climb, primary control of altitude	
Propeller and jet aircraft	
Climb performance	156
Effect of weight and altitude	
Descending flight	

	Page
RANGE PERFORMANCE	158
General range performance	158
Specific range, velocity, fuel flow	
Specific endurance	
Cruise control and total range	
Range, propeller driven airplanes	160
Aerodynamic conditions	
Effect of weight and altitude	
Reciprocating and turboprop airplanes	
Range, turbojet airplanes	164
Aerodynamic conditions	
Effect of weight and altitude	
Constant altitude and cruise-climb profiles	
Effect of wind on range	168
ENDURANCE PERFORMANCE	170
General endurance performance	170
Specific endurance, velocity, fuel flow	
Effect of altitude on endurance	170
Propeller driven airplanes	
Turbojet airplanes	
OFF-OPTIMUM RANGE AND ENDURANCE	172
Reciprocating powered airplane	172
Turboprop powered airplane	173
Turbojet powered airplane	175
MANEUVERING PERFORMANCE	176
Relationships of turning flight	176
Steady turn, bank angle and load factor	
Induced drag	
Turning performance	178
Turn radius and turn rate	
Effect of bank angle and velocity	
Tactical performance	178
Maximum lift	
Operating strength limits	
Constant altitude turning performance	
TAKEOFF AND LANDING PERFORMANCE	182
Relationships of accelerated motion	182
Acceleration, velocity, distance	
Uniform and nonuniform acceleration	
Takeoff performance	184
Forces acting on the airplane	
Accelerated motion	
Factors of technique	
Factors affecting takeoff performance	187
Effect of gross weight	
Effect of wind	
Effect of runway slope	
Proper takeoff velocity	
Effect of altitude and temperature	
Handbook data	

	Page
Landing performance	192
Forces acting on the airplane	
Accelerated motion	
Factors of technique	
Factors affecting landing performance	196
Effect of gross weight	
Effect of wind	
Effect of runway slope	
Effect of altitude and temperature	
Proper landing velocity	
Importance of handbook performance data	200

CHAPTER 3. HIGH SPEED AERODYNAMICS

GENERAL CONCEPTS AND SUPERSONIC FLOW PATTERNS

NATURE OF COMPRESSIBILITY	201
Definition of Mach number.....	202
Subsonic, transonic, supersonic, and hypersonic flight regimes.....	204
Compressible flow conditions.....	204
Comparison of compressible and incompressible flow.....	204
TYPICAL SUPERSONIC FLOW PATTERNS	207
Oblique shock wave.....	207
Normal shock wave.....	207
Expansion wave.....	211
Effect on velocity, Mach number, density, pressure, energy.....	213
SECTIONS IN SUPERSONIC FLOW	213
Flow patterns.....	213
Pressure distribution.....	213
Wave drag.....	215
Location of aerodynamic center.....	215

CONFIGURATION EFFECTS

TRANSONIC AND SUPERSONIC FLIGHT	215
Critical Mach number.....	215
Shock wave formation.....	218
Shock induced separation.....	218
Force divergence.....	218
Phenomena of transonic flight.....	218
Phenomena of supersonic flight.....	220
TRANSONIC AND SUPERSONIC CONFIGURATIONS	220
Airfoil sections	220
Transonic sections	
Supersonic sections	
Wave drag characteristics	
Effect of Mach number on airfoil characteristics	
Planform effects	226
Effect of sweepback	
Advantages of sweepback	
Disadvantages of sweepback	
Effect of aspect ratio and tip shape	
Control surfaces	236
Powered controls	
All movable surfaces	

Supersonic engine inlets	Page 238
Internal and external compression inlets	
Inlet performance and powerplant matching	
Supersonic configurations	240
AERODYNAMIC HEATING	242
Ram temperature rise	242
Effect on structural materials and powerplant performance	242

CHAPTER 4. STABILITY AND CONTROL

DEFINITIONS

STATIC STABILITY	243
DYNAMIC STABILITY	245
TRIM AND CONTROLLABILITY	247
AIRPLANE REFERENCE AXES	249

LONGITUDINAL STABILITY AND CONTROL

STATIC LONGITUDINAL STABILITY	250
General considerations	250
Contribution of the component surfaces	253
Wing	
Fuselage and nacelles	
Horizontal tail	
Power-off stability	259
Power effects	259
Control force stability	264
Maneuvering stability	268
Tailoring control forces	270
LONGITUDINAL CONTROL	275
Maneuvering control requirement	275
Takeoff control requirement	275
Landing control requirement	277
LONGITUDINAL DYNAMIC STABILITY	279
Phugoid	279
Short period motions	281
MODERN CONTROL SYSTEMS	281
Conventional	
Boosted	
Power operated	

DIRECTIONAL STABILITY AND CONTROL

DIRECTIONAL STABILITY	284
Definitions	284
Contribution of the airplane components	285
Vertical tail	
Wing	
Fuselage and nacelles	
Power effects	
Critical conditions	290
DIRECTIONAL CONTROL	290
Directional control requirements	291
Adverse yaw	291

	Page
Spin recovery	291
Slipstream rotation	294
Cross wind takeoff and landing	294
Asymmetrical power	294
LATERAL STABILITY AND CONTROL	
LATERAL STABILITY	294
Definitions	295
CONTRIBUTION OF THE AIRPLANE COMPONENTS	295
Wing	298
Fuselage and wing position	298
Sweepback	298
Vertical tail	298
LATERAL DYNAMIC EFFECTS	299
Directional divergence	
Spiral divergence	
Dutch roll	
CONTROL IN ROLL	300
Rolling motion of an airplane	300
Rolling performance	301
Critical requirements	305
MISCELLANEOUS STABILITY PROBLEMS	
LANDING GEAR CONFIGURATIONS	305
Tail wheel type	
Tricycle type	
Bicycle type	
SPINS AND PROBLEMS OF SPIN RECOVERY	307
Principal prospin moments	
Fundamental principle of recovery	
Effect of configuration	
PITCH-UP	313
Definition	
Contribution of the airplane components	
EFFECTS OF HIGH MACH NUMBER	313
Longitudinal stability and control	
Directional stability	
Dynamic stability and damping	
PILOT INDUCED OSCILLATIONS	314
Pilot-control system-airplane coupling	
High q and low stick force stability	
ROLL COUPLING	315
Inertia and aerodynamic coupling	
Inertia and wind axes	
Natural pitch, yaw, and coupled pitch-yaw frequencies	
Critical roll rates	
Autorotative rolling	
Operating limitations	
HELICOPTER STABILITY AND CONTROL	319
Rotor gyroscopic effects	
Cyclic and collective pitch	
Longitudinal, lateral, and directional control	
Angle of attack and velocity stability	
Dynamic stability	

CHAPTER 5. OPERATING STRENGTH LIMITATIONS

GENERAL DEFINITIONS AND STRUCTURAL REQUIREMENTS

	Page
STATIC STRENGTH.....	326
Limit load	
Factor of safety	
Material properties	
SERVICE LIFE.....	328
Fatigue consideration	
Load spectrum and cumulative damage	
Creep considerations	
AEROELASTIC EFFECTS.....	330
Stiffness and rigidity	
AIRCRAFT LOADS AND OPERATING LIMITATIONS	
FLIGHT LOADS—MANEUVERS AND GUSTS.....	331
Load factor.....	331
Maneuvering load factors.....	331
Maximum lift capability	
Effect of gross weight	
Gust load factors.....	332
Gust load increment	
Effect of gust intensity and lift curve slope	
Effect of wing loading and altitude	
Effect of overstress.....	334
THE V-n OR V-g DIAGRAM.....	334
Effect of weight, configuration, altitude, and symmetry of loading	
Limit load factors	
Ultimate load factors	
Maximum lift capability	
Limit airspeed	
Operating envelope	
Maneuver speed and penetration of turbulence	
EFFECT OF HIGH SPEED FLIGHT.....	339
Critical gust	
Aileron reversal	
Divergence	
Flutter	
Compressibility problems	
LANDING AND GROUND LOADS.....	343
Landing load factor	
Effect of touchdown rate of descent	
Effect of gross weight	
Forced landing on unprepared surfaces	
EFFECT OF OVERSTRESS ON SERVICE LIFE.....	344
Recognition of overstress damage	
Importance of operating limitations	

CHAPTER 6. APPLICATION OF AERODYNAMICS TO SPECIFIC PROBLEMS OF FLYING

	Page
PRIMARY CONTROL OF AIRSPEED AND ALTITUDE.....	349
Angle of attack versus airspeed	
Rate of climb and descent	
Flying technique	
REGION OF REVERSED COMMAND.....	353
Regions of normal and reversed command	
Features of flight in the normal and reversed regions of command	
THE ANGLE OF ATTACK INDICATOR AND THE MIRROR LANDING SYSTEM.....	357
The angle of attack indicator	
The mirror landing system	
THE APPROACH AND LANDING.....	360
The approach	
The landing flare and touchdown	
Typical errors	
THE TAKEOFF.....	365
Takeoff speed and distance	
Typical errors	
GUSTS AND WIND SHEAR.....	367
Vertical and horizontal gusts	
POWER-OFF GLIDE PERFORMANCE.....	369
Glide angle and lift-drag ratio	
Factors affecting glide performance	
The flameout pattern	
EFFECT OF ICE AND FROST ON AIRPLANE PERFORMANCE... ..	373
Effect of ice	
Effect of frost	
ENGINE FAILURE ON THE MULTI-ENGINE AIRPLANE.....	376
Effect of weight and altitude	
Control requirements	
Effect on performance	
Effect of turning flight and configuration	
GROUND EFFECT.....	379
Aerodynamic influence of ground effect	
Ground effect on specific flight conditions	
INTERFERENCE BETWEEN AIRPLANES IN FLIGHT.....	383
Effect of lateral, vertical, and longitudinal separation	
Collision possibility	

	Page
BRAKING PERFORMANCE.....	387
Friction characteristics	
Braking technique	
Typical errors of braking technique	
REFUSAL SPEEDS, LINE SPEEDS, AND CRITICAL FIELD LENGTH.....	391
Refusal speed	
Line speeds	
Critical field length, multi-engine operation	
SONIC BOOMS.....	396
Shock waves and audible sound	
Precautions	
HELICOPTER PROBLEMS.....	399
Rotor aerodynamics.....	400
Retreating blade stall.....	402
Compressibility effects.....	404
Autorotation characteristics.....	405
Power settling.....	408
THE FLIGHT HANDBOOK.....	411
SELECTED REFERENCES.....	413
INDEX.....	414



Chapter 1

BASIC AERODYNAMICS

In order to understand the characteristics of his aircraft and develop precision flying techniques, the Naval Aviator must be familiar with the fundamentals of aerodynamics. There are certain physical laws which describe the behavior of airflow and define the various aerodynamic forces and moments acting on a surface. These principles of aerodynamics provide the foundations for good, precise flying techniques.

WING AND AIRFOIL FORCES

PROPERTIES OF THE ATMOSPHERE

The aerodynamic forces and moments acting on a surface are due in great part to the properties of the air mass in which the surface is operating. The composition of the earth's atmosphere by volume is approximately 78 percent nitrogen, 21 percent oxygen, and 1

percent water vapor, argon, carbon dioxide, etc. For the majority of all aerodynamic considerations air is considered as a uniform mixture of these gases. The usual quantities used to define the properties of an air mass are as follows:

STATIC PRESSURE. The absolute static pressure of the air is a property of primary importance. The static pressure of the air at any altitude results from the mass of air supported above that level. At standard sea level conditions the static pressure of the air is 2,116 psf (or 14.7 psi, 29.92 in. Hg, etc.) and at 40,000 feet altitude this static pressure decreases to approximately 19 percent of the sea level value. The shorthand notation for the ambient static pressure is " p " and the standard sea level static pressure is given the subscript " 0 " for zero altitude, p_0 . A more usual reference in aerodynamics and performance is the proportion of the ambient static pressure and the standard sea level static pressure. This static pressure ratio is assigned the shorthand notation of δ (delta).

Altitude pressure ratio

$$\delta = \frac{\text{Ambient static pressure}}{\text{Standard sea level static pressure}} = p/p_0$$

Many items of gas turbine engine performance are directly related to some parameter involving the altitude pressure ratio.

TEMPERATURE. The absolute temperature of the air is another important property. The ordinary temperature measurement by the Centigrade scale has a datum at the freezing point of water but absolute zero temperature is obtained at a temperature of -273° Centigrade. Thus, the standard sea level temperature of 15° C. is an absolute temperature of 288° . This scale of absolute temperature using the Centigrade increments is the Kelvin scale, e.g., $^\circ$ K. The shorthand notation for the ambient air temperature is " T " and the standard sea level air temperature of 288° K. is signified by T_0 . The more usual reference is

the proportion of the ambient air temperature and the standard sea level air temperature. This temperature ratio is assigned the shorthand notation of θ (theta).

Temperature ratio

$$\theta = \frac{\text{Ambient air temperature}}{\text{Standard sea level air temperature}} = T/T_0 = \frac{C^\circ + 273}{288}$$

Many items of compressibility effects and jet engine performance involve consideration of the temperature ratio.

DENSITY. The density of the air is a property of greatest importance in the study of aerodynamics. The density of air is simply the mass of air per cubic foot of volume and is a direct measure of the quantity of matter in each cubic foot of air. Air at standard sea level conditions weighs 0.0765 pounds per cubic foot and has a density of 0.002378 slugs per cubic foot. At an altitude of 40,000 feet the air density is approximately 25 percent of the sea level value.

The shorthand notation used for air density is ρ (rho) and the standard sea level air density is then ρ_0 . In many parts of aerodynamics it is very convenient to consider the proportion of the ambient air density and standard sea level air density. This density ratio is assigned the shorthand notation of σ (sigma).

$$\text{density ratio} = \frac{\text{ambient air density}}{\text{standard sea level air density}} = \sigma = \rho/\rho_0$$

A general gas law defines the relationship of pressure temperature, and density when there is no change of state or heat transfer. Simply stated this would be "density varies directly with pressure, inversely with temperature." Using the properties previously defined,

$$\text{density ratio} = \frac{\text{pressure ratio}}{\text{temperature ratio}} = \frac{\rho}{\rho_0} = \left(\frac{P}{P_0}\right) \left(\frac{T_0}{T}\right) = \sigma = \delta/\theta$$

