AERODYNAMICS

Course Description: General fluid flow equation, potential parallel flow theory with some applications of aerodynamics, thin airfoil theory, finite wing in incompressible inviscid flow and introduction to viscous fluid flows and boundary layers.

Course Objectives:

This course deals with flow of air around objects. While most of the applications in this course are wings and aircraft, a wide variety of applications are also considered in this course i.e. flow around cylinder or sphere. Therefore, this course has a set of objectives that you need to keep on mind during the semester. These objectives will help you keep in track of your learning as the semester progresses.

1. Introduce basic concepts and governing equations of aerodynamics.
2. Provide a clear understanding of the fundamental concepts and theories of incompressible and inviscid aerodynamics.
3. Use mathematical theories (thin airfoil and finite wing theories) to provide approximations to some actual aerodynamic problems we are attempting to solve.
4. Provide a comparison between theory's results and experimental (actual) results.
5. Introduce viscous flow and boundary layer concepts and the difference between inviscid flow and viscous flow treatments.
6. Enable students to design and execute computational and experimental aerodynamic analysis and design together with members of a team.

Textbook: John D. Anderson Jr. Fundamentals of Aerodynamics (3rd) McGraw Hill, 2001.

References:

1. A.M. Kuethe and C-Y Chow, Foundation of Aerodyanmics, John Wiley & Sons, 1998.
2. R.S. Shevell, Fundamentals of Flight (2nd Ed.) Prentice Hall Int'l Inc., 1989.
3. B.W. McCormick, Aerodynamics, Aeronautics and Flight Mechanics, John Wiley & Sons, 1979.

Aerodynamics: Introduction

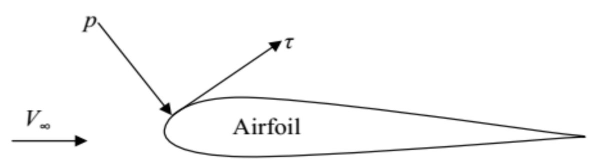
• Aerodynamics deals with the motion of objects in air. These objects can be airplanes, missiles or road vehicles.

• The Table below summarizes the aspects of vehicle performance directly influenced by aerodynamic design.

Performance	Fuel Economy
	Emissions
	Maximum Speed
	Acceleration
Stability	Directional Stability
	Response to Flow Unsteadiness
	Crosswind Sensitivity
Cooling	Engine
	Transmission
	Brakes
	Condenser
Comfort	Heating, Ventilation and Air Conditioning
	Wind Noise
Visibility	Dirt Accumulation
	Splash and Spray

Aerodynamics: Aerodynamic Forces

• When a body moves in the air, a pressure and shear (friction) stresses are produced at every point of the body.



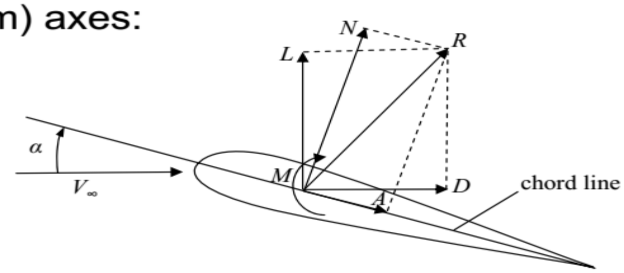
• The pressure, *p*, acts normal to the surface and the shear, *τ*, acts tangential to the surface of the body.

• The sum of the pressure and shear forces gives the resultant force, *R*.

• The aerodynamic forces are mainly due to *pressure and shear stress distribution* over the body surface.

Aerodynamics: Aerodynamic Forces

• The resultant force, *R*, can be resolved into two components along the wind (freestream) axes:



lift = *L* = component normal to V_∞
drag = *D* = component along V_∞

or along the body axes axis:

normal force = *N* = component normal to the airfoil chord
axial force = *A* = component along the body chord

• The point at which the resultant force acts is called the *center of pressure*.

• It is convenient sometimes to specify the *aerodynamic center* which is defined as the point at which the aerodynamic moment, *M*, is independent of the angle of attack, α.

Aerodynamics: Aerodynamic Forces

• In aerodynamics, we usually deal with aerodynamic forces and moments *coefficients* more than forces and moments.

• The freestream *dynamic pressure*, q_∞, $$q_\infty = \frac{1}{2}\rho_\infty V_\infty^2$$

ρ_∞ is the freestream density and V_∞ is the freestream velocity.

Pressure Coefficient: $$C_P = \frac{P - P_\infty}{q_\infty}$$; P_∞ = the freestream pressure

Lift Coefficient: $$C_L = \frac{L}{q_\infty S}$$

; S = the reference area

Drag Coefficient: $$C_D = \frac{D}{q_\infty S}$$

Moment Coefficient: $$C_M = \frac{M}{q_\infty S l}$$; l = the characteristic length.

Aerodynamics: Aerodynamic Forces

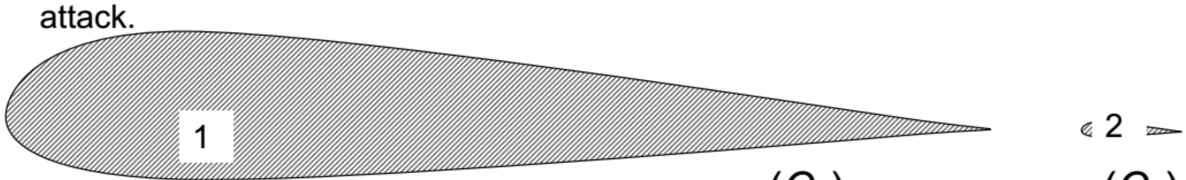
From dimensional analysis, the above coefficients depend on some parameters:

- *Mach number*, $M = V_\infty / a$ where a is the speed of sound.

- *Reynolds number*, $Re = \rho V_\infty l / \mu$ where ρ is the air density and μ is the dynamic viscosity of the air.

- *Angle of attack*, α.

- In many practical problems, the lift, drag and moment *coefficients* are identical for geometrically similar bodies at the same Mach, Reynolds number and angle of attack.



$$(C_L)_1 = (C_L)_2$$

$$(C_D)_1 = (C_D)_2$$

$$(C_M)_1 = (C_M)_2$$