Sub module 8.2 - Aerodynamics

8.2.1 Airflow around a body

- In addition to definition given in sub-module 8.1 aerodynamics as the science describing body's movement in an air.

- Thus it is a branch of dynamics which deals with the motion of air and other gases, with the forces acting upon an object in motion through the air, or with an object which is stationary in a current of air.

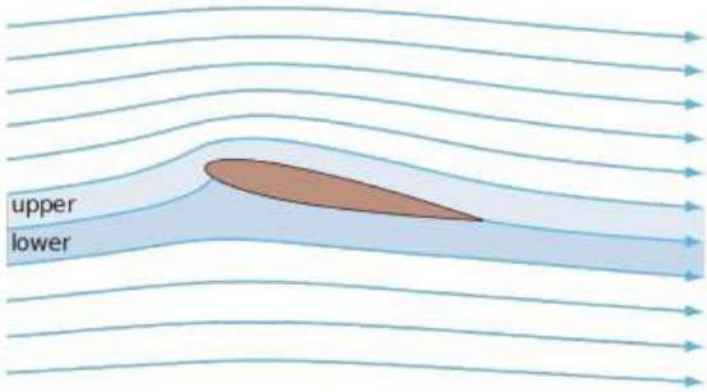
- In effect, in aviation aerodynamics is concerned with three distinct parts. These parts may be defined as the aircraft, the relative wind, and the atmosphere.

- An airfoil is a surface designed to obtain a desirable reaction from the air through which it moves.

- Thus, we can say that any part of the aircraft which converts air resistance into a force useful for flight is an airfoil.

- The blades of a propeller are so designed that when they rotate, their shape and position cause a higher pressure to be built up behind them than in front of them so that they will pull the aircraft forward. The model of a wing gives an excellent example of streamlines around airfoil.

Although the top surface of the conventional wing profile has greater curvature than the lower surface, the principal thing is the larger density of streamlines above the wing. The larger density of streamlines means the greater velocity of air



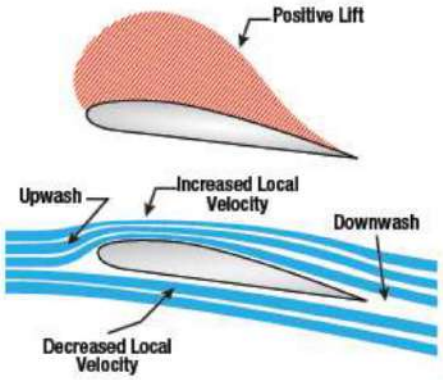
8.2.2 Basic Terms

- Boundary Layer - In physics and fluid mechanics, a **boundary layer** is the **layer** of fluid in the immediate vicinity of a bounding surface where the effects of viscosity are significant.

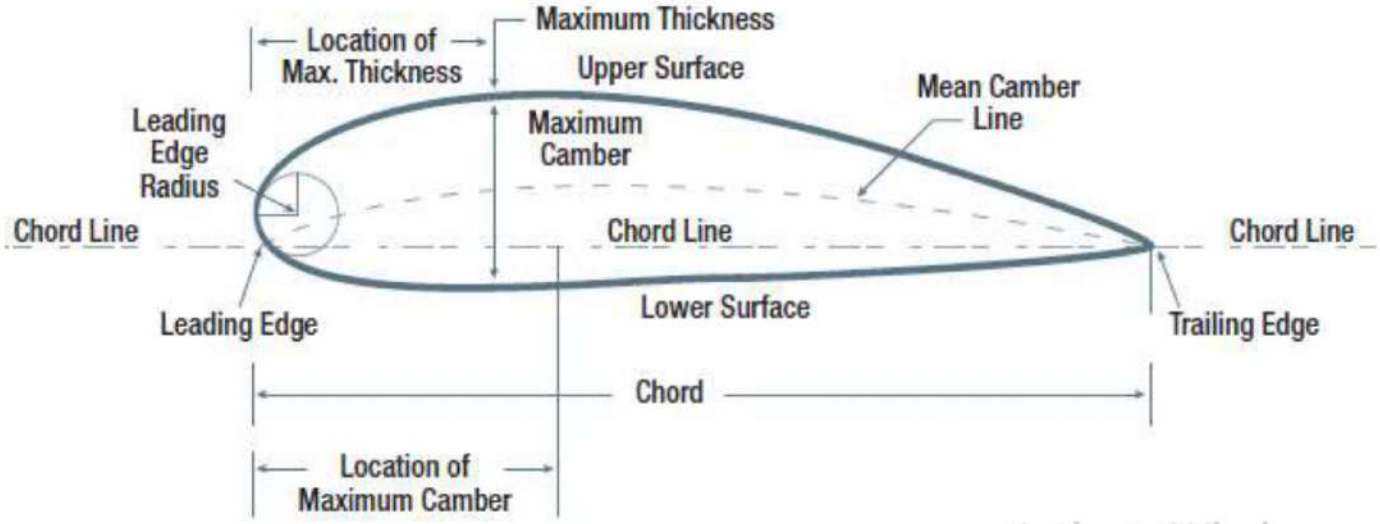
- Laminar and turbulent flow - Turbulence is flow characterized by recirculation, eddies, and apparent randomness. Flow in which turbulence is not exhibited is called laminar. The presence of eddies or recirculation alone does not necessarily indicate turbulent flow—these phenomena may be present in laminar flow as well.
- Free stream flow and relative airflow - **free-stream flow**. Continuous lines are **free** air **stream airflow**. The air in a region where pressure, temperature, and **relative** velocity are unaffected by the passage of aircraft through it. Also known as **relative airflow** (RAF).

- Upwash and downwash - upwash is generated ahead of the airfoil, the forward stagnation point moves under the leading edge, and a downwash is evident aft of the airfoil. (Upwash and downwash are the deflection directions of the air as it negotiates its path around the airfoil.)

- Stagnation point - In fluid dynamics, a **stagnation point** is a **point** in a flow field where the local velocity of the fluid is zero. **Stagnation points** exist at the surface of objects in the flow field, where the fluid is brought to rest by the object.



8.2.3 Airfoil nomenclature



- The forward section of the airfoil is named the **leading edge** and the rear the **trailing edge**. The airfoil upper and lower surfaces meet at the leading and trailing edges.

- The length of the airfoil from leading to trailing edge is known as the **airfoil chord**. This often varies down the span of the wing as the wing tapers from the root to the tip.

- The thickness of the airfoil is a very important design parameter and as always expressed as a percentage of the total chord. The airfoil plotted above has a **thickness-to-chord ratio** of 12%. This means that the thickest section has a height equal to 12% of the total chord.

- The final design parameter **camber** is a measure of the asymmetry between the upper and lower surface.

- Camber is generally introduced to an airfoil to increase its maximum lift coefficient, which in turn decreases the stall speed of the aircraft. The camber line is a line drawn equidistant between the upper and lower surface at all points along the chord.

- Highly cambered airfoils produce more lift than lesser cambered airfoils, and an airfoil that has no camber is symmetrical upper and lower surface.

8.2.4 THRUST, WEIGHT, LIFT AND DRAG

- There are four forces that act upon an aircraft in flight: thrust, weight, lift and drag. A brief description of each is given. A discussion of angle of attack, lift and drag follows. Further exploration of the relationship between the four forces of flight occurs in *Sub-Module 03*.

- 1. *Thrust*—the force that moves the aircraft forward. Thrust is the forward force produced by the powerplant that overcomes the force of drag.
- 2. *Gravity or weight*—the force that pulls the aircraft toward the earth. Weight is the force of gravity acting downward upon everything that goes into the aircraft, such as the aircraft itself, crew, fuel, and cargo.

- *3. Lift*—the force that pushes the aircraft upward. Lift acts vertically and counteracts the effects of weight.

- 4. *Drag*—the force that exerts a braking action to hold the aircraft back. Drag is a backward deterrent force and is caused by the disruption of the airflow by the wings, fuselage, and protruding objects.

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- An aircraft in flight is continuously affected by thrust, weight, lift and drag.
- The directions in which the forces act is known.
- The magnitude of the forces can be calculated.
- When the forces are not in balance, a resultant or resulting force will exist.
- This is the combined force of all of the forces acting on the aircraft. In all types of flying, flight calculations are based on the magnitude and direction of the four forces.

Figure 2-13. Forces in action during flight.

Figure 2-14. Resultant of lift and drag.

8.2.5 GENERATION OF LIFT AND DRAG

- As stated, lift is the force that pushes the aircraft upwards. The *Angle of Attack (AOA)* is the angle between the relative wind and the chord line of the wing.

- Within limits, lift can be increased by increasing the angle of attack, wing area, velocity, density of the air, or by changing the shape or size of the airfoil.

- When the force of lift on an aircraft's wing equals the force of gravity, the aircraft maintains level flight.

- Drag is the force that opposes the thrust created to move the aircraft forward. Induced drag is an inevitable consequence of the creation of lift.

- It is caused by the downwash at the trailing edge of the wing meeting the air that flows underneath the wing and the general movement of the vortices created by this towards the wingtip where wingtip vortices are created.

- The greater the lift, the greater the pressure differential between these two flows of air which increases the induced drag.

- Since lift is able to be increased by increasing angle of attack, so too is induced drag.

- A discussion of the various types of drag and their production occurs after an examination of angle of attack.

✓ DRAG

- There are many different types of drag. The most common are *parasite drag*, *induced drag* and *wave drag*. Additionally, there are three types of parasite drag:

- 1. *Form drag* which results from the aerodynamic resistance to motion due to the shape of the aircraft.
- 2. *Skin friction drag* which is related to the smoothness (or roughness) of the aircraft surfaces.
- 3. *Interference drag* which occurs where surfaces with different flow characteristics meet (e.g. wing and fuselage). Briefly, induced drag is a secondary effect of the production of lift and wave drag comes into play when shock waves develop close to the surface of the aircraft during transonic or supersonic flight. In the following paragraphs, each of these types of drag will be explained in more detail.