AERODYNAMICS

Okay, what is a constant speed propeller?

THE ATMOSPHERE: The atmosphere or air is a layer of gases which surround the earth. The greater mass of the earth attracts and holds the gases close to the surface through the force of gravity. These gases form a fluid with mass or weight. Since air is a gas it can be compressed or expanded and, when compressed, it becomes more dense. A high column of air will be heavier, under more pressure, and thus more dense than a lower column. Given a constant temperature, doubling air pressure will double the density. Air at a lower temperature has higher density and dry air is more dense than moist air.

As an aircraft gains altitude, air pressure and density decrease. Conversely, air is colder and thus more dense as altitude increases but the rapid drop in pressure offsets the change in temperature, so density usually decreases with altitude. Reduced density affects aircraft performance by reducing the power of the engine as it takes in less air, by making the propeller less efficient, and by reducing lift.

AN AIRFOIL (AEROFOIL IN BRITISH ENGLISH): A foil is a surface designed to maximize lift in a fluid while minimizing drag when there is relative motion between the foil and the fluid. Lift is the force generated perpendicular to the fluid flow or the motion of the foil while drag is the force generated in the direction of the flow of fluid or opposite to the motion of the foil. A flat plate set at an angle to the flow of a fluid will deflect the flow and create lift and drag. If you put your hand out the window of a rapidly moving car and hold the palm at an angle into the wind, you will feel the lift and also the drag.

A curved airfoil with a concave lower surface which is often used in kites will produce a very large amount of lift but also substantial drag. Achieving an appropriate lift/drag ratio for the planned use of the airfoil is important and, accordingly, the minimizing of drag at the design speed is critical to the design of an airfoil. In small and relatively slow general aviation aircraft, the airfoil or wing is curved at the top and nearly flat on the bottom, tapering from a thicker cross section at the front to a very thin cross section at the rear. A typical cross section is shown on the next page.

A small general aviation aircraft will have an L/D ratio of about 7/1 and, without power, will glide forward about seven feet for every foot lost in altitude. Some jet airliners with a more efficient wing have an L/D ratio of 15/1 but at a higher speed. A modern sailplane may have an L/D ratio of 30/1 or greater but the design speed is very low.

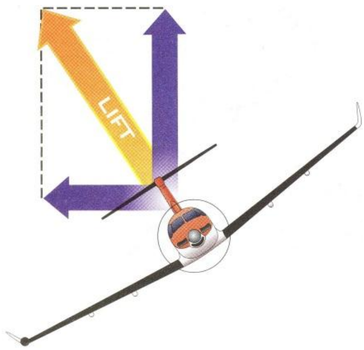
As an airfoil achieves velocity through the air, lift is created by a combination of forces acting on the airfoil. The pressure of the air against the bottom of the airfoil usually provides a portion of the lift. Other sources of lift are explained by Bernoulli's principle and by Sir Isaac Newton's Third Law. Daniel Bernoulli, an 18th century Dutch-Swiss mathematician, showed that high speed fluid flow results in lower pressure on surfaces parallel to the flow. The related Coanda Effect named for Henri Coanda an early 20th century Romanian engineer, states that a fluid stream will follow a surface that curves away. Accordingly, the curved upper surface is designed to accelerate airflow over the top surface and deflect it downwards at the rear. The reduction in pressure at the top of the airfoil caused by the accelerating airflow creates lift. In addition, the downward deflection of air, following Newton's Third Law, which states that for every action there is an equal and opposite reaction, results in a matching upward force on the airfoil. The relative amounts of lift generated by these factors vary with airfoil design and with the speed and purpose of the aircraft for which it is designed.

Manifold pressure is the absolute pressure of the fuel/air mixture within the intake manifold which is being delivered to the combustion chamber. Manifold pressure is usually measured in inches of mercury. This pressure is directly related to the amount of power being produced by the engine. When the throttle setting is increased, more fuel and air will flow to the engine and manifold pressure will increase correspondingly.

CONTROL SURFACES: The primary control surfaces are the **ailerons, the rudder and the elevator (or stabilator)**. They are the control systems which are required to safely control an aircraft during flight.

The **Ailerons** are attached to the outboard trailing edge of each wing and are linked so that they move in opposite directions. When one aileron is up, the other is down. The use of the terms “up” or “down” are in relation to the sitting position of the pilot and not to the ground. This is to avoid confusion in steep banked turns and in more advanced maneuvers such as inverted flying. Moving the stick or control yoke to the right causes the right aileron to deflect upward and the left aileron to deflect downward. The upward deflection of the right aileron decreases the camber of the right wing reducing the lift of that wing while the corresponding downward deflection of the left aileron increases the camber of the left wing thereby increasing its lift. As a result, the aircraft will roll or bank to the right along its *longitudinal axis*. Since the left aileron is now providing more lift, it is also causing more drag which will tend to “yaw” the nose of the aircraft to the left, away from the turn.

The aircraft turns because, as it rolls or banks, total lifting force becomes the resultant of two components as shown in the diagram to the right. The vertical lift component continues to act perpendicular to the earth and opposes gravity. The horizontal lift component acts parallel to the earth’s surface to oppose inertia or centrifugal force. These two lift components act at right angles to each other, causing the resultant total lifting force to act perpendicular to the banked angle of the aircraft thereby causing the aircraft to turn in the direction of the bank. Unlike a boat, the rudder is not often used to turn an aircraft except for making miner corrections to the compass heading.



The **Rudder** is a moveable vertical surface hinged to the trailing edge of the vertical stabilizer or fin at the rear of the aircraft and rotates the aircraft around its *vertical axis*. The rudder is manipulated with foot pedals; pushing forward with the left foot moves the rudder to the left (left rudder) and vice versa. Often the aircraft’s brakes, used when taxiing on the ground, are at the top of the same foot pedals. The rudder is used to counteract the adverse “yaw” described above, where the lift created by the left aileron is also causing increased drag and moving the nose to the left, around the vertical axis, and away from the turn. If the use of the rudder, in this case tilted to the right (right rudder), is coordinated with the movement of the ailerons; the yaw will be prevented. This is referred to as a coordinated turn. Most aircraft have either a turn and slip indicator or a turn coordinator each of which contains an inclinometer which is a liquid filled glass tube with a ball inside. A skillfully coordinated turn will keep the ball centered in the tube.

The aircraft is also affected by several forces which create a tendency to turn to the left, assuming a clockwise rotation as seen from the cockpit, and right rudder is used to correct this. The effect is especially pronounced during the takeoff run. The forces vary in effect depending on the aircraft size, design, type of engine, horsepower, propeller, RPM, and type and condition of the ground surface. They include the torque reaction from the engine and propeller, the corkscrewing effect of the slipstream and its effect on the airframe and on the rudder, the gyroscopic action of the propeller, and the asymmetric loading of the propeller (P factor).