THE PHYSICS OF FLIGHT

About the author

This series of articles relates the physics of flight to model airplanes. Model airplanes fly much like the full scale airplanes yet there are differences caused by "scale". These articles attempt to relate model flight characteristics to "physics" on a smaller scale. An understanding of these principles will make model aircraft building and flying more enjoyable.

This is a on-going series dependent on the whims (available time) of the author.

Dave Pickenpaugh wrote these articles for publication in TORKSTALK, the newsletter of the Ohio Radio Kontrol Society. Portions of the articles were picked up by a national magazine and published there.

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Chapter I - The Four Forces of Flight

By Dave Pickenpaugh

When an airplane is in stabilized flight, there are four forces that are acting on it: *lift, weight, thrust*, and *drag*. Lift acts in the opposite direction of weight, and thrust from the propeller acts in the direction opposite to drag. Unless one of these forces changes, the airplane will continue in the same direction and at the same speed.

LIFT

Lift is a force exerted primarily by the wings, but some aircraft may have smaller amounts of lift produced by the fuselage or other components. Lift from the wings is generated by the airfoil shape of the wing being moved through the air (or the air being moved past the wing as in a wind tunnel). The direction and speed of the wind over the wing is called the relative wind. Ground speed should not be confused with relative wind speed, as the only important factor for lift is the speed of the air over the wing.

Lift can be increased by increasing the angle of attack of the wing, by increasing the thrust from the engine, or by increasing both. Angle of attack is the angle between the relative wind and the chord of the wing. At some critical angle of attack (which is constant for each airfoil type), lift begins to reduce due to the airflow over the wing becoming turbulent. This disruption in smooth airflow quickly reduces lift and results in a partial or full stall. Many of us have either experienced or seen the effects of an excessively high angle of attack combined with slow air speed when coming in for landing. All of a sudden one wing drops and the airplane "snaps over", often with disastrous results.

WEIGHT

Weight acts in the direction of gravity, regardless of the attitude of the airplane. When an airplane is in upright and stable flight it is easy to visualize how weight and lift counteract each other. But as that airplane rolls to inverted, you have to understand that weight continues to act in the direction of gravity, and the pilot has to change how lift is generated to always counteract the downward direction and effect of gravity.

THRUST

Thrust is generated by a power source such as the propeller, the ducted fan, or the jet engine. Newton's Third Law states that for every action there is an equal and opposite reaction. When flying airplanes this means that the propeller takes a large mass of air and moves it rearward with considerable force. The "equal and opposite" force is what moves the airplane forward, and is called thrust. With fixed pitch propellers, the faster the engines spins, the more thrust generated by the propeller. The propeller blades are actually air foils, and generate "lift" in the forward direction of the airplane.

DRAG

Drag can be thought of as the "friction" of trying to move the airplane through the air. Drag acts parallel to and in the same direction as the relative wind. There are two types of drag acting on an airplane -- *parasite drag* and *induced drag*.

Parasite drag is composed of several components. *Form drag* is caused by things sticking out of the airplane such as radio antennas, the shape of the wings and fuselage, switches, landing gear, flying wires, etc. *Skin friction drag* is attributed to the minor imperfections in the surface finish of the aircraft. Smoother finishes have less drag. *Airflow interference drag* is caused by air piling up at the junction between airplane components such as where the wings or empennage meet the fuselage. This disruption in the smooth flow of air over the airplane results in drag that acts against thrust, and slows the aircraft. Parasite drag increases as the square of the airspeed increase. Doubling the airspeed increases parasitic drag four times, tripling the airspeed increases the parasitic drag nine times!

Induced drag is a concept that is a little more difficult to understand. Remember that lift acts perpendicular to the wing span and to relative wind. This means that as the angle of attack increases, the lift vector actually begins to lean "backward" toward the rear of the aircraft. So lift is now acting in an upward direction <u>and</u> in a rearward direction. This rearward component of lift is called induced drag. This force is at its greatest when the angle of attack is highest, usually in low speed attitudes such as take-offs and landings. As airspeed increases, the pilot is able to trade some of the need for lift for increased speed. As the speed increases and the angle of attack is reduced, induced drag is reduced.

Another component of induced drag is the turbulent vortices that develop at each wing tip. Since the pressure on the bottom of the wing is greater than the pressure on the top, air has a tendency to move around the wing tip from bottom to top. This results in a spiraling area of turbulence that is called a tip vortex, and can be visualized as a miniature tornado. The strength of these vortices (and induced drag) increases radically at higher angles of attack, so the slower the airplane flies induced drag increases dramatically.

SUMMARY

Although there are only four forces acting on an airplane in stabilized flight, the interaction among those forces is fairly complex. The pilot of the full-scale aircraft has one advantage of the R/C pilot in that he gets a "seat of the pants" feel while flying.