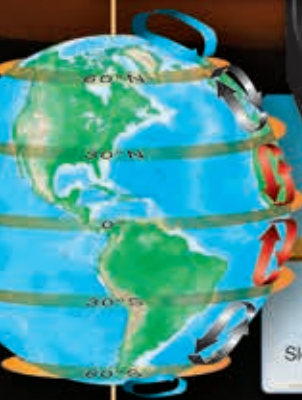


Pilot's Handbook of Aeronautical Knowledge



U.S. Department of Transportation
Federal Aviation Administration



Type of Sign	Action or Purpose	Type of Sign
A 4-22	Classified Runway Head Positioning System (RHS) 4-22 or TSV A	
26-8	Runway/Runway Intersection	
B 4-22P	Runway/Runway Intersection	
C ILS	Runway Approach Head Positioning System (RHS) 4-22 or TSV B	
B	Runway Location	
22	Runway Location	
4	Runway Distance Remaining	

Power On Stall

Slow to lift-off speed, maintain altitude

Set takeoff power, raise nose

When stall occurs, reduce angle of attack and add full power.

As flying speed returns, stop descent and establish a climb.

Climb at V_Y , raise landing gear and remaining flaps, trim

Level off at desired altitude, set power, and trim

87 percent, depending on how much the propeller “slips.” Propeller slip is the difference between the geometric pitch of the propeller and its effective pitch. [Figure 5-45] Geometric pitch is the theoretical distance a propeller should advance in one revolution; effective pitch is the distance it actually advances. Thus, geometric or theoretical pitch is based on no slippage, but actual or effective pitch includes propeller slippage in the air.

The reason a propeller is “twisted” is that the outer parts of the propeller blades, like all things that turn about a central point, travel faster than the portions near the hub. [Figure 5-46] If the blades had the same geometric pitch throughout their lengths, portions near the hub could have negative AOAs while the propeller tips would be stalled at cruise speed. Twisting or variations in the geometric pitch of the blades permits the propeller to operate with a relatively constant AOA along its length when in cruising flight. Propeller blades are twisted to change the blade angle in proportion to the differences in speed of rotation along the length of the propeller, keeping thrust more nearly equalized along this length.

Usually 1° to 4° provides the most efficient lift/drag ratio, but in flight the propeller AOA of a fixed-pitch propeller varies—normally from 0° to 15° . This variation is caused by changes in the relative airstream, which in turn results from changes in aircraft speed. Thus, propeller AOA is the product of two motions: propeller rotation about its axis and its forward motion.

A constant-speed propeller automatically keeps the blade angle adjusted for maximum efficiency for most conditions encountered in flight. During takeoff, when maximum power and thrust are required, the constant-speed propeller is at a low propeller blade angle or pitch. The low blade angle keeps the AOA small and efficient with respect to the relative wind. At the same time, it allows the propeller to handle a smaller mass of air per revolution. This light load allows the engine to turn at high rpm and to convert the maximum amount of fuel into heat energy in a given time. The high rpm also creates maximum thrust because, although the mass of air handled per revolution is small, the rpm and slipstream velocity are

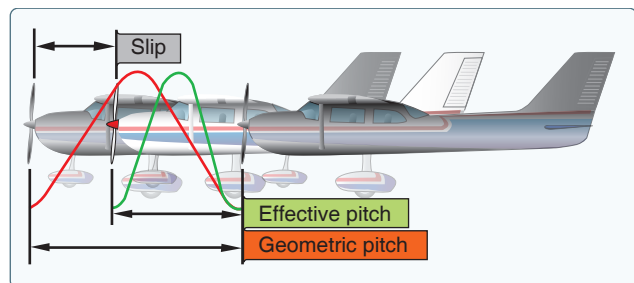


Figure 5-45. Propeller slippage.

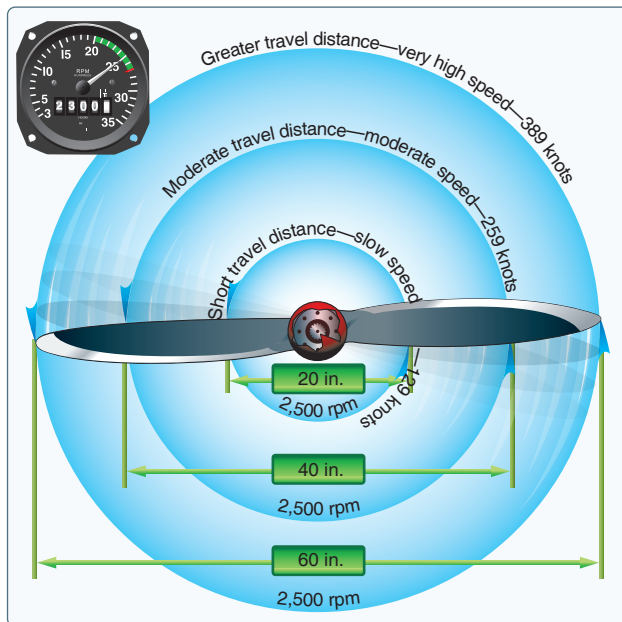


Figure 5-46. Propeller tips travel faster than the hub.

high, and with the low aircraft speed, there is maximum thrust. After liftoff, as the speed of the aircraft increases, the constant-speed propeller automatically changes to a higher angle (or pitch). Again, the higher blade angle keeps the AOA small and efficient with respect to the relative wind. The higher blade angle increases the mass of air handled per revolution. This decreases the engine rpm, reducing fuel consumption and engine wear, and keeps thrust at a maximum.

After the takeoff climb is established in an aircraft having a controllable-pitch propeller, the pilot reduces the power output of the engine to climb power by first decreasing the manifold pressure and then increasing the blade angle to lower the rpm.

At cruising altitude, when the aircraft is in level flight and less power is required than is used in takeoff or climb, the pilot again reduces engine power by reducing the manifold pressure and then increasing the blade angle to decrease the rpm. Again, this provides a torque requirement to match the reduced engine power. Although the mass of air handled per revolution is greater, it is more than offset by a decrease in slipstream velocity and an increase in airspeed. The AOA is still small because the blade angle has been increased with an increase in airspeed.

Torque and P-Factor

To the pilot, “torque” (the left turning tendency of the airplane) is made up of four elements that cause or produce a twisting or rotating motion around at least one of the airplane’s three axes. These four elements are:

1. Torque reaction from engine and propeller

2. Corkscrewing effect of the slipstream
3. Gyroscopic action of the propeller
4. Asymmetric loading of the propeller (P-factor)

Torque Reaction

Torque reaction involves Newton's Third Law of Physics—for every action, there is an equal and opposite reaction. As applied to the aircraft, this means that as the internal engine parts and propeller are revolving in one direction, an equal force is trying to rotate the aircraft in the opposite direction. [Figure 5-47]

When the aircraft is airborne, this force is acting around the longitudinal axis, tending to make the aircraft roll. To compensate for roll tendency, some of the older aircraft are rigged in a manner to create more lift on the wing that is being forced downward. The more modern aircraft are designed with the engine offset to counteract this effect of torque.

NOTE: Most United States built aircraft engines rotate the propeller clockwise, as viewed from the pilot's seat. The discussion here is with reference to those engines.

Generally, the compensating factors are permanently set so that they compensate for this force at cruising speed, since most of the aircraft's operating time is at that speed. However, aileron trim tabs permit further adjustment for other speeds. When the aircraft's wheels are on the ground during the takeoff roll, an additional turning moment around the vertical axis is induced by torque reaction. As the left side of the aircraft is being forced down by torque reaction, more weight is being placed on the left main landing gear. This results in more ground friction, or drag, on the left tire than on the right, causing a further turning moment to the left. The magnitude of this moment is dependent on many variables. Some of these variables are:

1. Size and horsepower of engine
2. Size of propeller and the rpm
3. Size of the aircraft
4. Condition of the ground surface

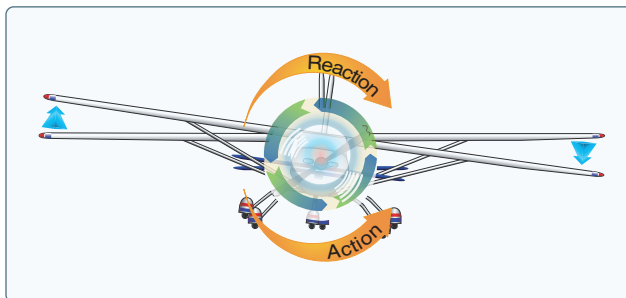


Figure 5-47. Torque reaction.

This yawing moment on the takeoff roll is corrected by the pilot's proper use of the rudder or rudder trim.

Corkscrew Effect

The high-speed rotation of an aircraft propeller gives a corkscrew or spiraling rotation to the slipstream. At high propeller speeds and low forward speed (as in the takeoffs and approaches to power-on stalls), this spiraling rotation is very compact and exerts a strong sideward force on the aircraft's vertical tail surface. [Figure 5-48]

When this spiraling slipstream strikes the vertical fin, it causes a yawing moment about the aircraft's vertical axis. The more compact the spiral, the more prominent this force is. As the forward speed increases, however, the spiral elongates and becomes less effective. The corkscrew flow of the slipstream also causes a rolling moment around the longitudinal axis.

Note that this rolling moment caused by the corkscrew flow of the slipstream is to the right, while the yawing moment caused by torque reaction is to the left—in effect one may be counteracting the other. However, these forces vary greatly and it is the pilot's responsibility to apply proper corrective action by use of the flight controls at all times. These forces must be counteracted regardless of which is the most prominent at the time.

Gyroscopic Action

Before the gyroscopic effects of the propeller can be understood, it is necessary to understand the basic principle of a gyroscope. All practical applications of the gyroscope are based upon two fundamental properties of gyroscopic action: rigidity in space and precession. The one of interest for this discussion is precession.

Precession is the resultant action, or deflection, of a spinning rotor when a deflecting force is applied to its rim. As can be seen in Figure 5-49, when a force is applied, the resulting force takes effect 90° ahead of and in the direction of rotation. The rotating propeller of an airplane makes a very good

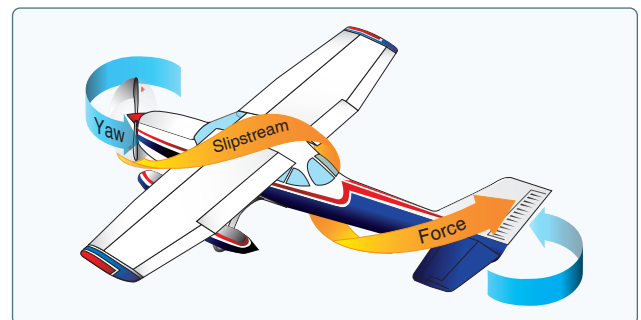


Figure 5-48. Corkscrewing slipstream.