Types of Propeller Forces and Impact on Flight
07/19/08

Having problems with your takeoffs? Is your takeoff roll all over the place? Does your tail dragger nose over or ground loop before breaking ground? Does your climb-out always veer to the left? Your problem might be with a lack of understanding of what effects your prop has on your plane and the corrections that need to be made to neutralize these effects.

The following is a discussion of the various forces that act on a propeller, some of their adverse consequences on flight, and the control surface movements that are required to counter the forces. Understanding your propeller should allow you to modify your takeoff techniques and improve your takeoff performance. For discussions that follow, the propeller will be assumed to rotate clockwise as viewed from the cockpit.

1. Torque:

The prop rotating clockwise imparts a torque to the air moving thru the prop. From Newton's third law of motion, the air in turn exerts an equal and opposite torque to the airframe. As a result, the airframe will tend to rotate counterclockwise along the longitudinal (roll) axis of the airframe.

In flight, most airframes are designed to counter this rotation at the designed cruising speed. At other speeds, aileron trim is required to counter the rotation caused by torque, adding credence to the adage that you can only trim a plane at one speed.

During the takeoff roll, the tendency to rotate the airframe counterclockwise will produce a greater force on the left landing gear than on the right landing gear. This greater force increases the drag of the left gear causing the plane to turn left while on the ground. Right rudder is required to counter the tendency to turn left and to keep the plane straight on the runway.

2. Airflow "Corkscrew" Around Airframe:

The rotating of the propeller together with the forward speed of the plane causes the air to corkscrew in a clockwise direction around the airframe. This "corkscrewing" force is strongest at combinations of high propeller speeds and low plane speeds such as encountered during takeoff and approaches to stall. At higher plane speeds, the

spiral elongates and minimizes the effects on the airframe. The "corkscrew" affects the plane in 2 ways:

a. It exerts a strong sideways force on the vertical stab and rudder causing the plane to yaw left around the vertical (yaw) axis.
b. It exerts a clockwise rolling moment around the longitudinal (roll) axis causing the plane to roll to the right.

The impact on the plane is a combination of the 2 effects. Depending on airframe design, the effects may cancel requiring no control surface correction. In a lot of cases, right rudder is required to correct for the tendency to turn left during takeoff. Many planes will perform a stall turn better to the left than to the right because of the "corkscrewing" airflow.

3. <u>Gyroscopic Effects</u>:

A rotating prop acts like a gyroscope. If you try to deflect the prop out of the plane of rotation, a resultant force will appear on the prop disk 90 degrees from the point of application of the deflecting force in the direction of rotation. For example, if you push the prop disk at the top, a force will be produced at the right of the disk pushing the nose of the plane to the left. Similarly, if you push from the left of the disk, a force will be produced at the top of the disk pushing the nose of the plane down.

The gyroscopic effects in general can cause a yawing moment, a pitching moment, or a combination of the two depending on where the deflection force is applied.

A good example of this effect is a tail dragger on takeoff. When the tail rises, the top of the prop disk is forced forward. This results in a force at the right of the prop disk which moves the nose left. Right rudder is required to counter this resultant yaw force.

Note that gyroscopic effects are dependent on speed of application of control system movement, so lift the tail slowly on takeoff roll. Less rudder will be required to keep the takeoff roll straight as a result. If you correct with too much right rudder during takeoff, you will produce a gyroscopic force which pushes the nose down resulting in the plane "nosing over" unless up elevator correction is applied rather quickly.

4. <u>P-Factor</u>:
P factor is the asymmetric loading of a propeller at high angles of attack due to the propeller blades seeing different velocities of air over the prop disk. For positive angle of attack, the downward moving blade sees a higher velocity of air over the blade than the upward moving blade. The downward moving blade produces more lift (thrust) than the upward moving blade. The resultant asymmetric force pushes the nose of the plane to the left.

The effects of P factor are more noticeable when the airspeed is low, angles of attack are high, and the propeller is rotating fast.

You normally see this effect during climb-out after takeoff. If right rudder is not applied after the plane breaks ground, the plane will veer left during the climb-out.

As you can see, the effects of the propeller on flight are considerable. If you are able to counter these effects with timely control surface movements, your flights will be smoother and you will be on your way to becoming an accomplished pilot.

May the Force (propeller) be with you!

Steve Grabowski