GROUNDSchool...

Skill Level: **Medium** Category: **Aerodynamics**

Instructor...**Greg Trainer**

..."Swinging On Takeoff"

We often hear of pilots revealing stories of how their aircraft seem to be possessed on takeoff by violently yawing to one side or the other. Perhaps it has happened to you while flying your favorite simulator? As with all aviation stories, there are a number of explanations to account for these tales, so hold off on calling in a divine influence for the moment, because in this article we are going to look at why aircraft decide to "swing" on takeoff!

Intro

Every pilot has experienced swinging on takeoff at one stage in his or her aviation careers. As we are soon to discover, the prominent causes of this swinging can be largely attributed to the propeller of our beloved aircraft… sorry to all the jet lovers out there!

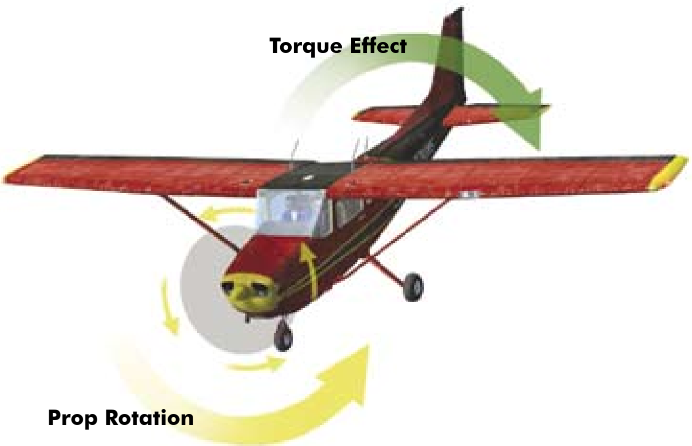
In our discussion today, we are going to assume our propeller rotates clockwise from the pilot's perspective, as is the case with most modern prop aircraft today. However, for those of us flying older British aircraft, we might find the propeller actually rotates anti-clockwise from the pilot's perspective and will need to apply the change to the effects we discuss.

There are 5 factors that determine if our aircraft is going to yaw on takeoff, so let's take a look at these now.

Torque

If we can imagine the propeller spinning on our aircraft… if we could somehow stop it from rotating, then what would happen? Most likely, because the engine is still operating, it and the aircraft which it is attached to will want to rotate around in the opposite direction. It is that opposite rotation of the aircraft that we call the torque effect.

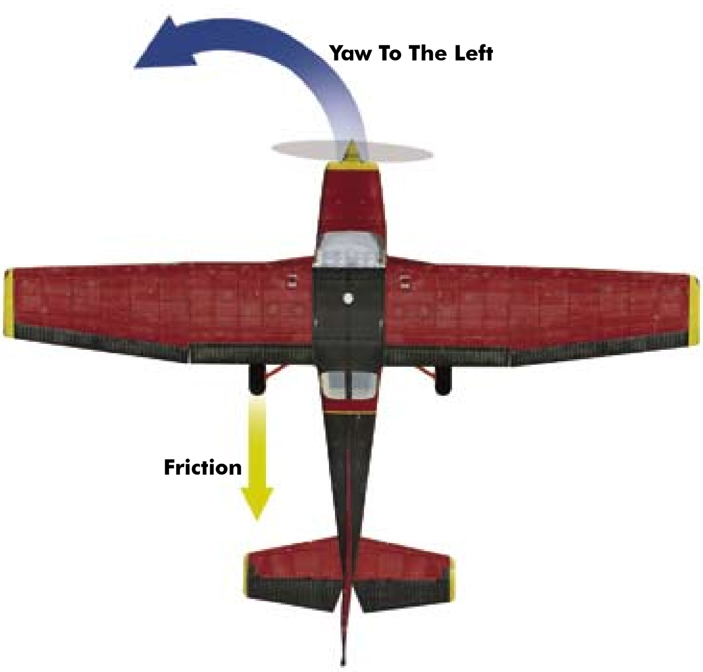
Now in real terms, no-one is going to hop out of the aircraft and stop the propeller from turning and cause our torque effect, but there is drag experienced on the propeller blades which do impart a 'slowing down' motion and alas, we have our torque effect.



"AIRCRAFT WILL ROTATE OPPOSITE TO PROPELLER ROTATION"

At high power settings and low airspeed (takeoff), this torque effect causes the aircraft to want to roll opposite to the rotation of the propeller. Of course it cannot do that with the ground preventing the motion, however, the left wheel is now experiencing a more downward force into the surface and hence, greater friction which essentially 'digs' into the ground and causes the aircraft to yaw to the left.

Torque effect can be easily compensated for during takeoff by applying opposite rudder to the direction of the yaw, if the aircraft has enough rudder authority to do so.



"WHEEL FRICTION CAUSES AIRCRAFT TO YAW"

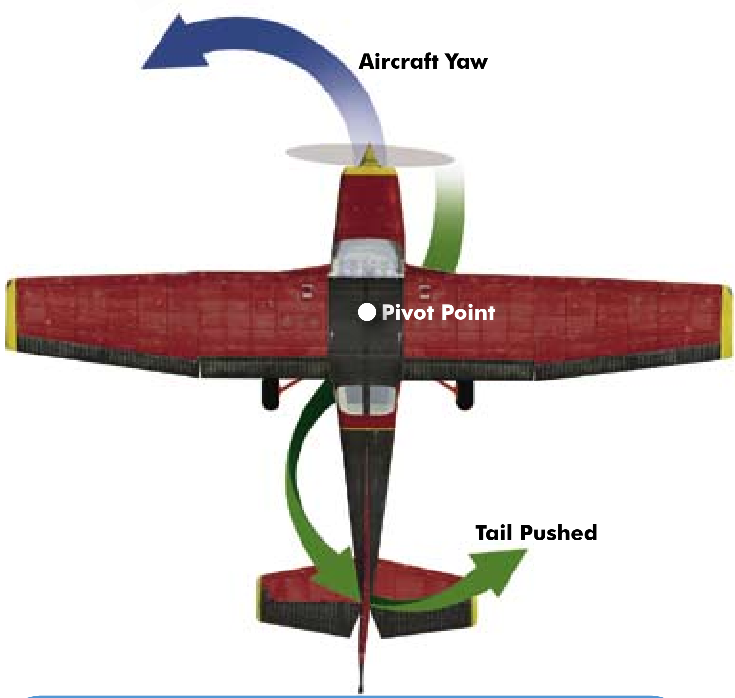
Torque effect primarily depends on the amount of power developed by the engine. The more power an engine has, the more torque effect the aircraft will experience - a rule that so many pilots found out rather quickly while flying the extremely powerful Spitfire aircraft during the war. Because the engine was so powerful, the power setting for takeoff had to be restricted so as to prevent aircraft from yawing violently around in circles while on the takeoff run.

Slipstream

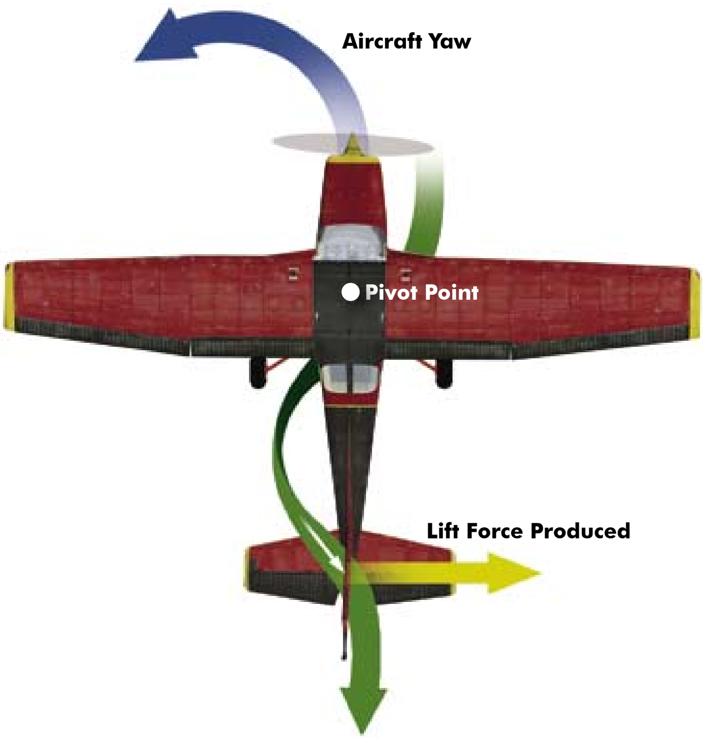
The slipstream produced by the propeller can be considered to be very beneficial, allowing the control surfaces to experience greater effectiveness by the increased airflow experienced at high power settings. One thing to consider though is that the slipstream is not only **"blowing"** straight back past the aircraft, but also spiraling past it due to the rotational mass of the propeller.

"SPIRALING SLIPSTREAM UNDER AND AROUND AIRCRAFT"

If we can visualise the airflow extending from the propeller and then spiraling under and around the fuselage then striking the vertical fin on one side, this is sure to cause a reaction on the aircraft.



"THE NOSE WILL YAW AS THE TAIL IS PUSHED BY THE WIND"



"A LIFT FORCE WILL CAUSE THE TAIL TO BE PULLED AND THE NOSE TO YAW"

One reaction is to push the tail in the direction of the airflow and cause the nose of the aircraft to yaw in the opposite direction. Another reaction will be that the angle of the airflow and the vertical fin will actually produce an aerodynamic force (lift) on the leeward side of the fin, causing the nose of the aircraft to yaw around in the opposite direction again. With our standard clockwise propeller, this causes our aircraft to yaw to the left.

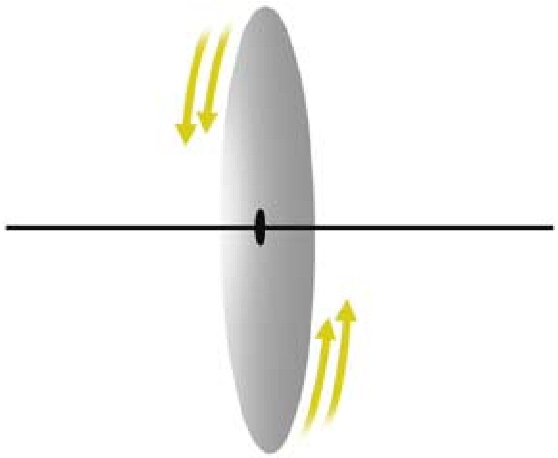
The slipstream effect is at its greatest when the aircraft is under high RPM and low airspeed conditions. As one would easily understand, this is the normal condition most aircraft experience when they are on their takeoff run. With the increase in airspeed, the slipstream becomes more elongated and the sideways forces acting on the aircraft diminish.

Some aircraft designs have compensated for this effect by offsetting the vertical fin, so that it lies away from the slipstream. If an aircraft does experience this effect on takeoff, applying opposite rudder can easily compensate it.

Gyroscopic effect

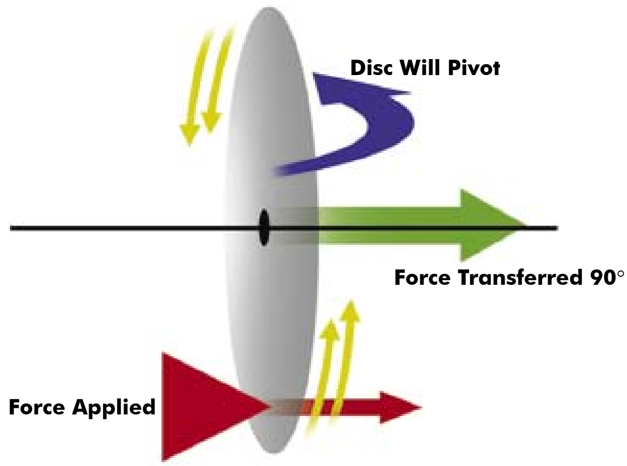
The gyroscopic effect is best known among tail dragger pilots and their aircraft, as it only tends to be a problem associated with them. However for every pilot it is a very good principle to understand as it does affect other situations apart from the takeoff.

The effect relies on what we call gyroscopic precession. Which states that if a force is exerted on a rotating mass, then that force will be transferred 90 degrees in the plane of rotation. Quite a lot to take in at this stage, but let's look at it simply.



"OUR IMAGINARY SPINNING DISC"

Lets imagine a spinning disc on its side. Without any outside influences exerted upon it, this disc is quite happy to continue spinning on its current axis and direction.



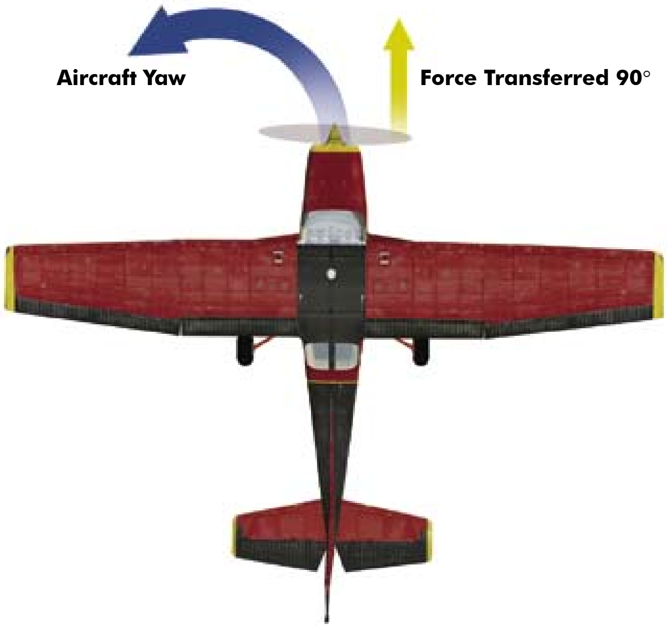
"APPLIED FORCE IS TRANSFERRED AT 90 DEGREES TO THE DIRECTION OF ROTATION"

Further using the imagination, what do you think would happen if we exerted a force on the top part of this spinning disc? Nine times out of ten, the answer would be that it would simply fall over. Not true. Given the gyroscopic precession statement, the force that we have exerted would be transferred ninety degrees in the direction of rotation…and thus the disc would actually turn or pivot!

Quite amazing wouldn't you say, but where does the aircraft swinging on takeoff happen to fall into the equation? Let's now look at a typical takeoff situation in a tail-dragger.

Gyroscopic effect will only occur when an aircraft's attitude is changed, as their needs to be a force applied to the propeller in order for it to occur. Understandably a tail-dragger requires that the tail wheel itself be lifted off the ground prior to takeoff, so that the takeoff run can be more efficient. This requires the pilot to lower the nose of the aircraft while on the takeoff run. If we think about the force this is applying to the propeller, the gyroscopic effect is sure to take place.

"NOSE LOWERED ON TAKEOFF RUN, FORCE IS APPLIED TO PROPELLER"



"FORCE IS TRANSFERRED CAUSING THE AIRCRAFT TO YAW"

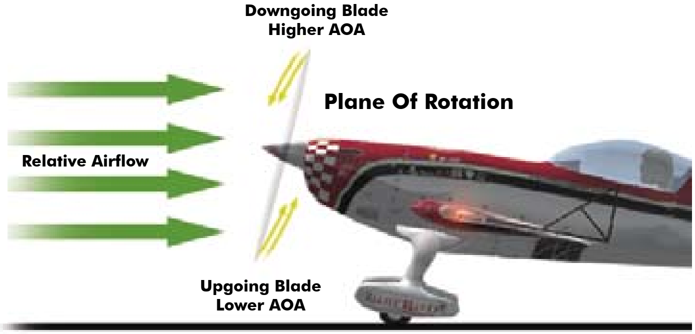
By lowering the nose, a forward force acts on the top surface of the propeller. As we discovered with the spinning disc, this force is transferred through 90 degrees in the plane of rotation. Hence instead of the forward force acting on the top surface of the propeller, the force is now going to act on one side of the propeller. Depending on the direction of rotation, the force will cause the aircraft to yaw one-way or the other. With our standard clockwise rotating propellers, this causes a yaw to the left.

Applying opposite rudder can counteract this like other effects we have discussed so far. If you have ever watched a tail-dragger during takeoff, you would have surely noticed that the rudder is needed and used 100% of the time to keep the aircraft travelling in a straight direction.

Asymmetric blade effect

This is another effect that is mainly predominant in tail-wheel aircraft but can be experienced in other aircraft depending on their structure. Most people refer to asymmetric blade effect as **"P Factor"**.

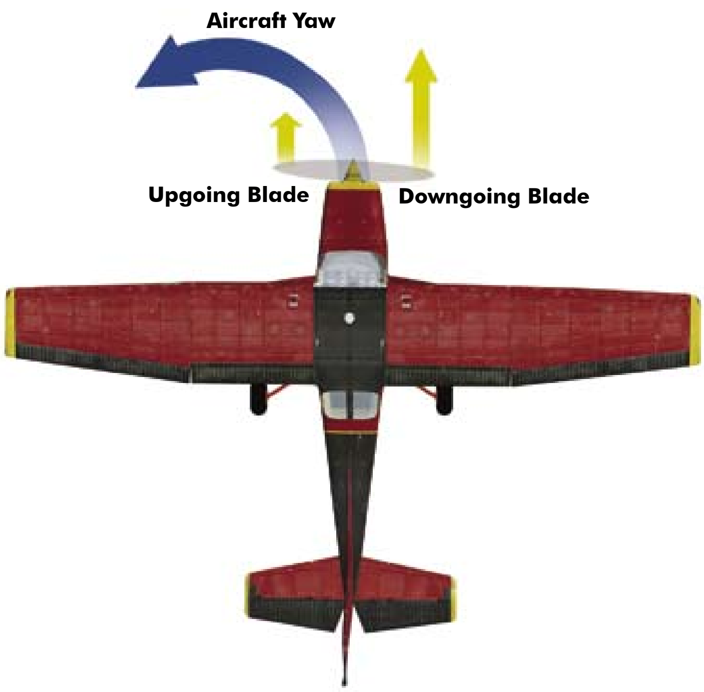
To put it simply, asymmetric blade effect is the result of the down-travelling blade of a propeller having a larger angle of attack than the up going blade. This only occurs when the relative airflow is striking the propeller blades at a non-perpendicular angle.



"NON-PERPENDICULAR AIR FLOW CAUSES A HIGHER ANGLE OF ATTACK ON THE DOWN-TRAVELLING BLADE"

The down-travelling blade, due to its high angle of attack, will be producing more thrust than its counterpart. The result is a larger amount of thrust produced on one side of the propeller disc.

If we look at the takeoff situation, especially in a tail wheel aircraft during the first phase of the takeoff run, the propeller disc will be experiencing a relative airflow that is not perpendicular and thus gives the greatest difference in blade angle of attacks and thrust produced. However once the nose has been lowered on the takeoff run, the asymmetric blade effect is reduced due to the relative airflow now acting at a more perpendicular angle than before.



"THRUST DIFFERENTIAL - AIRCRAFT WILL YAW"

The asymmetric blade effect due to its differential thrust being experienced on the propeller disc will yaw the aircraft in a set direction. For our standard clockwise rotating propellers, this will yaw the aircraft to the left during the takeoff roll.

Multi engine aircraft have overcome this effect by introducing counter-rotating propellers that each rotate in a different direction. Therefore the thrust differential is evenly spaced along the aircraft and no yawing moment will be produced.

Applying opposite rudder during the takeoff roll can compensate the yawing moment produced by the asymmetric blade effect. Are we starting to notice something in regards to how to counter these effects so far?

Wind

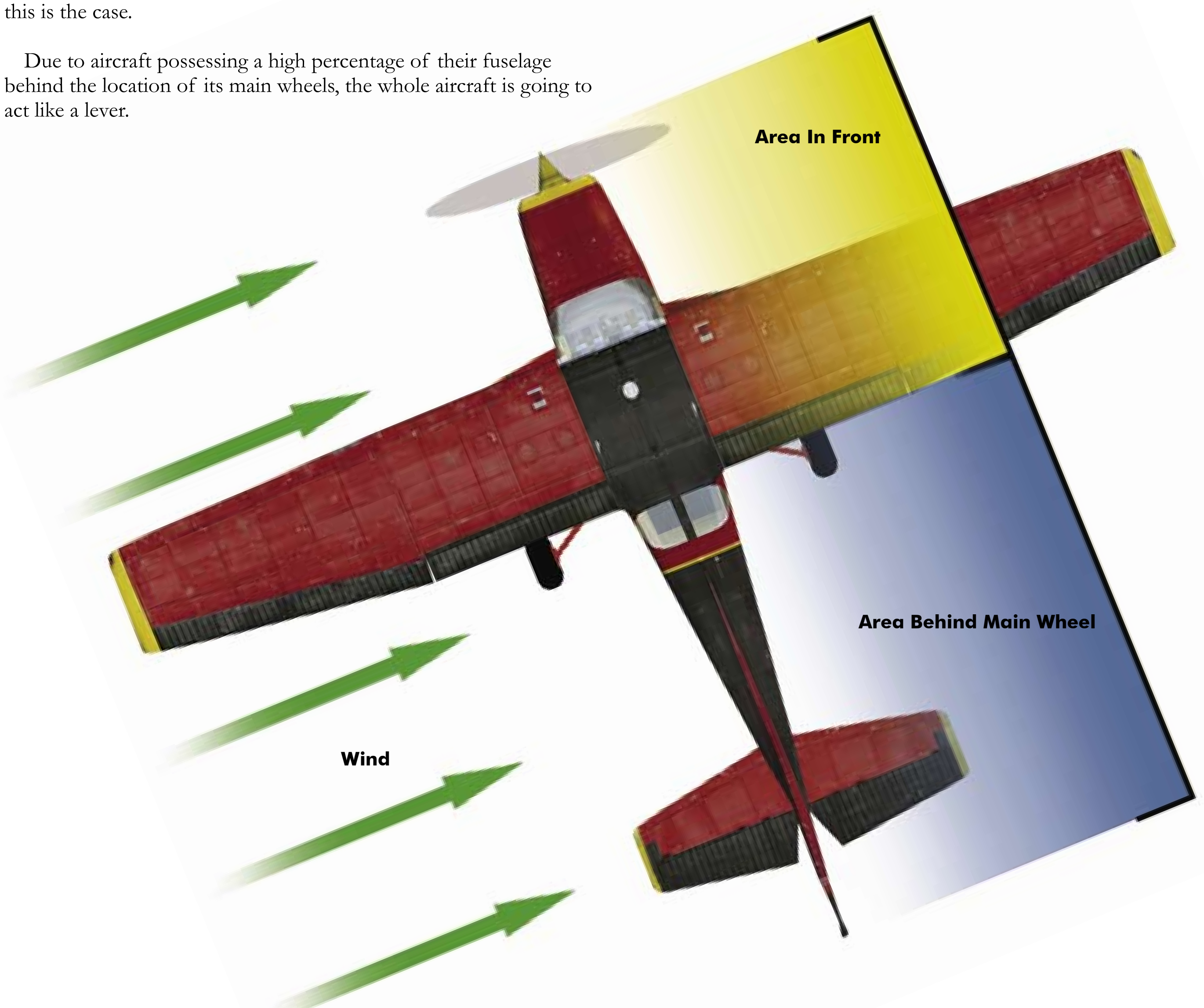
So far we have discussed what factors the propeller plays in the swinging motion on takeoff. Now we will look at the important role wind plays in the takeoff run. In terms of the effect it has on **"swinging"** on takeoff, we will only be interested in the crosswind component.

Most people assume that if an aircraft is experiencing a crosswind, the aircraft will be pushed over or yawed away from the wind. Nothing is further from the truth and we are going to find out why this is the case.

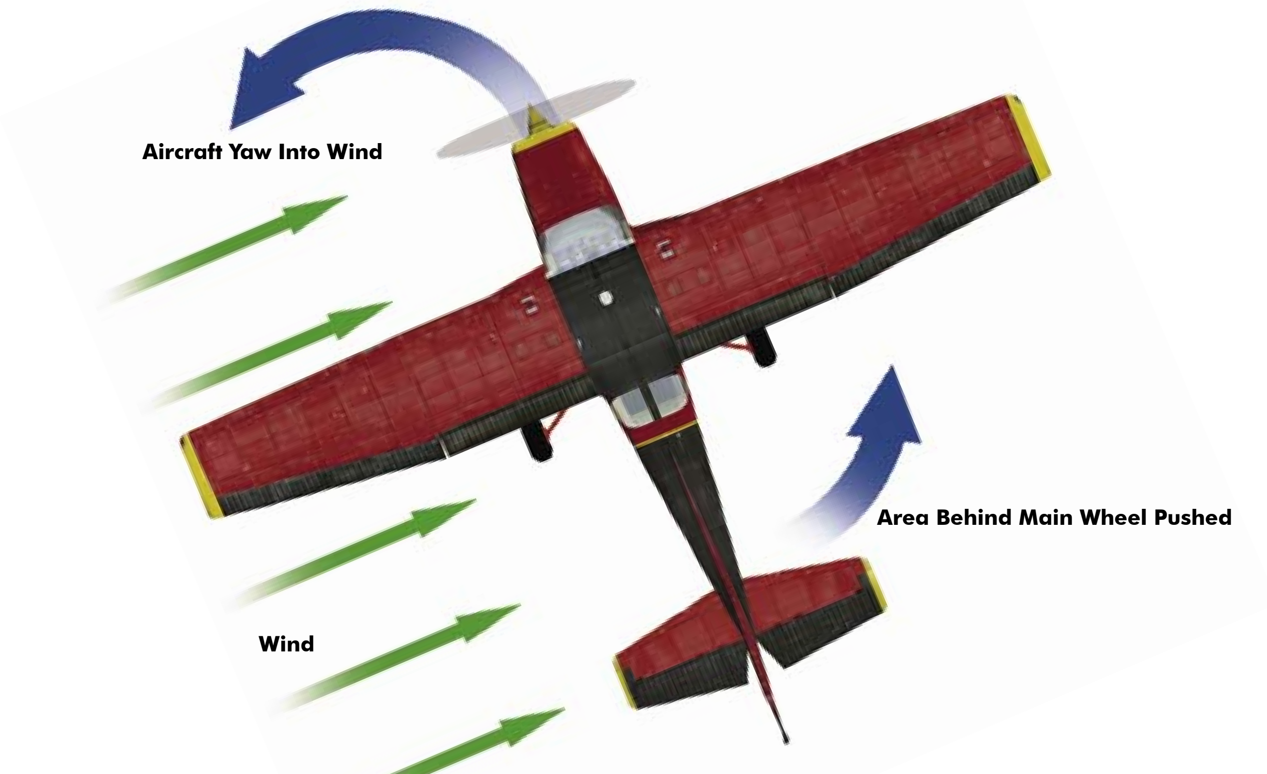
Due to aircraft possessing a high percentage of their fuselage behind the location of its main wheels, the whole aircraft is going to act like a lever.

If we can imagine a wind being experienced from the left hand side of our aircraft, it will want to push the fuselage to the right. As we mentioned before, because a larger percentage of the fuselage is behind the main wheels, then the nose of the aircraft will then yaw to the left... right into the wind! Some people might have heard this referred to as **"weathercocking"**

Different types and models of aircraft react differently to wind situations. For example, a tail wheel aircraft will be more susceptible to weathercocking due to an even greater percentage of fuselage behind the main wheels than normal tricycle undercarriage aircraft.



"LARGE AMOUNT OF AREA BEHIND THE MAIN WHEELS"



"AIRCRAFT YAWS INTO WIND"

What does this mean for our takeoff run? Simple… if we are experiencing a crosswind from the left, then our aircraft will want to yaw to the left and vice versa for a crosswind on the right. Simply using the rudder to keep the aircraft aligned with the runway should be adequate to counteract any weathercocking tendency.

This is the main reason why aircraft have a maximum crosswind component limit. If a crosswind is being experienced which is more than the limit suggests, then the aircraft may not have enough rudder authority or power to counteract the weathercocking tendency and the pilot may not be able to keep the aircraft aligned with the runway.

In practice

In the practical situation, knowing your aircraft and the prevailing conditions are the best defence against **"swinging"** on takeoff. After reading all the theory in regards to the various effects that cause our aircraft to yaw, there is only 1 compensation we can use for any takeoff situation. Rudder, Rudder and Rudder!

As with the examples we have discussed, all effects bar the wind cause our standard aircraft to yaw to the left on takeoff. Therefore we can be rest assured that our right foot is going to get quite a workout when practicing circuits!

In saying that, using the rudder is a very effective tool for keeping an aircraft aligned with the runway on the takeoff run, but the pilot must also be sure that the aircraft has enough rudder authority to do such a job. That is where the maximum crosswind component, power setting, and to an extent, the pilot's own ability comes into play. ✈

"RUDDER, RUDDER AND RUDDER!!"