From The Aeronautics File

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Topic #4: The Downwind Turn.

Introduction

The topic this time is one which is sure to stir up opinions. People I've heard discuss the dreaded "downwind turn" seem evenly divided into two camps. On one hand are those who are sure that their airplane flies differently upwind than downwind, and that when the wind is strong it loses altitude noticeably after a turn downwind. On the other hand are those who think the first group are quite foolish, and that an airplane never feels which direction the wind is blowing. Try as they might, people from the two groups rarely convince each other of their own viewpoint. However as we will see, both groups have good reason to believe what they do.

Inertial Reference Frames

The most common argument by those who worry about turning downwind is that the momentum of the airplane will be small after the turn and that the airplane will feel a tailwind until its momentum has a chance to increase. For example, say the wind speed is equal to the plane's airspeed. It will seem to be hovering when flying upwind and after a 180 degree turn downwind it will surely be affected by the wind blowing to speed it up to twice its airspeed.

This is not a sound argument, however. The way a physicist might explain what's wrong with the above paragraph is that any point of view that moves at a constant speed can be adopted as an "inertial reference frame". In this case if we take the uniformly moving mass of air as our reference frame, the motion of anything within it is the same as if there were no wind. Another example of an inertial reference frame is the earth. It is actually moving through the solar system, or even the universe, at millions of miles per hour. We do not notice this since we compare everything to our local reference frame, the earth. Similarly, an airplane in flight does not notice the ground since the air has no attachment to it. In fact, if you were actually sitting in an airplane and the ground was obscured by clouds, you would not be able to determine the wind direction. Wind direction is something humans use since we live on the ground, so we measure it with respect to the ground.

The R/C flyer is especially at a disadvantage when judging the effect of wind on their airplane since they stand on the ground and so measure everything with respect to the "wrong" reference frame. This causes numerous optical illusions. The only time the two reference frames match is when there is no wind at all. We could actually simulate a calm day when it was windy if we flew a model airplane from the deck of an aircraft carrier. Even a very stiff breeze could be matched by the ship's engines. With the aircraft carrier travelling at the same speed and direction as the wind, the flight of a model airplane from its deck would be the same as if there was no wind. The only way for you (or your airplane) to tell which way the wind was blowing would be to look at the ocean.

Gusts and Gradients

So far I hope I have convinced you that if the wind is blowing evenly, then your airplane cannot feel it or its direction. But this is not the end of the story since no wind ever blows evenly. The two main effects found when the wind blows are gusts and gradients.

Wind creates turbulence and vortices which are felt as gusts. Fortunately these are generally random in nature and their effects tend to cancel each other out over time. For this reason gusts generally do not affect an airplane any differently no matter which direction it is flying. Gusts are still important since on a very windy day your airplane may pitch, roll, or lose altitude without warning. On such a day it's a good idea to land with a slightly higher airspeed than usual.

A second and much more important effect is wind gradient. Wind speed may increase dramatically as you move up from ground level. The biggest increase is in the first few hundred feet, exactly where model airplanes tend to fly. Here we can see that the ground really does have an effect on the wind - by friction it slows down the lower layers of the moving air mass. On a windy day, this altitude related wind gradient can be quite large: 20 knots or more in the space of two or three hundred feet.

For the person convinced that the wind direction is felt by their airplane, wind gradient explains some of the anomalies they might be seeing. For example, imagine taking off with a badly adjusted engine, so that there is barely enough power to gain altitude. After making a turn and heading downwind, things seem to get worse. This is because it is actually harder to gain altitude when flying downwind. Gradient works against you and gives more and more of a tailwind as the airplane climbs. Flying downwind is not all bad however. If the engine quits and you are still flying downwind, the gradient will help you. Altitude is lost more slowly when gliding downwind since there is more and more of a headwind as the airplane gets closer to the ground. The airplane's ground speed may be quite high though, making landing difficult.

Another effect you may have seen which is purely due to altitude-induced wind gradient is "weathercocking". After pulling the plane vertical in a crosswind, if the wind is coming from the left then the airplane will not only move visibly from left to right with the wind, but it will also yaw to the left (into the wind) as it follows the vertical up-line. If there was no gradient, the airplane would still move from left to right with the moving air mass, but it would not rotate about the yaw axis. If we take the idea of weathercocking one step further, we can deduce that the plane will yaw to the RIGHT (out of the wind) on the vertical downline, even though the wind is still coming from the left. Observant fliers will have noticed this, perhaps when working on their stall turns. This "opposite yawing" on the downline is not quite as pronounced since the plane is accelerating on the way down, making the effect of an increasing sideways wind component less noticeable.

Inside and outside loops into the wind seem snappier as well. This is part optical illusion, but wind gradient plays a part making the loop entry quicker. Alternatively, loop entry when flying downwind can be more sluggish, however in the downwind case pulling out on the back side of the loop is improved when compared with a loop into the wind.

Gradient can also have an effect on banked turns near the ground since the higher wing will be in a region of higher wind. This is most noticeable in gliders, which have long, slender wings.

Gradient is not always produced by altitude changes. When slope soaring, the venturi effect causes wind speed to increase over the crest of the hill. If you fly too close to the hill and straight towards it, then this gradient will mean a loss of airspeed, making turning out of danger more difficult.

Summary

We can summarize what I have said above by remembering four main points:

i) If an airplane is flying at a very high altitude then wind direction will never have any effect on it since there will be no real altitude-related wind gradient. Model airplanes rarely get this high.

ii) No matter what altitude an airplane is flying at, if it flies at a constant height then turning upwind or downwind will make no difference. To somebody on the ground this may not be obvious since observing from a different reference frame creates optical illusions.

iii) If an airplane is flying near the ground and gaining altitude, wind speed increases. This makes climbing into the wind more effective, makes climbing downwind less effective, causes weathercocking, snappier loops, etc.

iv) If an airplane is flying near the ground and losing altitude, wind speed decreases. This makes gliding into the wind less effective, makes gliding downwind more effective, causes weathercocking out of the wind, etc.

One final note: Turning in itself makes you lose energy and can put you into a compromising position (e.g. higher stall speed), so a decision to turn when you are in a tight spot may be a bad one even if you are in a position to take advantage of wind gradient.

Well, that’s it for now. Next time we’ll look at the following question: “Do windmilling props produce more drag than a stopped prop?” As with most of the topics I have dealt with, you’ll find there is no straight “yes or no” answer to this question either!