

Understanding The Spiral Dive

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The Spiral Dive, sometimes called the “Death Spiral” for good reason, is something not many pilots understand. A lack of understanding of a manoeuvre generally leads to fear of doing it, which in turn leads to mishandling of the aircraft should the pilot inadvertently end up in such a situation. The spiral dive is something that needs to be understood for the simple reason that the instinctive reaction to extricating oneself from a spiral dive is not the correct reaction, and only makes it worse.

Before analysing the spiral dive we must first understand some basics about pitch control. Most aircraft designers go to great lengths to build as pitch-stable an aircraft as possible within the limits of their design goals for C of G envelope, efficiency, etc. In fact most aircraft end up being very stable in pitch - much more so than in roll. The way this is achieved is an interesting discussion of relative angle of attack between the front and rear wings. However, this is outside the scope of this article so I will limit myself to discussing the final result. That, of course, is that almost any aircraft will try to maintain it's trimmed angle of attack, all by itself.

Let me explain. Suppose you are flying along in cruise with pitch trim set to maintain the correct angle of attack to keep the aircraft in level flight at your chosen airspeed. Should your airspeed decrease slightly, perhaps by encountering a gust, the lift produced by the wing will decrease slightly and, as we all know, the aircraft will pitch down in an attempt to regain it's lift. The airspeed will increase and likely surpass the previous cruise airspeed at which point the aircraft will pitch up due to excess lift. It has entered a phugoid oscillation and most well-behaved aircraft will continue for 2 or 3 cycles until the oscillation dampens out and the aircraft is back to level flight at its original cruise altitude. The same thing would happen if the angle of attack changed momentarily, thus increasing or decreasing the lift. A simple way of putting this is, the aircraft “knows” what angle of attack it must maintain in order to stay in the air at a given airspeed, and it will try to return to it if disturbed.

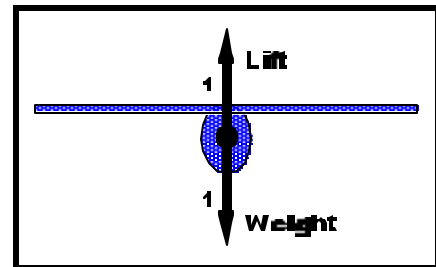


Figure 1 - Level flight

So what does this have to do with spiral dives, you say? Hold on, I have two more diversions before I explain that. Let's take a look at how we maintain lift in a turn. Figure 1 shows an aircraft in level flight. The lift exactly equals the weight, otherwise it would rise or fall, right? Figure 2 shows an aircraft in a 30 degree bank. As you can see from the vector diagram, in order to keep the aircraft in the air we must generate 1.2 times its weight in lift (20% extra). This is commonly referred to as load factor. The lift vector has two components. The vertical component holds the

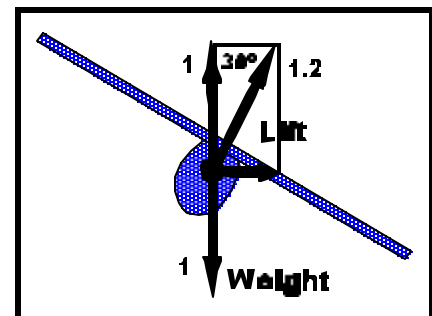


Figure 2 - 30 degree bank

aircraft up and the horizontal component cause the aircraft to turn, which is normally what we want from a bank.

So, when we roll into a 30 degree bank for a turn how do we get this extra 20% lift? There are two ways to generate more lift. We can increase the angle of attack, increase the airspeed, or a combination of both. You might remember your instructor telling you to add power and keep the nose up in a turn that will last more than a few seconds. So a little bit of both gives us the extra lift we need to keep us in the air and make the aircraft turn. Sounds simple.

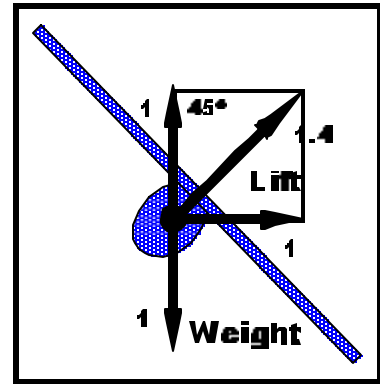


Figure 3 - 45 degree bank

Now take a look at Figures 3 and 4. In a 45 degree bank the wings must generate 40% more lift to keep us from dropping. In a 60 degree bank they must generate 2 times or 100% more lift, otherwise we drop out of the sky. The lift required to keep us air-borne increases exponentially with bank angle. At 70 degrees we need 3 times the lift which is beyond the capabilities of most aircraft. That's why your instructor should have told you to never, ever exceed 60 degrees! Unless you are flying an aerobatic aircraft with tons of power you won't even be able to stay in the air at 60 degrees.

There is one more factor we should consider before getting "into" our spiral dive. In a turn the outside wing has to travel farther than the inside wing. See Figure 5. Since it has to travel farther in the same amount of time it must be travelling faster. Therefore, the outside wing generates more lift than the inside wing, which tends to increase the bank and tighten the turn. In a shallow bank turn this will not be very noticeable, but as the bank angle increases and the turn tightens it becomes much more significant. This is easily calculated. The difference in airspeed depends on the radius of the turn and the wingspan. For example, I've done the calculations on an aircraft with a 32 foot wingspan in a turn with a radius of 500 feet. The outside wing will experience a 3% greater airspeed than the inside wing (as measured at the centre of each wing). Since the lift generated by an airfoil varies with the square of the airspeed over it (other things being equal), the outer wing will generate 9% more lift than the inner wing. That's a lot. In a coordinated steady turn we have to apply opposite aileron to prevent the bank from increasing. The tighter the turn the more opposite aileron we must apply.

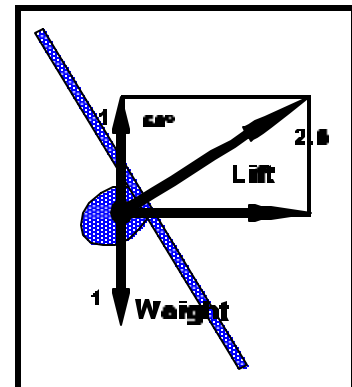


Figure 4 - 60 degree bank

Now let's go flying. Suppose we are flying along straight and level and our right wing suddenly drops 30 degrees due to unexpected turbulence. Unfortunately we have our head in the cockpit folding our map at the time with hands off the stick. The airspeed and lift are still the same but the lift vector is now pointing 30 degrees to the right, as in Figure 2. The aircraft does not have enough vertical lift to hold it up so it starts to drop which decreases the angle of attack. Since it is preprogrammed to maintain its trimmed angle of attack the nose automatically pitches down and the airspeed starts to increase. Due to the horizontal component of lift the aircraft starts to turn to the right. As the turn develops the differential airspeed over the wings takes effect and the bank angle starts to increase. An increase in bank angle

causes the vertical component of lift to decrease and horizontal component to increase further. Therefore, the aircraft continues to sink and the turn continues to tighten. Reacting to the sinking, the nose pitches down further and the airspeed continues to increase. We now have two factors causing the turn to tighten: the increasing horizontal component of lift and the increasing airflow differential over the wings. The decreasing pitch, increasing airspeed, increasing bank angle and tightening of the turn are now feeding each other and we are deep in the grip of a spiral dive.

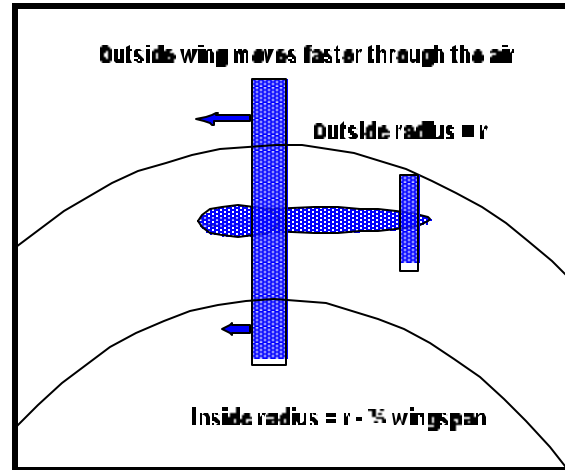


Figure 5 - Differential airflow

If we had been paying attention we would have noticed the nose dropping below the horizon and the increasing bank right away. However, we are still folding the map and haven't a clue the little bump we just felt is sending us into a death spiral. Luckily there are two non-visual clues we should be sensing by now. The first, and most obvious, is an increasing G load in the seat of our pants. Remember from above that if our bank has developed to 45 degrees the G's will be approaching 1.4, which is very noticeable. The second clue is an increase in wind noise. The aircraft is trying to increase its airspeed enough to produce 1.4 times the lift. Lift varies as the square of airspeed so it is diving to increase airspeed by about 1.2 times. By the time the bank angle reaches 60 degrees, which will happen in a few more seconds, the G's will be up to 2.0 and the airspeed will increase to about 1.4 times our original trimmed cruise speed.

With our butt pressing firmly into the seat we finally realize something is wrong and look outside. The windshield is filled with a kaleidoscopic view of the ground. Our instinctive reaction is to grab the stick and pull back. Unfortunately this is precisely the wrong thing to do. Pulling back on the stick will increase the angle of attack and if we are at a 45 degree bank or more, most of the resulting increase in lift will go towards increasing the tightness of the turn, making the spiral worse. We will already be getting close to our critical angle of attack and this action might just push us over the limit, and we all know what happens when we reach the critical angle! Yup, the wings stall and now we're in even more trouble. In fact we'll likely flip into an inverted spin any second with the stupid map wrapping itself around our head as we auger in.

Fortunately you're sitting in a comfortable arm chair reading this so we've got a second chance to figure out what we should have done. It should be obvious by now that there is only one way out of a spiral dive. One thing you can't do is nothing. As we've seen, once started a spiral dive will continue to get worse all by itself. The only way out is to get the wings level, and this will take lots of opposite aileron deflection, and rudder will help too. Most flying schools and training manuals instruct you to reduce the power first to slow the speed buildup, then roll the wings level. Unless you are very close to the VNE this is not the correct order to do things in. The first reaction must be to level the wings. Of course, we should be able to roll the wings level and reduce the power at the same time, but our drilled-in instinctive reaction to a spiral dive must be to **ROLL WINGS LEVEL** and reduce power. If you have

to think though the recovery steps you are wasting too many valuable seconds.

Once the wings are level, the aircraft will take over and bring the nose up automatically due to the high airspeed. Once level we actually have to begin applying forward stick pressure to prevent the aircraft from pitching up too high and possibly stalling. In other word, we need to start to dampen the phugoid oscillation that will ensue. The aircraft will soon slow down to its original cruise speed and we can then attend to gaining back our lost altitude.

The Transport Canada Flight Training Manual, third edition, states, “the spiral dive is not a manoeuver to be practised, but for recognition and recovery action purposes the flight instructor will demonstrate it.” I couldn’t disagree more. Something that could kill you so easily must be practised in order to drill home the proper recovery technique. However, first practice with an instructor.

Getting into a spiral dive is a lot easier that getting into a spin. Controlling the spiral dive is equally easy if you know what to do. And that is to “roll the wings level, reduce power, and DO NOT pull back on the stick or yoke.” The secret is knowing when you are entering a spiral dive. Anytime you feel an increase in G’s on your butt check if the nose is dropping and the wings are rolling. If so you know what to do.

I often use a controlled spiral dive to lose altitude without going anywhere. A good example might be when I’m above a layer of scattered clouds that are beginning to turn into broken clouds. I pick a big opening and spiral down below the layer, then continue on. First I reduce power, then roll lightly into a descending turn. The aircraft will automatically try to tighten the turn as the airspeed increases. By applying just the right amount of opposite aileron I can control both the speed and the tightening of the turn. I am very careful not to apply any back pressure until after I reach my desired altitude and have rolled wings level. Caution: please don’t try this until you’ve done it a few times with an experienced instructor in the other seat.

Getting trapped in a spiral dive can happen very easily if you get caught inadvertently flying into cloud. Once you lose visual reference the only clues you’ve got left are your flight instruments, if you have any, and the feeling in the seat of your pants. And according to the experts you have an average of 178 second before you lose orientation and exit the clouds down the old spiral staircase.

I hope this discussion has shed some light on the Death Spiral and will someday help one of you avert disaster. Remember the two key points: know you might be in a spiral dive when you feel the G’s increasing in the seat of your pants; then roll the wings level without back pressure.