Rolling Gs

Watch an F-22--or any other high-performance aircraft--maneuver, however, and you may notice an interesting pattern. Any time the fighter changes attitude under a G-load, the pilot does so incrementally. He or she changes pitch, then changes bank, or the pilot changes bank and then changes pitch. You never see a radical pitch and bank change simultaneously. Watch the other flight demonstration pilots and teams, from local aerobats to Julie Clark to the U.S. Navy's Blue Angels, and you'll see the same pattern.

The phenomenon to avoid is called "rolling Gs." Changing bank angle while simultaneously changing G-load creates a differential in the loading of one wing (or one stabilizer) relative to the other. This in turn applies a twisting force on the attach points that will be much more powerful than if the G-load is applied symmetrically on the airframe,

Rolling G limits do not appear in most civilian airplane Pilot's Operating Handbooks. For example, however, the USAF's Northrop T-38A is limited to +6.0/-2.5G at 3000 pounds of fuel on board (FOB) when symmetrical, but +4.3/-0G in unsymmetrical flight (where "unsymmetrical flight" is defined as "full aileron deflection"). The G-load envelope changes with reductions in fuel weight. The Bellanca De-cathalon gives a rolling G limit in its flight manual that is lower than its aerobatic G-load limitations. A reference standard is the FAA's small airplane certification rules in FAR 23, which define an airplane's asymmetrical flight G-limit for any given weight to be two-thirds of the symmetric G-load at the same weight for the same aircraft (FAR 23.349(2)(b)). In other words, if you're changing your rate of bank, you must be very careful about adding G-load.

WHY DOES THIS MATTER TO ME?

Rolling Gs can affect any airplane. Recently the NTSB released a preliminary report on an accident that took place in March 2011 (it's defined as an "accident" because the airplane--a V-tailed Beech Bonanza--suffered substantial damage in flight, although the pilot landed safely and no one was hurt). The pilot was cruising at 4500 feet and was engaged in correlating the indications of two panel-mounted navigation receivers in the cockpit. He also had a handheld GPS mounted on the flight control yoke. During the correlation effort, the pi lot noticed he was about to intrude into military restricted airspace. He initiated a turn to the right, with a bank angle estimated to be about 45 degrees, in order to avoid the restricted airspace. During the turn, the pilot referred to the GPS to ensure that he would clear the restricted area. When he returned his attention to the airplane's attitude, he noticed the bank angle had increased to about 75 degrees right-wing down, and the pitch attitude had decreased to about 20 degrees airplane nose-down. At that point, the pilot noted the airspeed was about 190 mph, which was in the yellow (caution) range of the airspeed indicator scale.

The pilot stated that he leveled the wings, and then initiated a pull-up. During the pull-up, he heard three or four "thumps" in rapid succession. After recovery to level flight, the airplane continued to "fly fine," but the pilot was concerned about the thumps, since he had never heard noises like them in that airplane. The pilot then flew the airplane "gingerly" back to his home field, where he landed uneventfully.

On landing, an inspection found a diagonal wrinkle about two feet long, extending up and forward from the juncture of the fuselage side and bottom. The wrinkle intercepted the juncture at about the second bulkhead/former forward of the tail cone.

On the opposite side of the aft fuselage, the skin was crumpled and dented in the same general region as on the right side, but the deformation did not exhibit the linear pattern observed on the right side. On the lower aft fuselage, the forward bottom skin was separated from its lap joint with the aft bottom skin at the aforementioned bulkhead/former; the skin was torn from the fasteners, which remained in the bulkhead. The inspection did not reveal indications of pre-event damage or corrosion in the affected areas. A cockpit G-meter registered a maximum of about 2.5G and a minimum of about minus 0.7G, but the meter's accuracy was not determined.

Three possibilities exist to explain the damage (which likely is enough to render the airplane uneconomical to repair): First is the G-meter was incorrect and the airplane experienced a much higher G-load than indicated (the type has a design load of 4.4Gs and an ultimate load of 6.6Gs).

Second, there might have been a pre-existing condition of some sort that reduced load-carrying capability or changed the balance of moveable tail surfaces enough to induce flutter at high speeds (the airplane in question is 55 years old, ample time for issues to arise due to improper maintenance or neglect).

Third, the pilot may have aggressively pulled up while still rolling out of the nearly vertical bank. As a result, the airplane may have suffered the effects of rolling Gs.

WARNINGS

The FAA warns us about rolling Gs without making it terribly obvious. At least it does so on the Commercial Pilot Practical Test Standards (PTS) and supporting Advisory Circulars. Two similar "performance maneuvers" from the commercial syllabus teach us to avoid large, simultaneous changes in pitch and bank--and to avoid rolling Gs.

The lazy eight--"poster child" of the so-called "commercial maneuvers"--requires bank angles up to 30 deg. and pitch attitudes to just above the power-on stall, with a correspondingly low attitude on the "down" side of each turn. But the key in flying the lazy eight to commercial standards is making continuous, but very small, changes in bank and pitch. Although you are continually changing both pitch and bank throughout the maneuver, you are intentionally changing them extremely slowly.

There's no rapid, big change in a properly flown lazy eight. In part, this is an attempt to teach pilots to avoid rolling Gs.

Contrast this with the chandelle, which also calls for changing pitch and bank to the same maximum values. Unlike the lazy eight, however, the PTS calls for a smooth but rapid roll into maximum bank, and a pitch up to maximum attitude, at the beginning of the maneuver. Tellingly, the proper technique for entering the chandelle is to roll to a 30 degree. bank angle first, then pitch to the maximum bank angle. No rolling Gs--just like the F-22, Julie Clark and the Blue Angels!

Chapter 9 of the FAA's Airplane Flying Handbook tells us "an important benefit of performance maneuvers [including chandelles and lazy eights] is the sharpening of fundamental skills to the degree that the pilot can cope with unusual or unforeseen circumstances. ..." The PTS and the Airplane Flying Handbook don't come right out and say it, but the techniques appear designed to teach, among other things, that big changes in bank and pitch should not occur simultaneously.

ONE AT A TIME

Sometimes when flying, especially during incipient emergencies, we must do the right thing without thinking. This in turn requires we sufficiently practiced the right type of response so we don't aggravate the emergency and make it unrecoverable. Avoiding asymmetric G-loads even when we're well within the certification envelope of our airplane is an example of having to get it right the first time.

With all this in mind, you now have a reason to include chandelles and lazy eights in your recurrent training regimen, even if you don't have a commercial checkride in your future.

Tom Turner is a CFII-MEI who frequently writes and lectures on aviation safety.

RELATED ARTICLE: UNINTENTIONAL ROLLING GS

When is a pilot most likely to encounter rolling Gs? Not while flying aerobatics--few of us participate in that activity, and (thankfully) few pilots are, shall we say, challenged enough to try aerobatic-like maneuvers without getting some training and using a properly certificated aerobatic airplane. No, if rolling Gs are going to get us, it's much more likely it will happen during instrument flight and as a result of a failed flight instrument or upset, leading to an unusual attitude.

A typical partial-panel loss of control quickly devolves into a nose-down unusual attitude, with increasing airspeed and a monstrous (and growing) rate of descent. If the pilot panics (and who among us would be totally immune in such circumstances?), this nose-down attitude will be accompanied by a growing angle of bank--the classic "graveyard spiral."

If the pilot does not recover just right, leveling the wings and then managing the pitch, then it's very possible a rolling Gs condition will occur. If the speed and G-load is already great enough that rolling Gs takes the airplane to a critical flight load, then it's all over.

Attitude indicators are notorious for "tumbling" under extreme bank and/or pitch conditions, so even a backup attitude indicator may be unusable in a radical unusual attitude. That's why it's so important to practice partial panel unusual attitude recoveries using a turn-and-bank or turn coordinator. If you have a "glass cockpit" airplane without a turn-and-bank indicator or turn coordinator installed, you might want to have one put in and practice using it. Your goal remains: Stop the turn (which creates symmetrical G condition), then adjust the pitch. At least in part, it's about avoiding rolling Gs.

UNUSUAL ATTITUDE RECOVERIES

An unusual attitude is any attitude not required for normal flight. Preventing an unusual attitude involves an effective instrument scan when in IMC, and avoiding effects such as wake and other turbulence.

When an unusual attitude is encountered, increase instrument scanning and execute procedures outlined in the AFM/POH.

RECOVERY FROM NOSE-HIGH ATTITUDES

* Add power

* Lower nose

* Level wings

RECOVERY FROM NOSE-LOW ATTITUDES

* Reduce power

* Level wings

* Raise nose

During recovery, look for stabilization or slight reversal in instrument indication trends, and make incremental corrections.

RELATED ARTICLE: The T-34s

The concept of "rolling Gs" entered the mainstream general aviation consciousness after the third in a series of fatal inflight break-ups of Beech T-34 Mentor aircraft in separate events. Each of these tragedies occurred in airplanes operated commercially for so-called "mock air combat flights"--aerobatic maneuvering to simulate air-to-air ("dogfighting") missions for recreational purposes.

The T-34 is ideally suited for this operation because the military-surplus airplane has the look and feel of a fighter airplane but the gentle handling and forgiving nature of the civilian Beech Bonanza on which it was based. But two perhaps unforeseen hazards were present in each of those T-34 flights the NTSB cites as possible contributors to all three events:

(1). The airplanes suffered from metal fatigue as a result of decades of use in high-stress military primary training and introductory aerobatics training environment, and frequent aerobatics in civilian use after the airplane was declared surplus by the federal government.

(2). Simulated air-to-air combat flights frequently controlled by pilots with little to no aerobatics training prior to the simulated dogfighting missions.

Although previous fatigue issues spelled the end of the third of the T-34 in-flight breakups, this excerpt from the NTSB's report on that accident at least suggests rolling the airplane while "under G" was the final event that triggered break-up of the aircraft:

While maneuvering during an upset recovery training flight, the left wing separated from the airframe, which resulted in an uncontrolled descent and impact with terrain. A review of an on-board video revealed the instructor and student were performing training maneuvers which included steep turns, stalls, accelerated stalls, unusual attitudes and recoveries from these to a wings level attitude using several techniques. During the final maneuver, the instructor asked the student to lower the nose to "about a hundred and forty knots," and afterwards told the student to slowly pitch the nose upward "until we're pointed straight up." The airplane was seen climbing vertically up and visual contact with the ground disappeared. The instructor then told the student to "pull the way we just did a minute ago and pull the airplane into a stall." A brief stall occurred, and then the airplane continued to pitch in the same direction, and its path resembled the remainder of an inside loop. As the ground reappeared into the view, the aircraft was inverted and descending. There was a slight roll to the left as the airplane was descending while its pitch attitude continued in the same trend toward a vertical nose down attitude. While in a steep nose down attitude (no sky visible in the view), the instructor told the student to "pull it into a stall right now." At that moment ... the recording appeared to end. ... Witnesses heard a "bang" and noticed an airplane in a near-vertical attitude. The witnesses then observed a wing and several other small components separate from the airplane.

Later investigation proved there was pre-existing fatigue damage that ultimately led to loss of structural integrity, but it's possible the combination of roll to the left and pull into a stall was what caused the fatigue cracks to give way.

RELATED ARTICLE: PERFORMANCE MANEUVERS

According to the FAA's Airplane Flying Handbook, FAA-H-8083-3A, performance maneuvers "are used to develop a high degree of pilot skill. They aid the pilot in analyzing the forces acting on the airplane and in developing a fine control touch, coordination, timing, and division of attention for precise maneuvering of the airplane. ... An important benefit of performance maneuvers is the sharpening of fundamental skills to the degree that the pilot can cope with unusual or unforeseen circumstances occasionally encountered in normal flight." Two such maneuvers, the chandelle and the lazy eight, are highlighted below.

Chandelle

(1).Enter the maneuver from straight-and-level flight, at the manufacturer's recommended entry speed (usually Va).

(2). Smoothly establish a turn, but not more than 30 deg. of bank. Then smoothly apply back pressure to climb.

(3). Maximum pitch angle should be reached here. Begin rolling out of the turn.

(4). The maneuver is complete when the wings are level, the airplane is at its minimum controllable airspeed and the pitch angle remains constant. Hold that attitude for a moment, then recover to cruise flight.

Lazy Eight

(1). Again, enter the maneuver from straight-and-level flight, at the manufacturer's recommended entry speed (usually Va). Smoothly establish a climbing turn, timing it to reach maximum nose-up pitch at the 45-deg. point.

(2). Maximum pitch angle should be reached here. Begin reducing pitch, continue increasing bank angle.

(3). Maximum bank angle by this point, and at 5-10 knots above stall.

(4). Maximum pitch down, approximately 15-deg. bank angle

(5). Level flight, entry airspeed and at entry altitude.

6-8. Repeat steps 2-4, but in the opposite direction. Maneuver is complete when re-established on entry heading.

The chandelle is the only standard flight training maneuver in which constantly varying forces and attitudes are required. In part because airspeed is also constantly changing, the maneuver helps a pilot develop subconscious feel, planning, orientation, coordination and speed-sensing skills.

Thanks to Tom Turner CFI/CFII for this article