Report - From the Rotary Forum

Research report on slips in a gyro

Slips in a gyro have been the topic of many heated discussions. The various opinions about them ranging from dangerous, via superfluous, to indispensible. Particularly with some notable accidents over the past couple of years in which slips have come up as a possible exacerbating circumstance, it has become clear that not enough hard facts are known about this maneuver.

As a reaction to this, slips have been edited out of the German training syllabus and the largest gyro manufacturer has added lots of cautionary verbiage about slips to their handbooks to the point where if you do slips and something happens to you, you're on your own.

So what's the scoop about slips? Wouldn't it be nice to have a clear-cut guideline specifying when slips are safe to perform and under what circumstances they can bite you?

The DLR (German Center for Aviation and Astronautics) picked up the ball and started to investigate this issue. They followed a two-pronged approach: First the developed a mathematical model of a gyroplane and built a pretty sophisticated simulator. Then they did extensive flight testing in a heavily instrumented MTOSport and used the data to tweak the model so that it would agree with the experiment. The benefit of this approach is that they now have first hand experimental data as well as a mathematical model which can be used to extrapolate real life flight experience to a point where no pilot would want to sit in the gyro anymore.

The test pilot is a friend of mine with 6000 hours in gyros and a firm scientific background. We talked at length about slips and found that our individual experiences match very closely. What's also nice is that our explanations about what happens aerodynamically in a slip are in good alignment. There is one important thing that I learned which I had no clue about, and it seems to be important in slips. I will tell you more about it in a bit.

The instrumentation they carried in their test gyro is pretty impressive. They measured rotor head angle, rotor blade angle, rotor rpm, stick position, rudder position, flight attitude in roll, pitch and yaw and stick force (in addition to all the usual flight parameters). They also had threads taped all over the horizontal and vertical stabilizer and rudder to measure the airflow across these surfaces. The maneuvers they performed were slips in all variations, to both sides with varying degrees of bank and yaw with all imaginable power settings including engine off.

(Just as an aside to Bryan Cobb: they did measure flapping angle and nobody was surprised to find out that the rotor disk rides highest in the front.)

The results of this research are being written up in a Master's Thesis and will be available publicly once the thesis is published. There was a brief superficial report published in the German UL quarterly (DULV Info) but it was too watered down for public consumption so that you couldn't really grasp the important implications. Everything I write in this thread is from private communications with the test pilot. Just wanted to be clear about this.

Slips in gyros differ from slips performed in fixed wing aircraft in several important aspects. First, the required control inputs are much smaller in gyros, making them, in efffect, more sensitive to entering and exiting from a slip. This point alone can lead to precarious situations for pilots transitioning to gyros from their Cessnas and the likes.

The second point of difference is that the aerodynamics of slip performed in a gyro are more complicated than in a fixed wing. This requires the gyro pilot to be aware of, and often manage properly, a large number of variables which his fixed wing colleague wouldn't even have to know about. Among these parameters are engine torque, airspeed, direction of roll, direction in which the rotor turns, wind gusts, etc. Let me discuss some of the more important ones in turn.

A gyro depends on the horizontal and vertical stabilizer surfaces to enhance stability around the pitch and yaw axes. This is true whether the gyro is CLT or HTL. In an aggressive side slip, these stabilizing surfaces receive airflow from the side and become less efficient with increasing degree of yaw.

This was demonstrated by observing the airflow across the tail surfaces using an array of wool threads taped to its surface. The effect of this is that sensitivity to cyclic pitch input (stick for-aft) increases. Also, yaw and roll stability both decrease. Thus, the gyro depends more on the pilot to provide accurate cyclic input to maintain the desired flight attitude.

The gyro used for flight testing was an MTOSport powered by a Rotax 912. I mention this as the direction in which the propeller turns (counter clockwise, as seen from behind) as well as the sense of rotor rotation (clockwise as seen from below) are important.

Engine torque exerts a roll moment to the right. Therefore a slip with the nose pointing left and a bank to the right will be less stable due to the engine torque working to increase the bank angle. For the same reason it is important to enter a slip with a retarded throttle and not change the throttle setting during the slip.

A common mistake is to enter a slip with the power well back, then realize that airspeed is too low or the descent angle too steep and shove the throttle forward. This will suddenly increase engine torque and lead to an increased roll moment to the right. If you're already slipping in this direction (i.e., nose left, right bank) you'll find yourself confronted with a suddenly increasing bank which you may not have the wits, skills or control authority to counteract.

It is a common mistake to judge airspeed in a slip by the indication of the ASI. The ASI will read low in a slip due to airflow hitting the pitot tube at an angle instead of right on. Students who forget to take this into account will instinctively add throttle in the attemptto regain the apprently lost airspeed. This reaction is a prime setup for increasing engine torque which -- in slips with banks to the right -- is a destabilizing condition.

Another factor which tends to steepen the bank has to do with the center of aerodynamic pressure of the cabin. In many gyros it is located below the center of gravity. Therefore, as the relative wind impinges on the cabin from the side, it will push it to the opposite side and increase the bank. This condition becomes a factor if slips are entered at too high an airspeed so that drag forces are significant.

The last factor is something I didn't know about before and learned during the dicussion with Jörg. Apparently it is a well known effect in helicopters, though apparently nobody thought it would matter in gyros. During test flights it became clear that the rotor disk behaves different in slips to the right vs. to the left. The stability margin is measurably less in slips banked to the right. The mathematical model was not able to reproduce this until the effect of airflow around the cabin interfering with the downwash of the rotor was added.

Apparently there is a significant effect on the rotor dynamics which comes from how the airflow around the cabin interacts with the downwash of the rotor. Banks to the right decrease the stability margin and banks to the left increase it. Once the model was changed to incorporate this effect, agreement between theory and experiment became extremely good.

To sum up, here is the recepe for a safe slip in a gyro:

1) Enter the slip with engine at or near idle and airspeeds not in excess of about 80 km/h.

2) When entering the slip, lead with rudder and apply lateral cyclic as needed to maintain your flight path.

3) Use smooth and gentle control inputs to establish the slip and minute corrections throughout the slip to maintain a constant bank and yaw attitude. Don't let the gyro fly itself, stay on the controls all the time.

4) Disregard the ASI and judge airspeed by flight attitude, wind noise and other outside clues. Keep the slip attitude constant.

3) Do not touch the throttle while slipping, leave it at or near idle.

5) Upon exiting the slip, reduce lateral cyclic input and rudder to neutral, leading with the stick. Keep the pitch attitude constant. Use smooth and gentle control input on stick and rudder.

6) Once again in a level attitude, check your airspeed and use throttle as required.

The upshot is that slips are an advanced maneuver which can be performed safely if those points are heeded. There are situations where slips offer an advantage over other maneuvers as e.g., in an emergency landing situation into a confined space. If you want to add slips to your repertoire, train them with an experienced instructor first.

Greetings, -- Chris Lang