Rotor Management for Gyroplanes

By

Ian Morcombe

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One major difference with operating a Gyroplane compared to a fixed wing plane is the need to understand the rotors and manage them correctly. With the advent of factory, 'turn key' models and powerful pre-rotators becoming common on recreational gyroplanes, it is possible to fly a gyroplane without really having a feel for the rotors or understanding the operating limits.

Here is a scenario which may make this point clearer.

A gyroplane pilot who has clocked up quite a few hours in his new gyroplane is lining up on final approach to land in a stiff breeze coming straight down the runway. He decides to land just before the mid field exit so adjusts his power setting accordingly. As he touches down, he feels quite pleased with himself to have judged the touch down point so close to the taxiway. He immediately pushes the stick forward, applying a little wheel brake to slow his roll and starts to turn right into the taxiway without stopping. As is quite common with many people who ride motor bikes, as he turns, he unconsciously moves the stick a little to the right as well. Almost instantly the left wheel lifts off the ground and the machine topples forward and to the right like a wheelbarrow. Next, he knows is that the whole machine is violently flung around, pieces of aircraft go flying past him and there is a terrible thumping noise over the motor. Finally, everything stops moving with him in one piece but entangled in a heap of metal and broken fibreglass.

The Incident Report our pilot friend sends to the Incident Manager is that "as he was landing he was struck by a freak gust which picked him up off the ground and threw him sidewards, totally destroying his aircraft." If only he knew it, the damage was self-inflicted!

It is important that we understand our rotors. We need to know that they require the right techniques to build up their RPM to flying speed or we can cause serious structural damage or a roll over. We also need to understand that after we have landed the rotors are still 'flying' and can help us or 'burn' us if not handled correctly.

Even though hand spinning rotors is not necessary with gyroplanes fitted with a good pre-rotator there is a lot of value in learning the skill. It is one sure way for a pilot to learn the basics of how a rotor responds and the best way to build up the rotor RPM without the risk of flapping them if things are not going quite as the textbook says. So, in the following article on Rotor Management I will cover hand spinning, not only for the few who still do not have a pre-rotator fitted on their gyroplane (or are purists and do not want one) but for those who would like to learn the skills which will help them to be more in tune with their rotors.

I will split the sequence into 3 sections for building up the rotor RPM to take-off.

1. 40-50+ RPM (typical hand spinning speed)
2. 100-120+ RPM (typical RPM for a simple electric starter motor pre-rotator)
3. 200+ RPM (typical powerful pre-rotator)

Before we get started, I will mention 2 instruments which are most useful when learning rotor management.

- Drift Indicator (a piece of string or wool tied to the radio antenna or similar, away from the windscreen). This can act as a windsock which is always relative to the air passing through the rotor either when you are stationary or more importantly as you are taxiing. This is much more useful when building up the rotors than looking at the windsock which can be quite different to the relative air flow into your rotors. It can also assist you in gauging air speed which I will cover later.
- Rotor Tacho (this can even be a push bike speedo using the KPH to indicate Rotor RPM) It is possible to learn to judge the rotor RPM by watching the blur of them, but a rotor tacho will teach you a lot more.

1. 40-50RPM (typical hand spinning speed)

Most rotors can be hand spun up. The exceptions are rotors with a lot of pitch or rotors which are designed to have a positive twist in them. Obviously, it is very hard if not impossible to hand spin rotors on a gyroplane which has a fully enclosed cabin. It is also not recommended to attempt to hand spin rotors on a tandem gyroplane with only one person. To safely hand spin with this configuration it is advisable to have the pilot seated in the front seat, holding the stick forward and a second person stand on the rear seat to spin up the rotor.

Hand spinning rotors is a skill and after it has been mastered there is a lot of satisfaction in knowing and practicing the skill.

Hand Spinning – 100 RPM

- Position the gyroplane so it is facing into the wind. The most ideal condition for starting rotors is a light wind. **<u>Do not have the engine running</u>**.
- Stand on the seat (if necessary) with the stick locked or held in the full forward position. Start spinning the rotors gently and slowly at first, pushing on each blade at first and then go to every alternate blade as the RPM builds while increasing the pressure you use. Typically, you will need to get to 40 RPM or 50 RPM with lighter blades.

a. **With no wind** you will need to move off immediately but slowly to get some air moving though the rotors. (only at a slow walking pace until you are confident the rotors revs are building up) When you are confident they are not slowing down and you have them under control at about 60 RPM, it is time to put on your seat belt and do your final pre-flight checks.
b. **With a light wind** quickly get into the seat and gently ease the stick all the way back. With a 2-3 knot wind the rotors should build up to 60 RPM+ without moving so there is no rush to taxi off.
c. **With a stronger wind** the stick must be moved back very slowly to prevent them from flapping while you watch the RPM building up.

- As you taxi off only increase the air speed a little at a time. This is when the drift indicator/yaw string is important to show you the wind speed and direction. You can gauge airspeed with it by seeing the angle it is inclined (at these very low speeds your ASI will not be reading anything) At this stage the string should be inclined at about 45 degrees or so but if it is near horizontal you are probably taxiing too fast.
- It is more important to have **maximum volume** of air going through your rotors rather than extra air speed. To do this you need to tilt your stick **away** from the wind so that you are facing the maximum area of the rotor disk at the wind coming into them.

- Until your rotors are over 100 -120 RPM they are virtually only lifting their own weight so your job at this stage is to get them spinning and you are not yet in a practical flying machine which would require you to tilt the stick into wind.

- There are 4 possibilities now:
    1. Air speed too slow. (Remember we are interested in air speed though the rotors not ground speed) - rotors will be slowing down.
    2. Air speed just right - the RPM will be increasing, and you can slowly increase your taxiing speed to keep the RPM building up.
    3. Air speed a little too fast - the rotor RPM will not be building up but not hinging on the teeter stops.
    4. Air speed too fast and the rotors will start to flap.

Note: The terms “hinging” and “flapping” have become synonymous and refer to the action of the rotors when the retreating blade hits the relative teeter stop due to excessive airspeed for the current rotor RPM.

Make sure you do not mistake going a little too fast with going too slow and try to go even faster. The next thing you will notice is a “knocking” feeling coming through the stick and the rotors will start to flap.

Why are the rotors flapping? Put simply, the advancing blade is getting too much lift and the retreating blade is travelling in the same direction as the on-coming air so is in ‘dead air’ and has little or no lift. The rotors are like an upside-down seesaw. As the advancing blade gets pushed up the retreating blade goes down, hitting the stop on the rotor head. This can happen easily at low rotor RPM but is still possible right up to 200 or 250 RPM with too much acceleration or a wind gust. At low rotor RPM (40 – 50) there is very little energy in the rotors so there is little likelihood of major stressing or damage but at higher revs the damage can be catastrophic.

What to do if they start to flap? At first you will feel a knocking feeling coming through the stick. (If you continue it may become so violent within a few seconds it can rip the stick out of you hand.)

1. Reduce the power (air speed through the rotors).
2. Move the stick forward firmly to flatten the rotor disk and reduce the air into it.

Here are a few things to note:

- The faster your rotors turn the faster the airspeed and acceleration they can tolerate.
- Your rotors will not spin up as well if you are taxiing over an uneven surface, so it is better to sit stationary, facing into any wind as long as possible rather than moving off over rough ground too soon.
- Typically, your rotors should speed up to 80 -100 RPM at an air speed which is not much more than a fast-walking pace.

Remember: The important thing is the airspeed through your rotors not your taxiing speed. The airspeed is **taxiing speed plus (+) wind speed** “up wind” and **taxiing speed minus (-) wind speed** “down wind.” If you have a good wind you do not need to be taxiing at all to get the rotors spun up.

2. **100-120+ RPM (typical RPM for a simple electric starter motor pre-rotator)**

If you intend to operate at an airfield with other aircraft, it is necessary to have some sort of pre-rotator as at some time you will need to stop or 'hold' which will mean your rotors could slow to a stop also, especially in a nil wind situation. You cannot expect other aircraft to wait for you to get up on your seat and start hand spinning your rotors in the middle of the taxiway or runway.

In Australia we require all gyroplanes to have their rotors spinning while taxiing, except on smooth tarmac. This is because taxiing over uneven ground or bumps will flex the rotors down, particularly at the root, causing fatiguing and possibly cracking over time. We have had one known fatal accident caused by this and **we don't want any more!**

100 -120 RPM is a good range when taxiing as it is fast enough that you do not need to concentrate or work too hard to keep them turning without flapping and they are lifting approximately their own weight to reduce fatiguing, but not producing enough lift to cause a roll over if a gust were to catch you.

For those who are using an electric starter pre-rotator or a pre-rotator where you can ease the stick right back while pre-rotating, you can get extra RPM and reduce the load on your pre-rotator by having the stick back with the rotors facing into the wind which will spin them up even quicker and to higher RPM than if there is no wind. Start with your stick forward or the wind may make the blades flap as you start rotating them and hit your tail. As they build up RPM start easing the stick back until it is fully back. The wind will then be passing through the rotors, assisting the build-up of RPM.

From 100-120 RPM upward it is important to **keep the stick tilted into the direction of the crosswind**.

Back to the take-off sequence.

- At 100 -120 RPM accelerate the airspeed gradually with the stick fully back while checking that the rotors are accelerating, progressively add more power/acceleration when you are confident the rotors are keeping up with it. If they do not seem to be accelerating, you may be accelerating too quickly.
- As you progress towards 200 RPM and beyond you will notice that you need more and more power, or you will be slowing down. This is because with the rotor tilted back the lift is up and backwards though the rotor axis so some of the lift is trying to pull you rearwards while your prop is trying to push you forwards. This phenomenon can be used to your advantage as a brake to assist you to pull up quickly if you just cut the power to idle (don't expect much of this effect under 200 RPM).
- If you are in an aircraft with a powerful pre-rotator and you have been taxiing with the rotors spinning at 100 – 120 RPM, there is no need for you to then stop at the threshold and pre-rotate again. Just follow this procedure by continuing to accelerate and go into your normal take-off run.

3. **200+ RPM (typical powerful pre-rotator)**

Most European style pre-rotators are set up so the stick is required to be kept forward while pre-rotating. It is still important to keep the stick tilted slightly into the wind when pre-rotating to prevent the rotors from any possible flapping as they start rotating in a strong cross wind. This is also important when the rotors reach higher RPM and have greater lift, to ensure the gyroplane *will not topple over. This position also prepares you for the correct stick position as you bring the stick back at the beginning of your take off roll.*

- In the early stages of your take-off run the stick should be fully back to load your rotors and bring them up towards flying RPM. Depending on the design and balance of your gyroplane, with the stick fully back the front wheel will start lifting off the ground at 200 -280 RPM. As the front wheel lifts the stick can be moved steadily forwards so the nose does not rear up before the appropriate take-off speed is attained. For a normal take-off, the gyroplane should fly off in a level attitude and the stick will be around the mid-forward position.
- In your take off roll, you should have the stick tilted into any cross wind to compensate for the wind trying to push you sideways on the airstrip. You will know if the stick is in the right place as you take off because the aircraft should continue straight along the runway. It is safer to have too much stick into the wind than not enough. As you accelerate up towards your take off speed and if you feel the gyroplane trying to skid sideways away from the wind you need to tilt the stick more into the wind (don't try to correct it with more rudder as all you will be doing is crossing your controls). This skidding, if not corrected (particularly on tarmac) could quite easily turn into a rollover situation for the following reasons;
  As you skid sideways, the tyre which is going to get the most weight will be the one away from the wind. If it grabs on the tarmac the other side will lift presenting more rotor disk to the crosswind which in turn lifts that side of the gyroplane more. You have suddenly got a 'snowball' effect and if not corrected quickly can get to the point where the gyroplane rolls to the side. To prevent this from ever happening to you, always tilt your stick into the wind.

With gyroplanes where you must keep the stick forward as you pre-rotate, you cannot use the wind to assist while pre-rotating but if you have a good stiff breeze, you can still use the wind to help build up the rotors. Pre-rotate as specified by the manufacturer and ease the stick back but don't rush off. Just move off slowly to build up the air speed through your rotors as required and you will find they will build up RPM quite quickly and you will cover very little ground. If the wind is light you will need to accelerate to about 15 knots air speed at first or the rotors will be slowing down. Don't get caught by letting your rotors slow down after you pre-rotate and then accelerate too quickly.

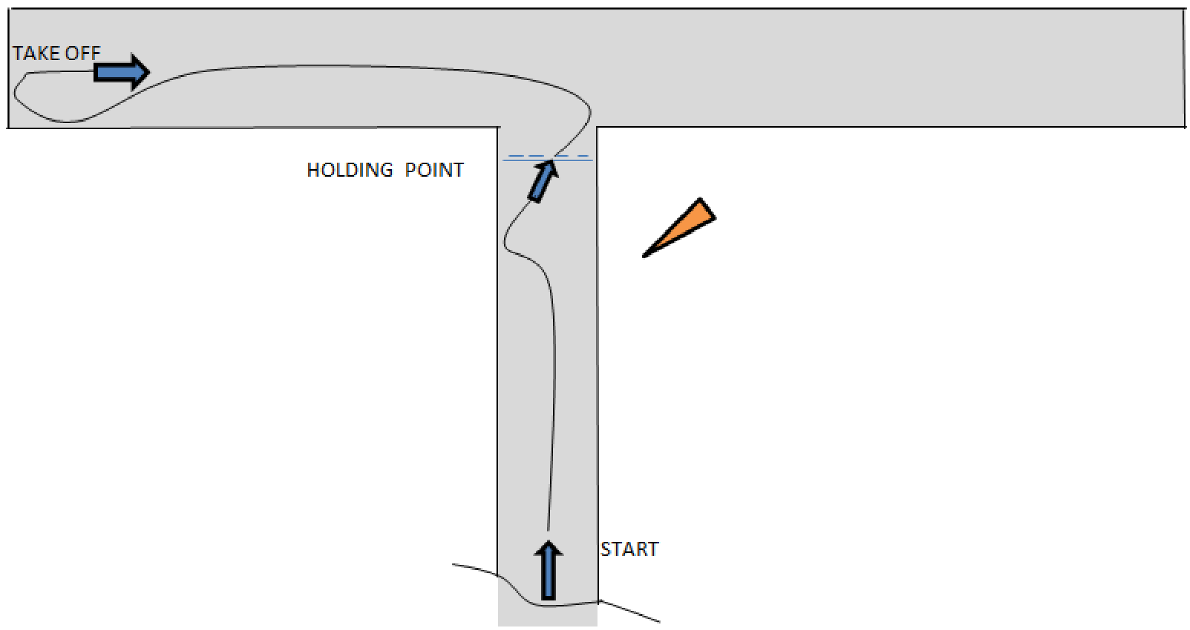
Note: It is quite possible to flap your blades after pre-rotating to 200 RPM in 2 ways.

1. With powerful light gyroplanes (particularly on tarmac) it is quite possible to flap your blades due to too much acceleration. (e.g. immediate application of full throttle) Your rotors simply cannot accelerate that fast.
2. In a strong head wind, after pre-rotating with the stick forward, the stick is pulled quickly back, and you taxi off too fast for those conditions. (i.e. **wind speed + taxiing speed**) For example, if there is a 15-knot headwind and you accelerated to 15 knots within a couple of seconds then you have created a 30-knot gust which the rotors cannot handle at 200 RPM.

Our Hypothetical Take-off

Now let us put all of this into practice by using what we have just considered with a take-off scenario. We will do it in an aircraft with a powerful pre-rotator which requires you to hold the stick forward while pre-rotating. Instead of taxiing to the threshold with the rotor brake on and stationary rotors, pre-rotating to 200RPM and blasting off with full power we will use our newly acquired skills and compare the difference.

We are away from our hangar and facing at 90 degrees to the runway on the taxiway, needing to taxi about 100 metres to enter at the midpoint of the runway. Then we will turn left to back-track down the runway to the threshold where we will turn around and commence our take-off roll. The wind is around 5 knots and will be coming at about 30 degrees from our left when we are taking off. As we are now sitting in our gyroplane about to taxi toward the runway the wind is blowing from our right, front at about 60 degrees.



To start we check that our wheel brakes are on and set the engine at 2,000 RPM. Holding the stick forward and a little to the right, into the wind, we press the pre-rotator button and allow the rotors to come up to 140 RPM which are the revs that they stabilize at with those engine revs. Without trying to spin them any more we disengage the pre-rotator and ease back the stick, keeping it tilted into the wind (RRPM greater than 100-120 RRPM) . We watch the rotor tacho for a few seconds and see the RPM start to decay slightly. At this point we release the wheel brakes and advance the throttle enough to start taxiing slowly. The rotor RPM which had been gradually dropping now stabilised at about 100 RPM as we moved forward and increased the air speed though the rotors. As we approach the runway another aircraft enters the runway at another taxiway and starts to back track, so we need to stop at the holding point until they have taken-off. As we stop, we turn the nose slightly to the right so we are facing the wind direction a little more. With the wind still coming from the right and the rotors now slowing to 80 RPM we move the stick to our left, presenting as much rotor disk area to the wind as possible, which increases the volume of air through them. The rotors now stabilise at 80 RPM while we wait for the other aircraft to take-off. Giving the wake from the other aircraft a few seconds to subside, we start taxiing out onto the runway, heading a little bit towards the wind direction to help speed up the rotors before turning left, downwind, to back track down the runway. As we taxi, we look at the piece of string on the antenna in front of the windscreen. It is sticking out at about 45 degrees from vertical and to our left, hardly back towards us at all. This is because our taxi speed is only about what the wind speed is from behind us, so the string is showing us the true air flow into our rotors. We increase the taxi speed to a fast-jogging speed (about 8 knots) so the airspeed through the rotors will be about 3 knots (8 knots minus the 5 knots wind from behind). At this time, the rotors have slowed down to about 80 RPM but with the extra air through them, stabilise at those revs. Keeping our taxi speed the same, we try to see what the influence will be by moving the stick to the left and catching more of that crosswind component which the string is showing us. The RPM picks up from 80 to 100 RPM, so we leave it there while taxiing at a comfortable speed down the strip. We have decided that we want to make our take off quite short so as we approach 200 metres from the threshold, we start to increase our taxi speed and as the rotor RPM reaches 120, we start to move the stick across to the right, into the crosswind. The rotors reach 150 RPM before we reduce power and slow down to turn at the threshold. As we have been approaching the threshold, we have moved over towards the left of the runway (e.g. away from the crosswind) so our turn can be made into the crosswind which makes sure we have air speed through the rotors throughout the turn. By doing this we keep as much air moving through the rotors as possible even though we slow down for the turn. The stick position is adjusted so it continues to be tilted into the wind as we turn so the wind cannot get under the rotors in the turn. If we were to move the stick to the left as we turned and the wind got underneath the rotors, with the RPM of 150 or more it is quite possible that the lift in the rotors and the centrifugal force of the turn could topple us outwards, to the left, like a wheelbarrow falling over.

As we complete the turn, tilting the stick over to the left into the wind again, we slow right down. We are aware that this is a common place for people to get caught by flapping their blades. The reason being is that as we taxied downwind at about 8 knots ground speed, we have only about 3 knots airspeed through the rotors (8 knots minus 5 knots) but as we turn into the wind, a taxi speed of 8 knots plus the wind speed would add up to 13 knots. (8 knots plus 5 knots) This sudden increase from 3 knots to 13 knots of airspeed is far too much for the rotors, particularly if they were at 80 – 100 RPM and they will flap.

Since we managed our rotors throughout the turn, we were able to maintain about 150 RPM. Coming out of the turn, we see the rotors start to accelerate with the 5 knots wind plus our 5 knots ground speed. We are now lined up with the runway and moving forward, checking the rotor tacho shows us that the rotors are accelerating nicely, even though we have not increased our taxi speed any more since the turn. At this stage, the rotors are at 170 RPM, so we start increasing the power gently and it's only a second or so before they are at 200 RPM. We take note that we are only about 50 metres from the threshold, at half power, the rotors are now over 200 RPM and accelerating well.

Thinking back to our standard pre-rotation take-off we can compare the difference. By the time we would have turned at the threshold, lined up and applied our wheel brakes for pre-rotation, we would have only been a little further back from this point. Even if we pre-rotated up to 220 RPM, the rotors would have dropped down to 200 RPM after pulling the stick back and applying power. At this point, and we would be near full throttle, but the gyroplane would feel sluggish and working hard. With our current procedure, the rotors are at 200 RPM, building up well, the aircraft feels more balanced, and the rotors seem to want to accelerate nicely.

Getting our minds back on the job we continue to advance the throttle and as the rotors are now approaching the revs to lift the nose, we start to move the stick forward, reduce the drag on the rotors (without pushing so far forward that we unload them) allowing the aircraft to accelerate more and making sure the nose does not rear up. At this point we feel the gyroplane trying to drift sideways to the right, away from the wind. Realising we are drifting; we correct it by moving the stick further to the left and resisting the incorrect instinct of new pilots to use the rudder pedal to overcome the sidewards drift. We continue to advance the throttle while maintaining the correct nose attitude for the wheel balance and we soon lift off the ground with the stick in approximately the midpoint forward but still tilted to the left. We allow the aircraft to get 2 to 3 metres off the ground, to prevent any possibility of contacting the runway again, and then level out. The rotors take another few seconds to reach their normal cruise RPM while we build up the air speed from our lift off speed of 40 knots to our safe climb out speed of 55 knots before starting to climb at the recommended climb speed. This is done to avoid climbing at a speed which is on the back side of the power curve but that is a good start for another discussion, *safe and defensive flying,* so we will not start that subject now.

Note: It is very important, particularly when flying from tarmac, that the aircraft is prevented from weathercocking due to a crosswind and then touching down, during your take-off phase. It would be a sure recipe for a potential roll over. The same applies to landing in a crosswind and touching the front wheel down while still travelling at any significant speed. As most gyros are constructed with the front wheel connected to the rudder pedals, the front wheel will be turned because of the necessity of applying rudder to counter the crosswind and keeping the gyro straight. Gyros shouldn't even need to do a 3-point landing so this issue should not occur if a proper flair landing is performed.

What our friend did wrong.

Let's analyse what happened to cause his gyroplane to roll over when our friend landed and turned off the runway.

As he landed the rotors still had flying RPM for the first few seconds and consequently had sufficient lift to fly as well. By pushing the stick forward and tilting them to the right as he turned right meant that the rotors wanted to lift forward and to the right. The underneath of the rotor disk was also exposed to the wind which was now coming from his left side as he turned "cross wind," and this gave the rotors sufficient lift to lift the left wheel off the ground which tilts the gyroplane over. This exposed more rotor disk to the wind and created even more lift and tilting action. By the time he started to react and move the stick back towards the left the machine was leaning over by more than 9 degrees which meant that however far he tried to move the stick to correct the problem the rotors kept pulling him over as the rotor head can only tilt to a maximum of 9 degrees. The result was to turn the gyroplane into a very expensive ditch digger!

What he should have done.

As he landed, he should have continued to flare until the gyroplane came to a stop and then eased the stick forward sufficiently so he didn't start rolling backwards which could happen because of the stiff head wind and the residual lift in the rearward tilted rotors. At first, he should have sat there for several seconds to allow the rotors to lose a considerable amount of lift as they slowed to something like 250 RPM. Then he could have started to taxi forward and commence his turn. As he turned to the right, the stick should have been moved into the wind (to the left) so there was no likelihood of the wind getting under the rotors and tipping him over. Then, having negotiated the turn safely, he could have continued on his way back to the hangar with his stick tilted forward and slightly into the wind, while ensuring that the rotors maintained at least 80 RPM. Having reached a safe location near his hangar, where he was not endangering anyone with the spinning rotors, he could have stopped. After applying the rotor brake, he should still keep the stick tilted into the wind slightly until the rotors stop completely, which prevents the wind catching the blades and hitting them against the teeter stops as they slow to zero.

I trust this article will help you, the pilot, understand your rotors better and with some practice learn to be more in tune with our unique form of aviation. These skills and the understanding of what is happening with your rotors should prepare you to react correctly when unforeseen and unexpected situations arise.