GYROPLANE ASTM STANDARDS – PART 3

POWER Longitudinal Static Stability

By Greg Gremminger

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This and the next two parts in this series of articles will specifically address the ASTM Gyroplane sections on static longitudinal stability:

- **Power Longitudinal Static Stability,**
- Airspeed Longitudinal Static Stability, and
- G-Load Longitudinal Static Stability.

POWER Longitudinal Static Stability:

What the standard says:

4.5 Stability (*Note 1*)

4.5 2 Static Longitudinal Stability

4.5.2.1 Static Longitudinal Power Stability

(1) At the cyclic stick position established in level flight at MPRS at MPRS power, a change in power from MPRS power to full power shall not result in a change in a steady state trimmed airspeed of more than 10 % from MPRS.

(2) At the cyclic stick position established in level flight at MPRS at MPRS power, a change in power from MPRS power to idle power shall not result in a change in a steady state trimmed airspeed of more than 10 % from MPRS.

(3) At the cyclic stick position established in level flight at MPRS at MPRS power, a change in power from MPRS power to engine off shall not result in a change in a steady state trimmed airspeed of more than 20 % from MPRS.

MPRS – Minimum Power Required Airspeed

Note 1: Extracted, with permission from F2352-04a Standard Specification for Design and Performance of Light Sport Gyroplane Aircraft, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. A copy of the complete standard may be purchased from ASTM (www.astm.org).

(The following discussion assumes calm air, no wind disturbances. This is the condition that all associated flight testing must be conducted in.)

HOW TO TEST A GYRO FOR POWER LONGITUDINAL STATIC STABILITY:

Now to the meat of the subject – how to test it? There are a variety of methods that could be used to understand a gyro's safety and the limits of operation in according with the standard. An example of a simple and effective test is described below. This test does not purport to identify a totally failsafe aircraft, but it should be very indicative of potential problem areas. This is not intended to be a fully definitive test method for gyroplane manufactures who wish to "comply" with the full ASTM Gyroplane standard. But, for those of us who would want to determine how safe our gyro is, ask more informed questions, or determine the safe limits of operation of our gyro, the following Power Stability test is described:

Power Longitudinal Static Stability Test:
(Note this test is similar to, and accomplishes the same thing as the *Sum of Static Pitch Moments* test described in the ***Thrustlines and Horizontals Stabilizers*** article published in the August, 2003 issue of *Rotorcraft* magazine.)

CAUTION: The following tests should only be conducted by a pilot who is experienced and proficient in that particular gyro. Higher airspeeds and gyros that are highly power unstable may be a common precursor to Pilot Induced Oscillations (PIO) and buntover incidents.

- Perform this test only in calm, no wind conditions at an altitude of at least 2000 ft.
- Establish steady straight and level airspeed and power for MPRS. This is the airspeed that requires minimum power to maintain altitude. (For a typical single-seat gyro, this might be about 50-55 mph with about 65% power setting.)
- Either trim the gyro for this airspeed hands-off, or fix or hold the cyclic stick fore/aft position that trims the gyro to that airspeed.
- Note the MPRS "trimmed" airspeed. Do not change stick fore/aft position.
- Slowly reduce engine power to idle. Maintain the cyclic stick in the original position without pilot input. Allow the nose to drop to establish a descent.
- After the airspeed has settled out and is steady in the descent, note the resultant airspeed. **No different stick position, fore or aft, should be required to maintain airspeed within 10% of the original "trimmed" MPRS airspeed.**
- Slowly increase engine power to full throttle. Maintain the cyclic stick in the original position without pilot input. Allow the nose to rise to establish a climb.
- After the airspeed has settled out and is steady in the climb, note the resultant airspeed. **No different stick position, fore or aft, should be required to maintain airspeed within 10% of the original "trimmed" MPRS airspeed.**
- If a different cyclic stick position is required to maintain the original "trimmed" cruise airspeed within 10%, the "balance" of the Horizontal Stabilizer with the

propeller thrustline and other aerodynamic static moments suggests possible stability/safety issues.

CAUTION: DO NOT conduct additional tests if any of the above tests do not meet the airspeed criteria.

EXPLANATION of CONCEPTS:

Any statically airspeed stable aircraft will inherently "trim" to maintain a steady airspeed without pilot input. Any aircraft that is statically unstable in airspeed will not maintain a steady "trimmed" airspeed – the airspeed will either begin to rise at a faster and faster rate, or the airspeed will drop below the initial airspeed at a faster and faster rate of slowing. So, if in the process of any STATIC flight testing, if the aircraft will not maintain a steady "trimmed" airspeed without pilot input, the aircraft is already determined to be not statically stable in airspeed.

The "trimmed" airspeed of a statically airspeed stable aircraft is determined by the position of the (cyclic) stick in the fore/aft direction. This position may be set "hands off" by a trim spring arrangement, it may be held by the friction in the control system, or it may be set by actually locking the stick in a fixed position. On most gyros, the hands-off stick position and its "trimmed" airspeed may be set by the balance of the forces on the stick – even if there are no trim springs involved. In any case, the stick fore/aft position determines the "trimmed" airspeed of an airspeed statically stable aircraft. The fore/aft cyclic stick position should determine the "trimmed" airspeed, regardless of power setting.

MPRS is typically at a moderate, low cruise power condition – or an approximate mid-range power condition. This is the airspeed that requires the minimum power to maintain flight altitude. This airspeed is often also referred to as the "peak of the power curve". Below this airspeed, more power is required to maintain altitude. Above this airspeed, more power is also required to maintain altitude. MPRS is used in this section 4.5.2.1 criterion mostly to establish a midrange power from which to evaluate Longitudinal Static Power Stability with a power change. Ideally, the gyroplane would have an adjustable "trimmed" airspeed. And, to conduct this test, the gyro would be trimmed to the MPRS. But, even if adjustable trim is not available, the flight testing for this criterion may be accomplished by "fixing" the stick in a position that results in the desired "trimmed" airspeed.

Again, if the gyro is not able to automatically maintain a specific "trimmed" airspeed at a specific stick fore/aft position, you have already determined that the aircraft is not statically airspeed stable. If this is the case, it will not be possible to conduct any of the static stability tests addressed in Parts 3, 4 or 5 of this series of articles – the gyro has already indicated that it is not statically stable. Many gyros in this condition are flown somewhat successfully – but not very safely. For such an aircraft, the pilot must "constantly fly the aircraft"! The aircraft must be constantly "balanced" at the desired airspeed. A gyro that is airspeed statically unstable, may be susceptible to buntovers.

But mostly such a gyro presents extra work and requires superior skills development for a new pilot to fly it or for even experienced pilots to fly it in adverse conditions.

There may be some confusion on the term of “trimmed” airspeed. Most gyros with an offset gimbal and a trim spring can be “trimmed” to an airspeed that requires minimal forces on the cyclic stick. However, even though this is the point at which minimal force is required on the stick by the pilot, the pilot of an airspeed (statically) unstable gyro will still need to be constantly “balancing” the aircraft at this airspeed and pitch attitude point. If the airspeed is allowed to deviate far from this “trimmed” airspeed point, the stick forces and effort required to re-establish the “balance point” will be greater the more the deviation from that point is. This is not unlike balancing a yardstick vertically in the palm of your hand – fairly easy when it is mostly vertical, but, more and more difficult if the yardstick starts to tilt significantly. The point is, even though the gyro may be able to be “trimmed” to balance stick forces at a specific airspeed, the statically unstable gyro will still require perhaps barely perceptible, but constant work on the part of the pilot to keep it at that equilibrium point. If the pilot lets go of the stick, or even somehow locks the stick with hands-off, the airspeed statically unstable aircraft will change airspeed from that “trimmed” point – requiring pilot intervention at some point. A statically stable gyroplane will inherently maintain this equilibrium “trimmed” condition without pilot involvement! On a statically airspeed stable aircraft, the stick fore/aft position will establish the stable “trimmed” airspeed point.

All of these criteria should be verified at all conditions of aircraft weight and balance. Especially for 2-seat gyroplanes, these tests may require repeating at different loading weights and balance – at least at the midpoint and extreme conditions.

Sidebar 1:

As a student pilot, you may recall your instructor constantly drumming two concepts into your head:

- **POWER controls ALTITUDE.**
- **STICK controls AIRSPEED**

This is actually an expression of the different concepts of POWER stability vs. AIRSPEED stability. A change in power should result in a change in altitude – not airspeed. The pilot should control climb or descent or level altitude by adjustments in power. A change in stick position should result in a change in airspeed. The pilot should control airspeed by adjustments in the fore/aft position of the (cyclic) stick. This is true for airplanes as well.

Although an aircraft may be set up differently, where a change in power results in a change in "trimmed" airspeed, it is has been traditionally found that pilots relate more readily, especially in the learning phase, to the Power/Altitude, Stick/Airspeed correlation. And, aerodynamically, it is easier to arrange that correlation in most aircraft.

WHY POWER STABILITY?

This ASTM standard section requires that the stable “trimmed” airspeed not be too significantly affected by the “disturbance” of a change in power. Ideally, a change in power will result in either a climb or descent. Ideally, when power is changed to a different power setting, the nose will rise or fall just appropriately to maintain or re-establish the original trimmed “airspeed” in a climb or descent. In real life, a change in power setting would normally also initiate a “dynamic” response (in nose attitude, airspeed, G-Load, etc.) as the aircraft adjusts to the new conditions to maintain or re-establish the original trimmed airspeed. This is the “dynamic” response of the aircraft. The dynamic response of the gyro is important also. The dynamic response to any disturbance should be rapid and exact and rapidly “damped”. But, with at least a statically effective HS, after some time, the dynamic response should readily “dampen” to nothing and the aircraft will be re-established into the new steady state condition – without pilot intervention. To limit a strong dynamic response, it is also highly desirable that a sudden change in power not radically disturb the pitch of the airframe. The desired response to power changes is illustrated in Figure 3A.

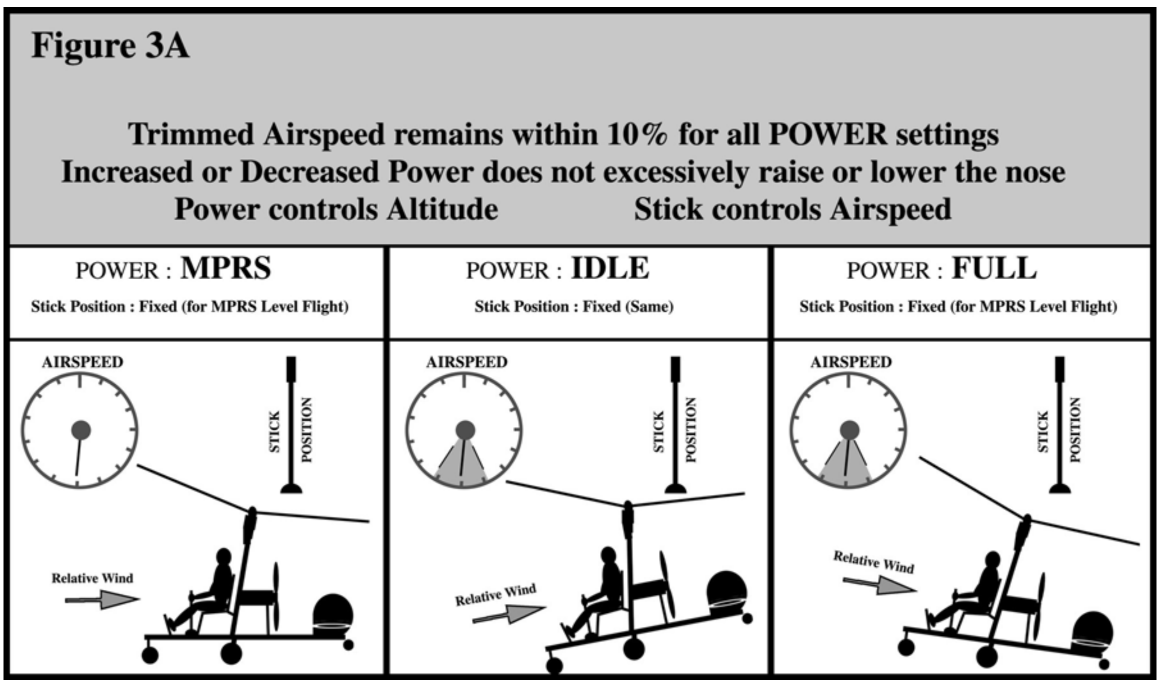
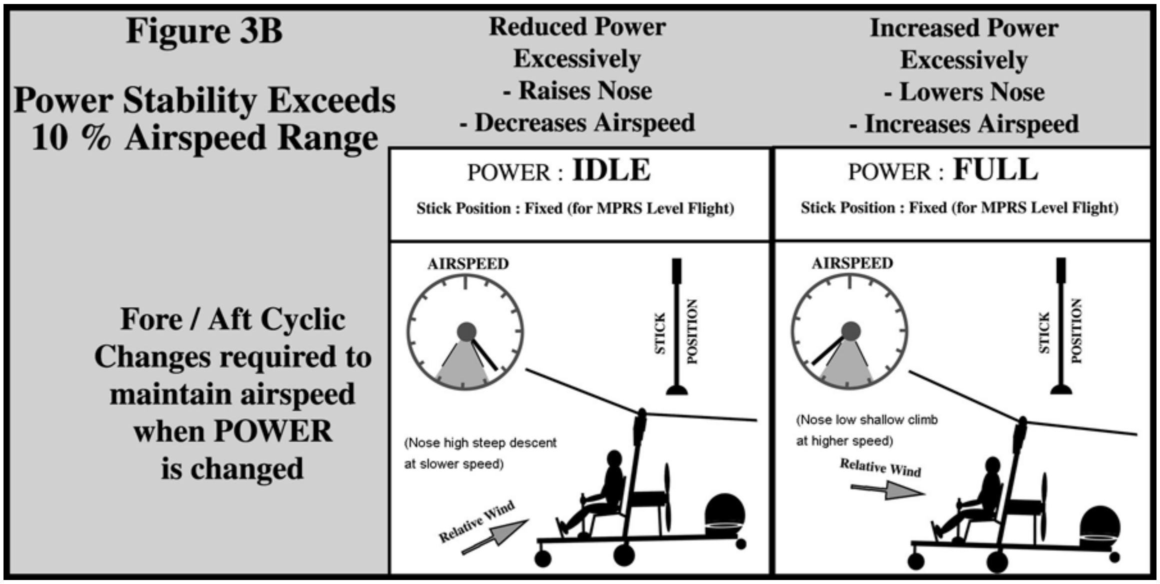
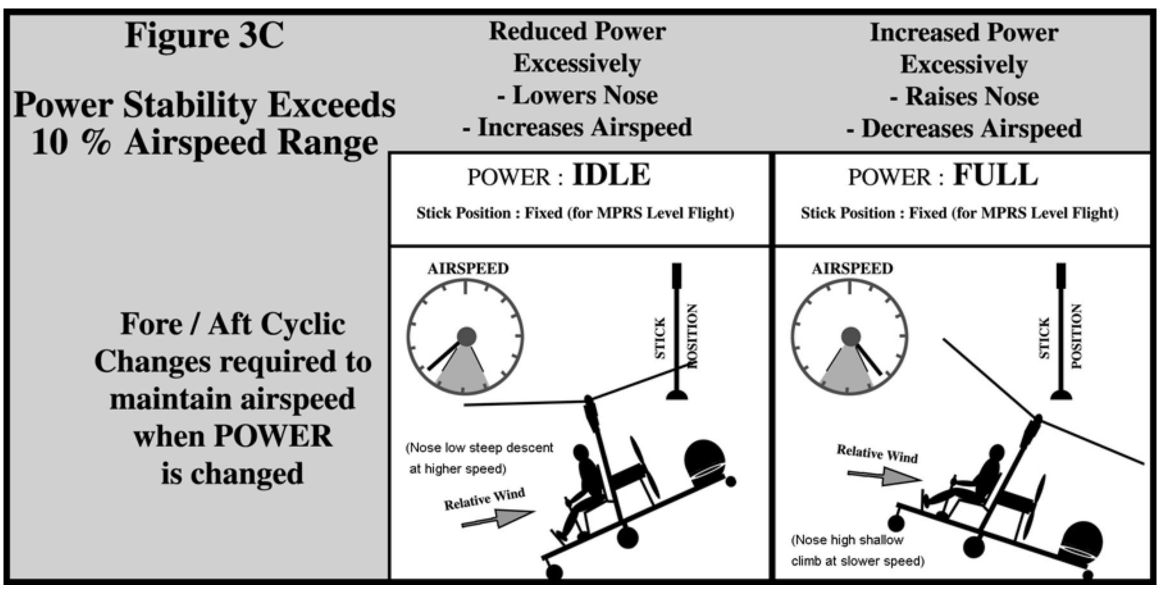


Figure 3A

Figures 3B and 3C illustrate undesirable airspeed (and pitch) changes as a result of a change in power setting.





The traditional intent of a Static Power Stability criterion is that a change in power will not change the steady state “trimmed” airspeed more than the normal inexperienced pilot could be expected to handle. Traditionally over the history of aviation, it has been observed that a pilot more readily adapts to maintaining constant airspeed in response to pitch attitude changes. The normal application of a HS on aircraft works well toward maintaining a statically stable airspeed inherently – regardless of power setting. It is not desirable that sudden application or loss of power result in such sudden nose-up or nose-down pitching as to require radical pilot input to compensate – such as suddenly applying full power on a botched landing.

MORE IMPORTANT FOR GYROPLANES:

For gyros, there is another very important reason for requiring a Power Stability criterion. This reasoning is even more important for gyros than the traditional reasoning for fixed-wing airplanes above. The degree of static stability of a gyro, not being a "fixed-wing" aircraft, can change dramatically depending on the nose-up or nose down condition relative to the flight path. Without getting too involved in this article, the position of the CG of the gyro, relative to the Thrust Vector of the rotor (RTV), can change dramatically depending on the power or thrust of the propeller. This is the issue often over-simplified by the term "propeller offset". The relative fore/aft positioning of the CG to the lift of the rotor determines the actual degree of static G-load stability of the gyro – directly analogous to the same effect of fore/aft CG position on an airplane! This gyro CG location is changeable in flight and a function of a number of aerodynamic conditions including drag offset and moments and propeller offset. The goal of a good design is to balance all these airframe "moments" so as to not cause or allow the CG fore/aft position to vary significantly from the stable position on or in front of the Lift Vector of the rotor. For a gyro with a poor balance of all the static moments on the airframe, a change in power can result in a significant re-positioning of the fore/aft CG to even a point where it might be in a dangerously unstable position aft of the RTV.

Especially when the CG is positioned aft of the RTV, the G-Load static stability can be neutral or even strongly negative. G-Load stability will be discussed and tested in more depth in the 5th part of this series of articles. But, G-Load instability is the direct root cause of buntovers in gyro. G-Load static stability being so important to gyros, the Static Longitudinal Power Stability criteria in the standard is about the best way to determine if any particular gyro might have a tendency, with high or increasing power, or with sudden decreasing power, to buntover. Those gyros popularly described as "high thrustline" (because the high propeller thrustline is not effectively balanced by other aerodynamic moments including a HS) are often associated with the "buntover" or Power Pushover (PPO) problem. This Static Power Stability criteria and test are very useful in determining whether there might be a buntover or PPO issue with any particular gyro – "high thrustline" or not, at different power settings!

HOW DOES THE TEST WORK?

For testing purposes, to readily and safely measure the effect a power change can have on the CG / RTV relative fore/aft position change, we simply measure the change in "trimmed" airspeed between the different power settings. Trimmed airspeed is a direct function of the gyro angle of attack relative to the flight path. If the cyclic stick position is not changed, the rotor disk also flies at the corresponding new disk angle relative to the flight path. With the stick in one position a higher airframe and rotor disk angle of attack amounts to a decrease in airspeed – much the same as an airplane flies slower at a higher wing angle of attack. With constant stick position, a higher "trimmed" airspeed with a power change indicates that gyro is flying at a lower angle of attack, nose lower, relative to the flight path. A lower "trimmed" airspeed with a power change indicates that the gyro is flying at a higher angle of attack relative to the flight path.

A change in airspeed, as a result of power changes, indicates the likelihood of a change in static G-Load stability margin. When the cyclic stick position is not changed, as in the criteria in the standard, fore/aft CG position relative to the RTV is not significantly changed either – that is why this test is safe to do! If the stick position is maintained in its initial position as in the test criteria, the G-Load static stability margin is essentially unchanged also. But, the airspeed and airframe pitch attitude does change and, in normal operation, the pilot will likely compensate with stick input to maintain the same airspeed and pitch attitude at that changed power setting. That repositioning of the cyclic stick and the corresponding RTV, then changes the RTV fore/aft position relative to the CG – with the corresponding change in G-Load static stability margin! In some cases then, especially those in which the pilot is inclined to apply more aft stick to keep the airspeed from building higher, the gyro is likely in a less statically G-Load stable condition – G-Load instability being the common root cause of either PIO or a buntover! This test, except when the airspeed changes are very high, cannot indicate conclusively if the resulting G-Load stability would actually be negative – dangerous! But, this test certainly can indicate if power application or change might be decreasing the degree of G-Load stability – possibly even to a negative condition!

Lest you think this is only important on “high thrustline” gyros, you may be surprised that G-Load static stability margin can also be less on some gyro configurations at the lower power condition. Anytime the airspeed increases with fixed cyclic stick position, with either higher or lower power, the G-Load static stability margin will be less if the pilot compensates by aft stick position. Whether that decreased G-Load stability might actually be negative stability (buntover prone) depends on the magnitude of the Power instability and the dynamic response of the gyro to power changes.

The Static Power Stability criteria in the standard allow some leeway from perfection. The specification allows 10% deviation of airspeed when power is either increased from MPRS power to full power, or when power is decreased from MPRS power to idle. A full 20% airspeed deviation is allowed for a power decrease from MPRS power to engine off – a very radical change in power, not proposing that you should do this part of the test. In respect to Longitudinal Static Power Stability, it is seen as not necessary to be perfect. However, the effect of power changes on pitch attitude and airspeed (and static stability margin) should have some limits – 10% as identified in the standard. Too much affect of power on pitch attitude would, in addition to the impacts noted above, run the risk of over reaction by the pilot to that sudden pitch change – such as on sudden power loss. During landing flare, and perhaps when a sudden nose-down pitch reaction might dramatically change the stability margin of the machine, over-reaction by the pilot at this critical time could spoil a safe landing or even possibly initiate a PIO or buntover in that marginal stability situation.

WHAT DO THE RESULTS MEAN?

What if my gyro does not meet the Power Stability test above? The answer depends on exactly what the test results were. The results require some interpretation, but this particular test is just the first indicator toward the ultimate pitch stability liability this gyro might have. The full static stability tests include the tests in the next two parts of this series of articles. This first static stability test should identify issues to be addressed and resolved before proceeding to the next static stability test:

If the change in airspeed with power changes exceeds the 10% margin, there might be a concern that a sudden power change, such as a sudden engine failure, could pitch the gyro so radically as to excite the pilot into over-reaction or even initiate an immediate buntover or PIO. A panicked pilot power change on a “botched” landing might also cause a sudden nose-up zoom, resulting in a hard, behind the power curve drop-in landing. Or, a panicked power change on a “botched” landing could cause a sudden nose-down pitch with sudden hard ground contact on the nose. Or, the sudden pitch change from a pilot “commanded” power change might excite an over-reactive secondary pilot reverse reaction at a point where the nose-lower, less stable condition could initiate a buntover or PIO. Any large airspeed or pitch changes resulting from a power change could result in extreme pitching rates. Especially for less experienced pilots, sudden excited reactions are not desirable!

If a power change, higher or lower, results in a higher static “trimmed” airspeed, this would indicate the tendency of that gyro to fly in a nose-lower, less G-Load stable condition - under that power condition. Such nose-lower flight at higher power and airspeeds are the traditional precursor to both PIO and buntovers and PPOs. A nose-lower attitude, induced by either power or airspeed or some combination, indicates a less G-Load statically stable condition. That nose-lower condition can even be a totally unstable G-Load static stability condition – the technical precursor in many buntovers! The nose-lower condition might occur also under even a low power condition. This would also indicate less G-Load static stability. G-Load static instability is the root of a buntover and can certainly excite PIO. Buntovers can occur on either “high” or “low” prop thrustline gyro configurations.

Even when the flight testing above indicates a nose-lower tendency with different power settings, even when it is within the 10% margin, I suggest you note that power condition and avoid turbulence and high speed and rapid maneuvers when flying at that power setting. In this way, these tests can indicate the flight conditions in which you should exercise more conservative flight.

HOW CAN I FIX ANY PROBLEMS?

Do not continue to the next static stability tests until any issues uncovered in this test are resolved within the 10% tolerances described in the test.

A radical pitch or airspeed response to a power change is most likely a result of the propeller thrustline offset (from the CG) being more than the HS can compensate. A very popular "solution" to "high thrustline" gyros is to drop the keel and lower the engine and propeller thrustline. In some cases, some high offset propeller thrustlines might require a larger HS than is efficient or practical. In these cases, some combination of improved propeller thrustline and more effective HS is probably required.

Less radical changes might suffice for less radical deficiencies. A HS can often be increased in effectiveness to better compensate for the pitching moments on the airframe. Effectiveness of a HS can be improved by a larger size, better airfoil shape, and positioning further aft on the tail. Immersing the HS more in the propwash (as opposed to minimal immersion when mounted on the keel) can improve the effectiveness of the HS when power (propwash) is applied. Only flight testing can determine whether this "power enhancement" of the HS will still provide adequate static and dynamic stability margins at reduced power (propwash) settings. This is why the ASTM standard specifies all stability criteria over a range of power settings, including at low power - to verify adequate stability margin with correspondingly lower propwash enhancement of the HS. A highly immersed HS can actually create overly strong pitch response to power changes – in such cases this response might be lessened just by changing the mounted angle of incidence of the HS.

In many cases, a strong pitch response to power changes might be simply that the existing HS is not properly installed to compensate for the propeller offset. A propeller thrustline that is above the gyro CG is trying to push the nose lower – destabilizing! A HS to compensate that nose down moment from the prop must react to the propwash with a tail-down moment – nose-up! Propwash (engine power) will often affect any HS – even ones that are placed low on the keel. Others, embedded more in the propwash, are highly affected by the propwash. Theoretically, the HS, reacting to propwash, should push the tail down as strongly as the prop is pushing the nose down. If the nose pitch attitude is not to react at all to changes in power, the HS would have to be "tuned" to perfectly balance the offset propeller thrustline. So, some improvements in Static Power Stability may be achieved simply by an angle of attack or positioning change of the HS.

As a general rule of thumb, the propeller offset should be less than 3 inches vertically displaced from the CG. A reasonably sized HS should be able to be arranged to compensate for that prop offset. This prop offset though, is not very easy to measure directly – it is hard to determine exactly where the CG of the gyro is. And, the CG position changes with different pilot weights, fuel loading, lunch, etc. This doesn't have to be perfect! This Static Power Stability test allows you to see just how far from ideal a gyro might be. But, even then, the Power Stability, a function of engine power may be only a portion of what affects the G-Load stability anyway. Anything that causes the airframe to fly at a nose-lower position in flight, such as aerodynamic moments and drag on the airframe, destabilizes the gyro. The aerodynamic effects on many gyros can have at least as much effect on G-Load stability – especially at higher airspeeds where those aerodynamic effects are higher.

In most cases, the HS is relied on to balance both the propeller (power) moments, and the other aerodynamic moments – the result of higher speeds. It is often difficult to "balance" all of these interacting moments from both power and airspeed. This Static Longitudinal Pitch Stability criteria and test is just one piece of the picture. The next two parts of this series of articles discusses the remaining two static longitudinal stability criteria in the ASTM standard. These criteria and tests should also be applied. All three static longitudinal stability criteria considered together, will much more fully indicate the overall stability safety or risks with a particular design. These remaining two tests are also very simple and easy to conduct. Individually, they also require some analysis and insight into what is happening. They may require some compromises in configuration to successfully meet all three sets of criteria. To assure safety and conclusive results, these static tests should be conducted sequentially, making the necessary initial adjustments on each test before proceeding to the next step.

In the Part 4 of this series we will investigate the ASTM standard criteria for Airspeed Longitudinal Static Stability – the next step in this process.

Fly safe, Greg