Europa Stall Spin Evaluation

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The intent of this document it to expand my previous flight stall test findings in the construction and flight test of numerous Europa Kit Aircraft, Classic and XS. This paper will go over the stall characteristics of a properly built and rigged aircraft. I will then attempt to expose some improper techniques which endanger the rusty or undertrained pilot when maneuvering near the stall angle of attack in a properly built aircraft. Finally, I will touch on some techniques to make the Europa stall characteristics more benign, then how to improve the rig and trim to improve a Europa which may exhibit "non-standard" stall characteristics.

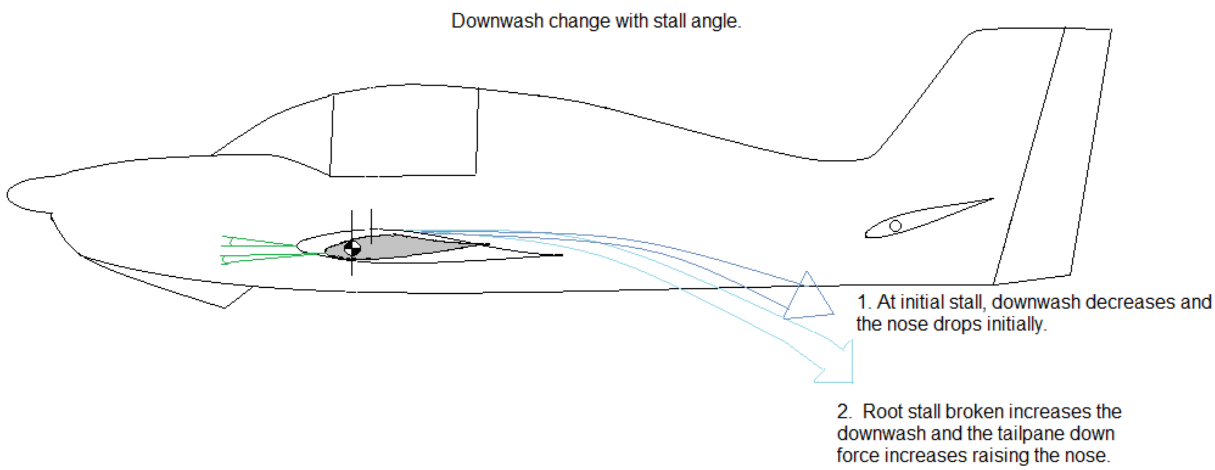
The Europa Aircraft:
The Europa Kit aircraft has a modified laminar flow wing of mild camber for high speed cruise with a leading edge modification to improve low speed stall warning and stall break. The wing has a mild taper and twist added to the wing to allow a smooth progression of the stall from the root to the tip during the stall. Wing area is slightly over 100 square feet and at a maneuvering weight of about 1300 pounds and a nominal 59-61 inch CG range will stall clean at nominally 49 KIAS, and with 27 degrees of flaps will stall at nominally 45KIAS. Nothing new there.

The layout of the longitudinal stability sets the main wing incidence at about 2.5 degrees positive to the longitudinal axis and the stab nominally at 0 degrees to the longitudinal axis. Pitch stability is positive in that the CG is slightly forward of the center of lift indicating the pitch stability is positive and dynamic stability is near deadbeat (rapidly corrects to pitch disturbance). The wing dihedral is nominally 2.5 degrees and the sweep is zero. Roll stability is near neutral / slightly positive (holds its initial roll without needing additional roll correction and slowly begins a side slip which eventually rolls the aircraft toward wings level rather than diverging deeper in bank). With the wing center of lift near the CG the pitch and roll stability and yaw roll coupling of the aircraft are delightful. By that I mean a slight amount of rudder induces a slow controllable roll toward the rudder direction (i.e. right rudder induces right roll). Pitch control is smooth and stiffens with airspeed increase, and ailerons are light and in harmony with the pitch. So roll control forces are very light at low speed and stiffen with speed increase.

Warning:
Stalls or high angle of attack maneuvering should be conducted at a safe altitude not below 3000 AGL and be done by an experienced pilot first in the test phase.

Armed with that knowledge I will look at the typical Europa Stall from the initial root stall to the full wing stall and its effect on pitch changes. Then I will introduce yaw/roll in and deeply in the stall. First the drawing below. Here the tip and root sections are depicted at the point where the root of the wing begins to stall. In 1 below the root is stalled, the stalled root reduces the downwash angle and the downward force of the stabilator. The initial tendency is for the disturbed or stalled root air will impact the stabilator transmitting a small but noticeable rumble through the airframe and due to the change in downwash (decrease) the nose will begin to drop.

In 2 below, it shows as the nose begins to drop the main wing root section is unloaded and the root stall is partially broken (rumble still present) and the nose begins to rise as the stabilator negative angle of attack is increased causing a slight nose rise. This nose rise is quite fast and the untrained or desensitized pilot may pull additional back stick increasing the angle of attack just as the wing goes slightly beyond the original stall angle (that is the delta of nose rise shown). As the root again stalls, the nose drops abruptly and the process of nose drop than rise repeats. The frequency of the nose rise and drop can increase to a fairly short porpoise frequency of one second per oscillation. Any additional back pressure at this highest point of the porpoise point may accelerate the stall causing a more rapid root to tip stall unzip resulting in a hard break.



NOTE:
RECOVERY OF THE AIRCRAFT STALL SHOULD BE AT THE FIRST INDICATION OF AIRFRAME BUFFET DURING RECURRING STALL PRACTICE RATHER THAN DEEP STALL EXERCISES.

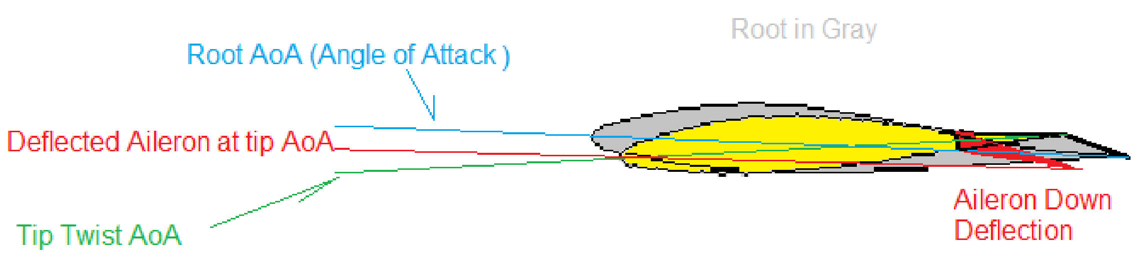
In a properly built Europa I am normally at about 1300-1350 pounds during testing and am able to use rudder, elevator, and NO AILERON, to bring the stick back to the stop and continue with a full aft stick deep stall. Many clients find this deep stall uncomfortable as the nose up and down bobble can get quite aggressive, and the airframe shutter is very pronounced. Then as the stall deepens, the root section becomes fully stalled the nose drops and the aircraft will stay in this full deep stall exercise with near or at full aft stick. Note that yaw control with the rudder is essential in this exercise and will be discussed further below. The deep stall is done only in flight testing to ascertain the fully developed stall which is useful for determining the aircrafts characteristics and corrections needed to allow the wing to be trimmed with stall strips to meet the owner's proficiency and landing needs. Tuft testing and photography may be necessary to determine the rate of stall unzip and stall strips may be necessary as well as rigging of flaps and ailerons. See the POH for stall strip discussion.

Stall Characteristics and Training considerations for the Europa:
Many laminar flow winged aircraft and some flatter bottomed airfoiled aircraft exhibit wing drop during the stall and a great fear of the aircraft's stall and failure to apply proper control at the stall warning is not uncommon. Normally, in a properly built aircraft any wing drop is normally due to the pilot failing to maintain coordinated flight. Civil instructors draw the trainee's attention to the turn and slip indicator to determine if the aircraft is in coordinated flight during stalls. This indicator is ideal for steady state cruise but in a stall series, it draws the trainee's attention into the cockpit to an indicator that lags and is damped. In more advanced training, trainees are taught to look over the nose and watch the nose

movement for precise yaw control. Instructors teach that as the aircraft begins to approach the straight-ahead stall, it is imperative that the trainee maintain the nose track of the aircraft (typically pointing precisely at a cloud). In this exercise, the pilot finds that P factor of the tractor aircraft changes noticeably with increased deck angle even at idle power. The Europa has the center of mass very near the center of pitch, yaw and roll and requires only small rudder inputs to immediately correct any out of yaw center condition. Normal certified aircraft have the engine many feet farther forward of the center of lift and the pilots are well behind the center of lift causing a larger moment of inertia and resistance to yaw to be overcome and a slower response of the controls is evident. In the Europa, the rudder response is quick and light and trainees find that it is not uncommon for nearly ½ inch of right rudder must be added as the slow creeping up on the stall progresses to hold the nose precisely on track with zero slip. The trainee is warned and forced not to add aileron to control roll but to use rudder to correct roll or wind drop as the stall progresses. When properly done, the break of the aircraft is normally straight ahead and benign. Recovery is immediate with a release of back pressure.

It takes a number of exercises to break the trainee's bad habit of adding aileron to correct roll in a stall. Most of today's aircraft have the wing tip to root twist at nearly 2.5 to 3 degrees of twist lowering the root to tip. However, it also allows the inattentive pilot to add aileron when in a root stall to control the roll as a 3-degree twist is significant and nearly 3-4 degrees of down aileron can be tolerated by the wing before the down aileron forces the tip to stall due to the lowering aileron. See the picture below of how the deflected down aileron will negate the effect of twist.

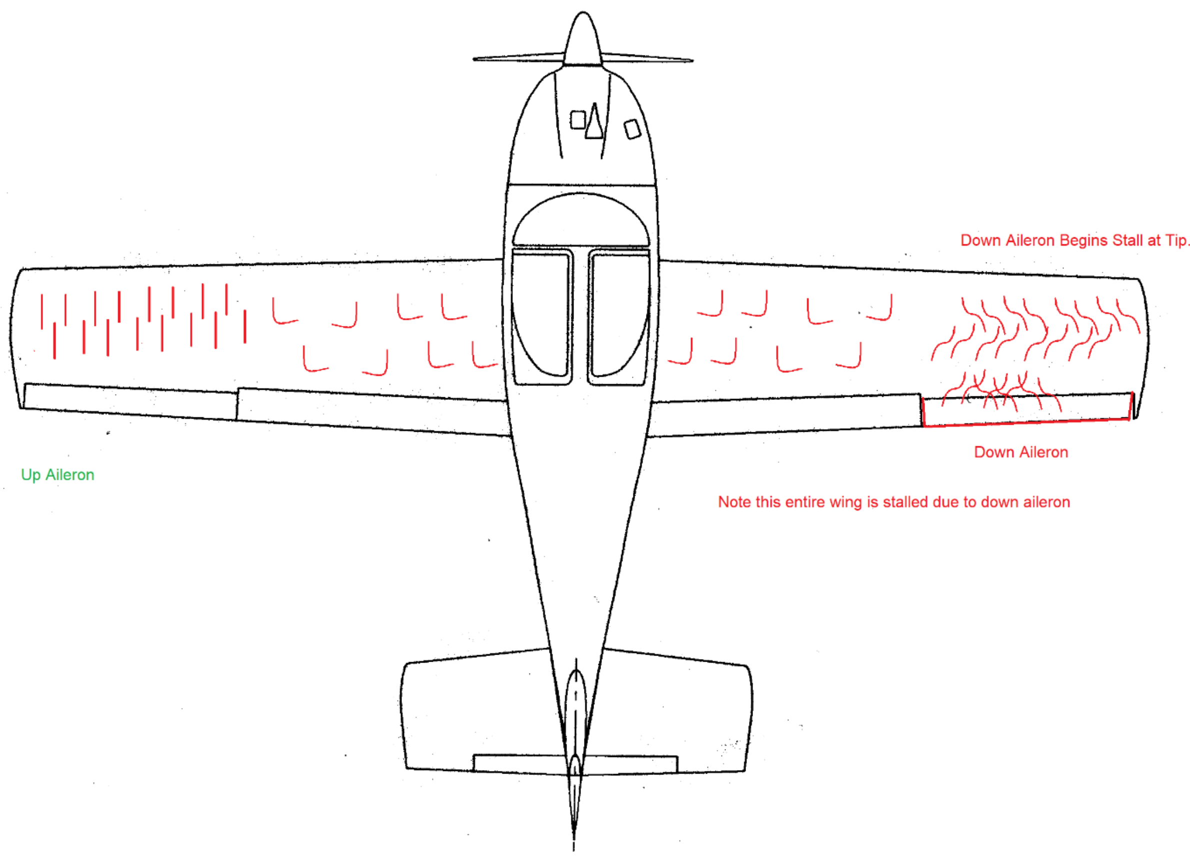
Aileron Deflection and Root to Tip Twist and its Effect on Tip AoA



The lowered aileron effectively increases the angle of attack of the "heavy" wing to the point where the aileron effectively eliminates the effect of twist and when the root is fully stalled the whole wing unzips or stalls with the root. With one wing fully stalled and the other still partially lifting the aircraft snaps into a quick roll. This is often confused as a spin. It is not, it is just a yaw/aileron, roll induced stall. See picture below:

The poor pilot habit of aileron use in the stall to pick up a low or drooping/heavy wing habit worsens with time and must be broken. The wing twist is a safety measure that improves low speed stall characteristics but unfortunately breeds improper pilot technique. Using any aileron in the stall is improper technique, the down aileron stall can result in a rapid wing drop opposite to the pilots stick input (i.e. right stick to counter the roll to the left lowers the left aileron so the stall will break into a left roll with right stick).

This sudden stall is not expected by the trainee, normally he adds more aileron to counter the increasing wing drop which exacerbates the approaching tip stall further causing a serious roll and perhaps startles the trainee. When the trainee applies additional back stick to raise the nose as the stall progresses, a roll rapidly begins and a spin entry is highly likely. In the case of departure from controlled flight (wing drop in our case above), the number one pilot action should be to unload or push the stick to neutral (pitch and roll). By breaking the stall, the roll will immediately stop, and the aircraft will begin a slight nose drop as if on a parabolic flight path. Continued increasing of aileron and backstick control inputs in a wing drop will eventually cause a fast spiral and if back stick is added to deepen the stall it will develop into a full spin.



Note I do not consider this aileron induced wing drop an <u>un-commanded roll</u> as it is a pilot induced deep wing stall that is causing this tendency for the rapid roll (aggravated snap roll) due to down aileron induced stall caused by poor technique. Nearly all aircraft exhibit this tendency above. <u>This aileron input during a stall or at low airspeed is a training deficiency that must be corrected through practice and proper control input practice.</u> Normally we consider a snap roll to be full back stick to the stall and then rudder input begins the snap roll. However, for a truly spectacular roll add opposite aileron (cross control) and the snap really wraps up. The lax or un-proficient pilot (myself included) has been easily lulled into adding aileron during the stall occasionally to pick up a wing because our well designed airplane allows some leeway. However, if encountering a secondary or deep stall, the nose drops then rises and then applying aileron leads to overcontrolling during the stall recovery, which from time to time causes a snap. Training prevents this recurrence of the bad pilot habit and proper rudder control will be relearned.

Slow flight and turn reversals during the slow flight drill helps improve the feel for the beginning of the stall, the aileron and the rudder and backstick needed for coordinated turns and maneuvers. This slow flight drill of a fully configured slow flight turn at 15 degrees of right bank then reversing to 15 degrees of left bank allows the pilot to feel how much back pressure aileron and rudder can be applied to make for a smooth coordinated turn or avoid a collision in the pattern.

Let us look back to a more traditional and proper control input needed during the approach to a stall.

As the trainee approaches the stall, he must maintain the flight path with rudder. As the nose rises with the increase in back pressure, the P factor draws the nose left and additional right rudder is needed to hold the nose steady on the point. As the root stall begins, the close proximity of the CG and low yaw moment of inertia of the Europa allows the P factor to have a more significant effect on the yaw of the aircraft. A solo pilot on the left side also has a minor effect as roll to trim will be essential in some aircraft. As the stall begins and the nose initially drops, it becomes quite evident of how much rudder is necessary. Normally, the trainee is impressed that the stall is straight forward and the recovery pleasant. I then train the pilot trainee to perform the stall in a more rapid manor by increasing the decrease in speed and speed of back pressure increase. Unless he already did it to himself. If the trainee was aggressive about getting to the stall as the burble began, he learns quickly how much rudder is needed for a straight ahead break as well as a feel for how to break the stall.

<u>To further the exercises the trainee then is introduced to the accelerated stall.</u> The accelerated stall has to be worked up to as the inexperienced pilot may not be comfortable flying beyond 15-30 degrees of bank and his ability to maintain bank, pitch and speed in a level steeper bank turn may need to be cleaned up. The accelerated stall is normally begun above maneuvering speed. In this exercise the stall is not approached with a one to two knot speed bleed off. We are accelerating the approach to the stall at a much faster rate, therefore there are some cues that are not going to be as evident, and the accelerated stall will quickly amplify any poor control technique.

Typically, I begin at about 120 KIAS three mistakes high. Normally stall strips have yet to be installed. I begin a warmup with 60 degree bank level turns and using power as necessary to maintain a level turn. Once warmed up, I do a series of hard turns followed by a quick unload and turn reversal to determine my and the aircraft's ability to roll left and right using aileron and rudder while max performing the aircraft. In the hard turns, small amounts of rudder control, slight nose up and down pressure, and aileron is necessary to correct minor roll corrections in the turn. To reverse the turn while in the burble of the stall, I teach an unloaded roll with aileron and rudder and re-establish the turn in the opposite direction to assess feel. Of course, unloading prior to the roll improves roll rate, and reduces a the tendency for a rolling stall due to the down aileron stall and resulting snap opposite to the stick input.

Note: Not unlike an auto tire, the tire can either accelerate or brake at maximum, or turn at maximum, rate without skid but it cannot do both at the same time or traction will be lost. A wing can pull to its maximum lift, or it can roll at maximum rate, but it cannot do both at the same time. UNLOAD to roll, and when the aircraft begins any un-commanded pitch or roll due to overcontrol UNLOAD IMMEDIATELY.

Back to the accelerated stall. Once established in approximately 60-degrees of bank and about a 2 G turn, back pressure is steadily and smoothly increased until the airframe begins to rumble. Normally, the recovery is at this point. For deep stall testing, the same is accomplished until into the rumble then back pressure is increased until the hard break occurs. Any un-commanded roll during the approach to the stall must not be countered with aileron. The rudder will be needed depending on the rate of approach to the stall and more importantly to overcome overbank and natural roll stability of the aircraft or roll correction of the pilot. P factor is fairly constant in this drill so not a lot of rudder is needed in the turn to control yaw into the stall. The trainee many times has his eyes straight ahead or on the attitude indicator attempting to fly a precise turn and does not notice the aircrafts flight path. In advanced pilot training, pilots learn that the aircraft flies to where his eyes are looking. In a low wing or canopied aircraft, I rotate my head to look for the point or position on the horizon I intend to maintain. By keeping one's head outside the cockpit the eyes and peripheral vision become God's attitude and slip indicator. This allows small rudder input to correct the flight path and typically the Europa responds with a rumble approaching the stall, then a noticeable heavy buffet to the stall followed by a nose rotation stop (break) as the aircraft root to tip stall progresses very quickly. Simply unload for control and recover to level flight.

Again, in practice the trainee should recover on the initial rumble until confidence and technique are fine tuned.

In training/proficiency and techniques, are summarized as follows:

1. The Europa is designed to have a benign root to tip stall progression.
2. Stall characteristics of the Europa are straight forward and can be made more benign through the use of stall strips but in many some cases satisfactory with no stall strip.
3. Pilot technique is essential to keep the sensitive yet easy to fly Europa under control at high angles of attack. The rudder at high AoA is the primary roll control and pilot proficiency is essential in its use in any aircraft.
4. Aileron for roll control is to be avoided at high AoA as in any aircraft.
5. In any event of un-commanded roll due to mis-applied controls unload for control.

Note:

In any aircraft, a spin entry from a stall is pilot induced. Once an un-commanded roll or pitch begins, unloading the pitch to zero breaks the stall and control is immediately regained. Simply recover back wings level and pull to level flight.

Only once the clean stall is analyzed with the trainee, may I go onto deep stalls with the flaps extended. This is a silly exercise mostly as there is no operational need for full flap deep stall maneuvering or accelerated stalls with the flaps down. However, there are important things to check in stalls with flaps.

Initially testing is in level flight begins with simply slowing to 80 knots straight and level and extend the flaps with hands free and determine the roll and pitch. Typically, a small roll is not uncommon with flap extension and there is a tendency for initial pitch up. Normally 5 clicks of down trim settles the plane to a 75 knot glide. Roll is first corrected with rudder then aileron to determine the amount of aileron/rudder that is needed to correct roll due to flap extension. Flaps are retracted and the roll is noted again. If roll with flap extension is very low, stalls tend to be straight ahead even when accomplishing a turning stall (30 degrees of bank max is normal). The aircraft power is pulled to idle and speed decreases rapidly with flaps fully down. As the stall is approached the buffet is noted about 3 knots prior to a slight nose bobble. Control stick forces suddenly lighten as the downwash over the flaps peaks prior to the burble and is my first indication of an impending stall. Once the burble begins the typical nose rise is less than when clean and the stall is quite abrupt. Stall strips do not give much more advance warning in my opinion, but the stick force lightening is very evident as is a pre stall buffet warning. Pitch control is noticeably lighter, so it is easy to overcontrol during the stall recovery. At the stall, full power and smooth pitch input to break the stall and arrest the rate of descent must be practiced due to light pitch control feel and the possibility of overcontrol is higher possibly causing a secondary stall. During the recovery from the approach to the stall, as the stall is broken and descent rate stopped, flaps are retracted slowly to initiate a slow climb and prevent airspeed bleed off. At any time once the initial nose drop has occurred followed by the nose rise with full flaps, aileron input to control roll can and will greatly increase the chance of severe wing drop. Failure to relax the back pressure with aileron will lead to a quick over-rotation and unless the stick is centered immediately a rapid spin entry is possible if back pressure is not released. To improve pilot technique, I fly a lot of slow flight drills at or near the burble at bank angles of 15 degrees and roll rates that are fairly aggressive to allow the trainee to become familiar with low speed maneuvering near the stall with flaps without overcontrolling.

Accidents from airshow arrival at Sun ‘n Fun and Oshkosh indicate there are a number of accidents which occur due to pilots attempting to maneuver aggressively at very low speed when startled by nearby aircraft landing or overshooting on a nearby parallel runway. Failure to maintain positive control is essential during a go around or collision avoidance maneuver.

Again, this can be a practice drill for the trainee. At final approach speed (three mistakes high) at a steady speed of 55 KIAS attempt a rapid pitch to best climb angle and roll aggressively to a turn away from the heading of about 15-30 degrees. I am often surprised that pilots forget where they are and the effect of failing to add power, unload to roll and setting a pitch rather than just pulling to the burble. Nothing good happens from a slow speed hard roll and pull with no power and an accelerated full flap stall can occur. Again, unload for control immediately if an un-commanded pitch or roll occurs and practice, add power, unloaded roll and smooth pitch increase to a climb attitude to avoid a collision. I can’t emphasize enough how beneficial go around practice is to set a habit pattern in how to establish a climb when safely airborne and fully in control while building speed.

Note:

I also do a drill flying down the runway fully configured in ground effect inches off the runway placing the left gear on the centerline, then the right then on centerline to increase the pilots proficiency flying close to the runway near the touchdown speed and then go around.

If there is noticeable roll with the flap extension or retraction in flight, land and investigate. After landing, the flap angles are remeasured, and flap retraction from up to fully extended in increments is measured. Since the flap tube is rather springy, I will look to see if there is binding or drag on extension that I may have been missed and normally the difference is a slightly crooked flap tube or difference in flap hanging causing about a degree difference in flap extension. I personally don’t mind if a couple clicks of aileron trim zeros out the roll in flight, but anything approaching 2-5 degrees of roll per second must be corrected. There are three primary techniques I use. If cruise trim is perfect when flaps up (clean) then I know the only issue is with the flap extension geometry.

1. Check the flap geometry and correct the flap arm lengths or position as required to get the flap extensions close to equal.
2. Check the fore and aft position of the flap pivot point as one flap may be ¼ inch different in its distance to the closeout. If so, disassemble and rebuild the flap brackets to get things equal.
3. Check the flap extension does not bias the flap tube one way or the other due to the angle of the flap drive tube.

Correcting for build errors that may contribute to an uneven stall break:
Let's now look at what can be done to tweak the stall characteristics to improve the "flyability" of the Europa aircraft for pilots that allow their proficiency to wane or for the novice or new to the Europa pilot to more easily transition to the Europa aircraft, and then analyze what must be done to correct the stall characteristics. In Custom Flight Trimming 101, I give three (more) techniques on how to check, correct roll, and trim ailerons from a construction and flight test standpoint to correct roll due to rig and how to trim it off. Of course, if the incidence between wings is off by more than 1/4 degree, get with your club, maintainer or other experts in composite repair and fix the darned thing. Once the incidence is corrected, if the flaps are off by more than 1/16 inch (one flap drooping) fix it with an up stop as in Trimming 101. This is fairly easy to do and techniques are in my writings. At the same time, if the ailerons have bias or spring in the mechanism, again, correct this until the ailerons will stay wherever you put the stick on the ground. That is if I set the stick at full right, it should stay, then check center, then left. If the stick springs back or the only thing holding the roll is the autopilot servo, again fix it.

I have found some wings have slight twist differences between the root and tip between wings. Again, checking the incidence and getting assistance in how much to adjust wing flap and aileron can correct the trimming of this twist and placement of stall strips can correct the stall characteristics to get excellent cruise trim and stall characteristics.

Similarly, if the rudder is not centered, adjust the rudder spring/cable length. If the engine offset is not per the book, adjust it. Square up the aircraft. If you bought the aircraft because it was cheap or you didn't want to build one, then I suggest you pay the money to find an aircraft that is square and flies true or devote the time and money necessary to correct the one you have.

Once we have a square aircraft, then proper fine adjustment of stall characteristic can be accomplished. My first go to of stall break or progression control is to add stall strips. The POH warns of the stall strip may cause too early of a root stall. Adjustment of these strips in size (I've done from 5mm to 12mm sized strips of about 9 inches long and adjusted the elevation until I get the right blend of pre-stall warning of about 4-5 knots and the proper rumble when the stall is slowly approached or accelerated. I adjust also to assure each root stalls about the same time when perfectly coordinated. Again, only through flight test and slight adjustments can these stall strips be adjusted to get the desired stall warning and prevent adverse "in ground effect full stall" landing characteristics.

Caution:

Stall strips set to trip the root stall too early will cause the aircraft to suddenly root stall in the flare and hit with a thud. Those pilots taught or allowed to fly toward the runway then pull to near level flight, begin to fall again then pull again to arrest the descent (falling leaf approach) may find he root stall may come on too early and the plane will literally stop flying abruptly.

NOTE:

ELECTRONIC STALL WARNING DEVICES AND OR AUTOPILOTS ARE NO REPLACEMENT FOR PROPERLY RIGGED AIRCRAFT WITH TUNED STALL CHARACTERISTICS. (Like auto antiskid, traction control and lane or autopilot, assistance in your auto, they cannot correct a damaged or poor suspension.)

A quick review of the POH Section 9 explains positioning and effects of the stall strip. I can't emphasize enough that the width, angle and position of the stall strip all have effects. Also, the minute positioning changes of the strips makes a difference in the stall warning characteristics. Flight test is essential for proper tuning.

In my paper “Stall Warning/Low Speed Warning/AOA Systems to consider for Europa Classic Tri-gear N12AY” contains more detail on warning devices as well as stall strips and placement.

In summary, if the plane is not square, fix it. Pay attention to rig and trim during construction. Correct any deviations. Ensure flap and aileron movements are within Annex E limits. In testing and analysis of the stall characteristics of an aircraft, a proficient and well-trained test pilot and sometimes cameras and video equipment will quickly find the stall, trim and rig issues. No pilot should attempt flight testing of deep stalls unless he is current and proficient and sufficiently high to recover from any situation. Routine proficiency training and review and proper flight evaluation is the key to a safe pilot who will be in positive control of his aircraft.

No pilot maintains proficiency without practice. Pilot practice should include recurrent stall training and annual flight evaluations. Do not rely on only flying one aircraft. Proficiency and practice in multiple aircraft assures a breadth of knowledge and improves discipline in preflight planning and skills. Never just plan to fly around. Plan your flight, your training events, emergency procedures for at least part of every flight. Then relax and enjoy your flight. Return to the field and squeak on that landing.

References mentioned are online at https://www.customflightcreations.com in the technics section and many are on the The Europa Club site.

Consider an annual review of some of these techniques during the preparation for annual flight evaluations. Those that only have a biannual flight evaluations comfortably flying around are not doing themselves a favor. Only through practice and inciteful evaluation can we improve as pilots and improve our home built aircraft.