Rigging the Pitts

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Pitts not flying so straight anymore? Don't believe that a Pitts can fly hands-off? Maybe you need to set aside a Saturday and do some rigging.

The maintenance manuals available from Aviat for the S-1 and S-2 are must-have items, as they contain the basic specifications and rigging information that you need. The manuals are the official "word"; this article is intended to explain a few of the details and tricks of rigging. Since any changes to rigging necessarily involve adjustment and/or disassembly of some major structural components, like flying wires, be sure that you have, or can hire, the qualifications required by the licensing category of your Pitts. Try to find an A&P who has at least some experience with rigging biplanes.

The following assumes that the airplane being rigged is already assembled, and is reasonably straight (i.e., it doesn't need any unusual rigging fixes just to make it fly well).

You'll need a set of rigging boards. 3 boards is the minimum; 4 makes the job easier. Volume 1 of IAC's Technical Tips Manual, page 50, has a drawing for some fairly sophisticated rigging boards. Mine are similar to these. I paint two of them white, and two red for contrast. If you only use 3 boards, 2 white and one red works well. It is possible to adjust these boards so that they will actually parallel the airfoil's chord line for either the top wing or the bottom wing, but this design can't be adjusted to do both, as the airfoils are different. Fortunately, that's not necessary; what is important is that the 3 or 4 boards be identical.

Leveling

Start by jacking up the tailwheel to level the fuselage using the upper longerons in the cockpit as the level reference. On the S-2B, the line of screw heads just below the aft cockpit coaming is parallel to the upper longeron, providing a convenient external reference. Next, level the fuselage laterally, again using the upper longerons are the reference; lay a level across just behind the instrument panel. Adjust tire pressure or slip shims under the main gear tires to achieve lateral level. Then re-check the longitudinal reference. This is a good time to be sure that your bank ball (if any) is centered. Also look at the compass card and see if it's level; more on this later.

Next, go to the tail. From behind the airplane, lay a level on each horizontal stabilizer. Both should be level. Check the tailpost for vertical. Adjust the four tail wires as needed. Check the tension in the tail wires. It may seem that the wires are so short that the tensiometer will be inaccurate, but this isn't really true. Because the tailpost and horizontal stabilizers don't have much rigidity, all four wires act as one wire, 4 times as long. You'll see that tensioning one tensions them all. See Aviat's manual for the tension specs.

Stabilizers and Elevators

From the side, check each stabilizer for twist. A Smart Level is handy here, or use a pair of boards about 30” long; lay one fore and aft near the stabilizer root, the other near the tip, and sight them. Note that the stabilizer has an angle of incidence, 2 degrees on the production S-1S and 2 ½ degrees on the S-2B. Adjust the stabilizer strut to move the outboard leading edge up or down as required to remove any twist. If you don’t have stabilizer struts and you are into hard aerobatics you may want to consider installing them. In addition to helping with stabilizer rigging, they help to prevent the known problems with the front stabilizer carry-through tube. With a Smart Level, you can easily check the left stabilizer against the right. If you’ve adjusted the struts, go back one step and re-check both stabilizers for level and the tailpost for vertical. Check the wires for streamline and re-tighten the jam nuts on the stabilizer wire clevises and on the struts. Note that the clevises have a tiny hole in the shank, as do the struts. Probe these holes with a piece of small safety wire to make certain that thread engagement is adequate. If the wire goes through the hole there is not enough thread engagement.

Clamp a board to one stabilizer to hold its elevator streamlined. Check the opposite elevator to be sure it’s also streamlined; if it’s not, you’ll have some trim drag. Fixing any difference here is beyond the scope of this article. With both elevators streamlined, adjust the trim lever to streamline one trim/servo tab, and be sure the other one is also streamlined. If it’s not, adjust the trim tab linkage on that side. Most S-1’s have only one tab and it is connected directly with a cable so there is no linkage to adjust. Make sure they trim lever is approximately in the center of its travel.

If you have a Smart Level, this is a good time to check the elevator travel. Up and down limits are given in the maintenance manual. Adjustable elevator stops are located on the control stick torque tube in the cockpit.

Wing Dihedral

OK, now for the wings. Start by stretching a string from the inboard end of one aileron bay at the trailing edge of the top wing, to the trailing edge at the opposite aileron bay. Clip on a hardware store “line level” exactly in the middle of the string, above the cockpit. Lay a rigging board on the top wing near each tip, parallel to the ribs (between the first two full-sized ribs, stay away from the tip rib). Lay a third, contrasting rigging board on the first rib bay outboard of the center section fuel tank; either side is OK. Adjust the aft rigging board supports to parallel the trailing edge. The rigging boards must parallel the ribs with the forward “hook” snug against the leading edge.

Place a ladder or stool about 15 feet to one side of the wing tip, and climb up for a look. If the top edges of all three boards line up perfectly (i.e. are at the same height and are parallel), then climb back down and check the line level. If the center board is below the line of sight between the outer boards, you have dihedral. If it's above that line of sight, you have anhedral. With the former condition, you must bring one or both wing tips down. With the latter, you must bring one or both up; the top wing must be flat, and dihedral/anhedral should be fixed before dealing with twist.

Suppose that you have some dihedral and the line level indicates that the left wing tip is high. The next step is to de-tension the landing wires on the left side. These are the wires which attach to the cabane at the rear of the top wing, and to the front spar of the lower wing near the I-strut. The S-2 has a clevis at each end of each wire, whereas the S-1 has a trunnion arrangement at the outboard end. Examine the jam nuts on the wire at the clevis, then when you've figured out which is left-hand thread and which is right, loosen the jam nuts. On the S-1, if not much adjustment is needed, just loosen the jam nut at the clevis; the outboard end of the wire can rotate in the trunnion. The two nuts on the trunnion end of the S1 will likely require some specially modified wrenches if you plan on adjusting this end in situ. Using padded wrenches near each end of the wire, rotate the wire so as to loosen, or lengthen, it, a half turn at a time. Rotate one wire a half turn, then the other wire a full turn, then the first wire a full turn, and so on, keeping track of the turns on each wire. Sight the rigging boards frequently, and as they begin to line up, take an extra half turn on the "first" wire to even up the turns on the pair. At this point, leave just a bit of dihedral. As the flying wires (the ones that attach to the fuselage at the forward landing gear attach fitting, and to the upper wing front spar out at the I-strut) are re-tensioned later, the outboard end of the upper wing will be pulled down a bit. That's the fun part of this job…any adjustment to anything adjusts everything else!

Level Upper Wing

Now that the top wing is approximately flat, check the line level to see if it's level. If it's not, you must shorten (tighten) the landing wires on the low side, and lengthen the wires on the high side. However, the landing wires not only support the weight of the wings, they also react the tension of the flying wires. So, before shortening a landing wire, relieve some of the tension in the flying wires on the same side. Once the top wing is flat and level, tighten the flying wires evenly to approximately the specified tension (750 to 1000 lb. for the S-2B, the S-1's wires are smaller and tension is less). Sight the rigging boards again for dihedral. This time, note any twist, keeping in mind that the center rigging board is the one that you can't change.

If an outboard (tip) rigging board indicates that the leading edge is twisted up (more incidence at the tip than at the center), you can add washers between the aft end of the I-strut and the bottom of the top wing rear spar on that side. Or,

remove washers at the forward end of the I-strut at the bottom of the front spar, if there are any. The former is possible without de-tensioning the wires; the latter is not. If the leading edge is twisted down at the outboard end, remove washers between the aft end of the I-strut and the bottom of the rear spar. If they're all gone, you'll have to add washers at the forward end of the I-strut beneath the front spar. Don't try to use washers to adjust dihedral. The idea is to get the top wing straight and level and make any tweaks to the system in the lower wings.

Lower Wings

Now, if you've tensioned the wires evenly and the top wing is flat and level, it's time to move to the lower wings. Place a rigging board near the root of a lower wing, and another near the tip, but stay on the full-sized ribs, not the tip rib. Be sure the rigging boards' aft supports are parallel to the trailing edge and the board is parallel to the ribs. If you have four identical boards, put a pair on each lower wing. Step back about 15 feet and sight the boards. You're looking for twist; it's the only thing you can adjust. It's easiest to add or subtract washers between the aft end of the I-strut and the top of the rear spar to make the wing at the outboard I-strut parallel the inboard, and this can be done without de-tensioning. If there are no washers at the rear spar and you need to lower the leading edge, you must de-tension and add washers at the front spar. Keep this fact in mind: If the landing wires are de-tensioned, the top wing is supporting its own weight, plus that of the lower wing and the I-strut, plus the downward component of the flying wire tension. So, de-tension the flying wires first, then the landing wires, and don't put any weight on the wings while installing washers at the lower wing front spar. Write down the number of turns that you use to de-tension the wires so that you can re-tension the wires the same way. Sticky notes on the individual wires are useful for this.

A few notes re: adding and subtracting washers:

- The washer which bears against the spar should be the large O.D. AN970-416. Don't remove this one.

- Use AN960-416 washers for the others. The AN960-416L is thinner and can be used for finer adjustments.

- Don't run out of bolt thread. Usually, a fixed number of washers are used at an I-strut connection. If you remove a washer from between the I-strut and the spar, replace it on the threaded end of the bolt.

- Aviat's manual allows a maximum of 5 AN960-416 washers at any I-strut bolt location. If you need this many, the strut fairings won't fit well.

I like to use four rigging boards and a Smart Level, because I can go from side to side and compare the angles of incidence. Obviously, you can't sight

through the fuselage. My Pitts flies best with about 0.4 degrees of leading-edge-down twist in the right wing, so that's how I set it. My theory here is that engine torque, P-factor, and propwash all try to turn the airplane to the left. The fixed rudder tab helps correct the yaw, and that little bit of washout on the lower right wing helps correct the roll caused by engine torque. Since the top wing stalls first, upright or inverted, and it's rigged true, the stall break is straight. Works for me.

Unlike the upper wing, the lower wings have dihedral. There's nothing you can do to adjust it, short of making new I-struts, but you can check it if you like by laying the Smart Level spanwise on top of the front spar. Spec. is 3 degrees for the production S-1S and the S-2B. Some experimentals have zero (or some other) dihedral in the lower wings.

Tensioning the Wires

OK, the top wing is flat and level, the lower wings have no twist unless you're trying a bit of Doug's anti-roll trim, and all the I-strut bolts are back in and tight. Time to tension the wires accurately. I use a Christen tensiometer from Aviat. Holloway Engineering (www.radialengine.com) also makes a tensiometer, which works fine, but requires a separate torque wrench. Start out by getting the landing wire tensions as even as possible on both sides, while continually checking for dihedral and level on the upper wing. At this point, just "twang" the wires until they sound about the same. Then, tension the flying wires evenly, checking occasionally with the tensiometer. Keep checking for dihedral and level on the top wing. As the flying wires reach specified tension, the landing wires are automatically tensioned. Here are a couple of things to think about while tensioning the wires:

- The landing wires will always have higher tension than the flying wires. They support the weight of the wings, plus their geometry is not as favorable (a more acute angle with the wing spar). The sum of tensions in a pair of landing wires will be roughly 200 to 300 lb. more than the sum of tensions in the corresponding (i.e. same side) pair of flying wires.

- It's difficult to get the tensions of each wire in a pair equal, because there's only a ½ turn "resolution". However, if you can't get them closer than 100 lb., try this: turn either wire of the pair ¼ turn one way or the other and check tensions. If you can get it closer this way, de-tension the wire, take the clevis pin out of one end, rotate that clevis ½ turn either way, and re-install. This actually gives you a ¼ turn resolution, and helps a lot. On the S-1, it's possible to adjust the hex nuts at the outboard end of the wires but you will need the specially modified wrenches referenced earlier. You will need to hold the inner nut with one wrench while you tighten the lock nut.

With the wires all tensioned and streamlined, make one last check with the rigging boards, lock the jam nuts, and probe the tiny holes in all of the clevises with a wire for adequate thread engagement.

Aileron Alignment

Align the lower wing ailerons with the trailing edges of the lower wings, at the inboard ends of the ailerons. This adjustment shouldn't have changed, but if it did, probably a half turn one way or the other on an aileron push-rod end will line them up. Always check those tiny holes! Be sure the control stick is centered. Note: Don't make major adjustments to the lower aileron linkage unless you really know what you're doing; it's possible to significantly alter the geometry of the pushrods and bellcranks, which could bind or even go over-center and get stuck. Now, examine the alignment of the upper ailerons at the inboard trailing edge. If not perfect, adjust by lengthening or shortening the slave strut. This is done by removing the clevis pin (actually a bolt) at the lower end of the strut and turning the clevis ½ turn at a time 'till it's right. If the upper aileron trailing edge is low, shorten the slave strut. If high, lengthen it. When it's right, re-install the clevis pin bolt and all of its washers and self-locking nut. Tighten the clevis jam nut. Now, all four ailerons should be aligned, and the stick should be centered.

Spades

Align the ailerons with the trailing edges of the wings. On the S-2B, it is just possible to sight from one spade, under the belly, to the other. You can see quite clearly whether they're parallel or not. If they're not, the spade plate can be shimmed a bit with washers, but if they're off by much, see if the support arms are improperly made, mounted, or bent. If you can't sight the spades, you can tape a small board to each, so that the boards hang down below the belly. Or, just use the Smart Level to compare one side with the other. Start out with spades parallel. Put all the fairings and javelins (the flying wire spacers) back on for the next step.

The Fun(ner) Part of the Job

Time to go flying. Try to stay upright long enough to establish a normal cruise speed and power setting. Trim the pitch for zero stick force in level flight. With reference to your bank ball, or your compass card if you, like me, have no bank ball, or to the calibrated seat of your Levi's, use a little rudder pressure as necessary to eliminate any yaw. Hold the wings level and note any control pressure needed. Look at the ailerons; are they deflected to maintain straight and level flight? Now, move the ailerons to align with the trailing edges, and note which way (if either) the airplane rolls and how fast. Make a mental note of all this. If you can let go of the stick long enough to write it down, you probably don't need any notes.

If, with the ailerons held neutral (i.e. trailing edges aligned), the plane rolls one way or the other, you need to adjust wing incidence a bit. Say it rolls left. The easiest fix is to reduce the angle of incidence at the outboard end of the lower right wing by removing a washer between the I-strut and the top of the rear spar. If there isn't a washer there, you can add a washer between the left I-strut and the top of the rear spar on the lower left wing. Either of these adjustments can be made without de-tensioning the wires, and either will require re-adjustment of the aileron slave strut on that side. If the plane rolled right, the fix is opposite of the above.

Once you get the plane flying wings-level with the ailerons held centered, you can deal with any remaining stick forces by trimming the ailerons with the spades. This is a precision operation, calling for thin washers. As an example, if you release the stick and it moves to the left, causing left roll, you can add washers between the top surface of the right-hand spade plate and the forward end of its mount (i.e. the front two of the four mounting screws). This gives the right-hand spade a little more "bite"; it's like right aileron trim. If gross amounts of adjustment are needed (like more than one thickness of washer), it's likely that the aileron effect of the spade itself will upset your wing incidence rigging. It might be best to remove the spade plates, fly and get the wing rigging right, then worry about trimming the spades.

The Bottom Line

Even if perfectly rigged and trimmed, the Pitts responds to every change in power, attitude, speed, and passenger movement. That's why we fly them. However, if your Pitts was built reasonably straight in the first place, it's possible to rig and trim it to fly for a hundred miles hands-off, using just a touch of rudder pressure and occasional pitch trim to compensate for fuel burn. A well-rigged Pitts will fly straight, stall straight ahead upright or inverted, spin well either direction, and is a delight to fly.