The Fine Old Art Of Rigging A Biplane

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When the center section is all done and the lower wings are hanging by the landing wires, it is time to install the upper panels. Depending on the ship's size, it can be easy or a struggle. Lay a plank across two step ladders at convenient working height just outboard of the wing tip so that two men can lift the tip to proper height while a couple others raise the root end, using the lower wing's walkway and the landing wheel for steps. Have handy spikes, awls, drift pins, Phillips screwdrivers, etc., to shove into strut, root and wire fittings quickly and take the strain off the men. Then one by one put the correct bolts in place.

Set the bubble protractor at the specified degrees of wing dihedral. Place the straightedge on the top of a lower wing as in Fig. 7 and by turning up the landing wire bring in correct dihedral. Sometimes it's necessary to bring the bubble a little past the line to take into account wire slackness; when the flying wires are tightened later, dihedral will be pulled down to the correct amount. Once the protractor has been set, do not change it until dihedral rigging is done, because one's hands and eyes are not sensitive enough to get exactly the same setting two or three times in a row. Put pencil marks on the wing to show where the straightedge was laid, so it can be replaced exactly if need be for a later check. If there are two landing wires on each side, use only the front one to rig in dihedral at this stage.

At this point, careful center section adjustment and carefully made wing root fittings will be holding upper and lower wing panels at the correct angle of incidence **at the roots.** Next step is to rig that angle into the panels all the way to their tips. Place the incidence board under the lower wings at or just outboard of the interplane struts, as the men in Fig. 5 are doing. If the ship has two landing wires, use the rear one to raise or lower the trailing edge. Or perhaps the rear interplane strut has a threaded fitting. Then rig incidence into the top wings with whatever strut or wire adjustments are obvious.

Then things can be tightened up, turning each of the several wires about half or one turn at a time in orderly fashion. **Never use pliers or common wrenches on them!** Saw and file a half-streamline shaped notch into the end of a brass or aluminum rod or bar, to fit the wire section nicely, and use that for turning them without causing dangerous scratches. Don't pull wires up agonizingly tight, for that will strain fittings and warp wooden structural members. Fair tension is ample. If a wire flutters on the test hop, it can be tightened a little . . . though you may find that has slacked off another one, which will then start wiggling! That's why they use "javelin struts" where the flying and landing wires pass each other as on the Waco 9, Fig. 3. These are of wood, taped on.

There is a difference of opinion in old texts on the question of rigging some wash-in or wash-out into biplane wings, to counter propeller torque's tendency to roll a plane in the opposite direction. One school of thought points to the corkscrew path of the prop slipstream. Obviously it makes the relative wind blow up on one wing root more, and blow somewhat down on the other one, resulting in an automatic difference in lift, changing with engine speed to counteract torque. Others say to use wash-in and wash-out, one old text recommending an inch of wash-in on biplanes powered by 100 hp engines! Some say to use wash-in only, others to divide the required corrective force between opposite lower wings with wash-in and wash-out.

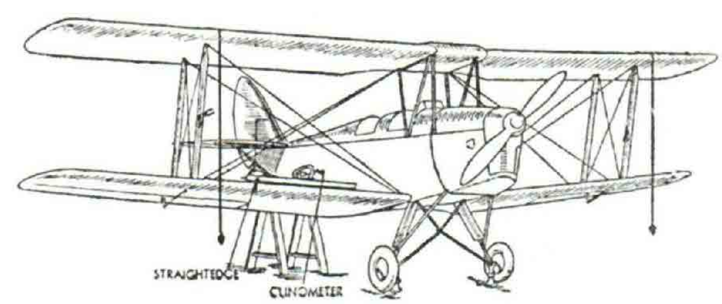

Fig. 7. Measuring dihedral.

It seems that the validity of the slipstream theory would depend on the relation of wing span to propeller diameter. The eight and nine-foot propellers on slow-turning 100 to 250 hp radial engines obviously puts prop wash over a considerable proportion of the wing area in biplanes of 28 to 30 foot span. But most texts describe the wash-in, wash-out method. Unless specific rigging data is available it might be best to test hop a biplane with no wash-in or wash-out, note wing heaviness, and adjust accordingly. If an undue amount of wash-in (higher angle of incidence) is needed to correct torque, it can lead to premature stalling of the wing tip concerned so it would be well to divide corrective measures between some wash-in on one wing and wash-out on the other side. Old biplanes with plain ailerons and unwarped wings can lose aileron control quickly and completely in a stall. Read pages 163-175 of "Stick and Rudder" by Wolfgang Langewiesche before flying an old biplane!

Still talking of torque correction, remember that when the wings are warped to counter it, any particular adjustment will work only for one air speed. Usually things are set to make the plane fly level at cruising speed — but that can vary with load though the engine rpm is held constant. Torque effect shows up more in big-propellered, short-spanned biplanes than in today's small-propellered, large-span monoplanes. Odd things in an old biplane's flying characteristics often are based on the nuances of torque and those big propellers. For example, if the engine is throttled back fully when gliding in to land, the big prop will windmill and slow down the flow of air through it. This retarded air stream passes over a sizeable proportion of the wing area and it makes the ship come down a lot faster than the average monoplane. Carrying a small amount of power in the approach lets wind flow through the prop without retardation and the approach is less bricklike! The same applies to today's midget biplanes, whose propellers are large in diameter relative to the span.

One cannot change the length of a strut or wire without changing others in its group to allow for the altered length. If a terminal is screwed out too far, too few threads do the holding job and there's danger of their stripping. When starting to assemble the plane, run end fittings on as far as common sense says they can or should go. Frequently there is a tiny hole in the side of terminal barrels, as can be seen in Fig. 8, so that a wire can be poked in to see if threads have gone in at least that far from the end. If, after rigging, you cannot feel the rod threads, safety demands that rigging be changed to allow that minimum number of threads to be engaged. Fig. 8 also points out that there are two measurements to take into account when working with or ordering tie rods. New streamline tie rods are expensive but can still be ordered to fit through supply houses such as Air Associates or from a manufacturer such as the Macwhyte Company of Kenosha, Wis.

Match up left and right wires and struts to have them of equal length before starting. Tie rods have left-hand threads on one end and right-hand on the opposite end. It is standard practice to have the right-hand thread ends at the lowermost, innermost and forwardmost points, so mechanics won't become confused as to which way the various lock nuts should be turned. Lightly grease threads before installing terminals. Do not jam lock nuts up very tight, for that puts a concentrated pull on the wire at that point; added to the normal flight stresses it could make a tie rod part.

Ailerons normally carry an up-load, and depending on the stretch characteristics of the control cable system, will or will not be affected in flight. Sometimes they are rigged so their trailing edges are even with the wing trailing edges on the ground. In other ships, they are rigged with their trailing edges from 1/4 in. to 1/2 in. low so that air loads in flight will hold them even with the wings. Less frequently, they are rigged to ride slightly above the wing trailing edges when in flight, perhaps an eighth of an inch, on the theory that this reduces overall airfoil incidence at the tips and causes that area to stall later than the rest of the wing so as to retain aileron control longer. If rigging data is lacking, rig them even with the wings and make test flights to decide if changes would help aileron effectiveness.

Some biplanes have no dihedral in the upper wing, and in these it is often the practice to set the top wing in place, rig it straight, and use it as a reference point to get the proper dihedral into the lower ones. The Fleet biplane is an example. Partly to illustrate typical, actual factory rigging instructions of the 1920's and 1930's and partly to make the information available to antique enthusiasts, herewith are erection and rigging instructions for the Fleet and Waco F airplanes.

Fig. 8. Measuring an aircraft tie rod. Note safety holes in terminals.

FLEET:

1. Place upper panel upright on leading edge, with padding on the floor.
2. Attach all interplane struts.
3. Raise panel above fuselage and attach center section struts to fuselage.
4. Attach center section wires and tighten to fair tension.
5. Attach lower panels to fuselage; tighten and cotter nuts. Lower wing-to-fuselage attaching bolts should be a snug fit without play; use 1/64 in. or 1/32 in. oversize bolts in reamed holes if there is play. Should be a light drive fit.
6. Attach landing and flying wires; left-hand thread at upper ends.
7. Level fuselage. Top longerons and cross tubes in both cockpits may be used or both bottom longerons and cross tubes between front and rear lower wing spars.
8. Drop plumb lines D, Fig. 4, from leading edge of upper panel at points in line with center section strut attaching points. Measure distances X and Y from bottom longeron to plumb lines and adjust wires A and B until X and Y are equal and center section is level.
9. Drop a plumb line from leading edge of upper panel at outer strut attach points; measure distance from leading edge of lower panel to plumb line for stagger. This should measure 23 in., both sides symmetrical within 1/8 in. and can be equalized by adjusting center section adjustable struts.
10. Dihedral of lower panel is 4 degrees. Upper wing has no dihedral. Center section of upper wing has been leveled as in (8). Level remainder of upper wing by adjusting landing wires L so that upper wing is straight, taking care that flying wires F are slack enough to allow this. Then tighten up flying wires F. Lower dihedral may be checked if desired.
11. Using incidence board, Fig. 6, adjust lower outer panel incidence to zero degrees via the adjustment on the rear interplane struts.
12. All streamline wires are lined up with the air stream and lock nuts tightened.
13. Insert bakelite spacers at all streamline wire crossings and tape. Use two of them at center section wire crossing and four on each side at flying and landing wire crossing.
14. Grease hinges on wings and ailerons, and inside of operating arm on inner end of ailerons.
15. Approach wing with aileron from rear, sliding aileron operating lever, on aileron, through opening in rear spar over operating lever tube in wing.
16. Push aileron forward until hinges mate.
17. Insert greased hinge rod through hole in wing tip bow. Secure with two drilled head fillister machine screws at outer end and safety wire.
18. Support ailerons with 1/4 in. droop on each. Support stick in neutral and adjust fork ends on inner ends of operating tubes to match holes in operating lever in cockpit, locking fork at proper adjustment with lock nut. Connect operating tubes to operating levers with bolts and bushings. If droop of ailerons on ground is such that trailing edges do not line up in flight, adjust to correct.
19. If in hands-off flight one aileron droops and the other rides high, the ailerons are unsymmetrical in contour, the high degree of balance of these ailerons making them sensitive to changes in contour. This produces an apparent wing heaviness that is corrected with the ailerons rather than on the wing rigging. On the under surface of the aileron near the outer end two ribs are provided with a variable camber device. Cover is cut to reach them. Two screws are turned to change camber, backing them off until the aileron rides evenly in flight on the one which rides high. Test fly until satisfactory.

WACO F:

1. Remove streamline wire-end terminals and screw them back on five complete turns to insure an equal amount of adjustment on each threaded end.
2. Bolt center-section struts to center-section.
3. Mount center section on fuselage.
4. Fasten center section wires.

5. Adjust center section wires so that the distances between pin centers are the same on both wires.
6. Fasten front and diagonal interplane struts on upper wing with adjustment ends at bottom. Fig. 9a.
7. Mount lower wing on wing fittings on fuselage, and insert 3/8 in. bolts, long one front, short one rear. Wing tip must be propped up in position until upper wing is mounted and landing wires are fastened and tightened.
8. Fasten long interplane strut to rear of diagonal strut. Fig. 9a.
9. Mount upper wings on center section, using 5/16 in. bolts with taper bushings.
10. Bolt interplane strut on lower wing.
11. Put on landing and flying wires, with left-hand thread to the top. Don't tighten.
12. Draw up front landing wire to 94⅛ in. between terminal ends, Fig. 9d.
13. Tighten rear landing wire until tension on both wires is equal.
14. Tighten flying wires.
15. Wings are rigged with no warp, as no allowance for propeller torque is needed.
16. Adjust interplane struts.

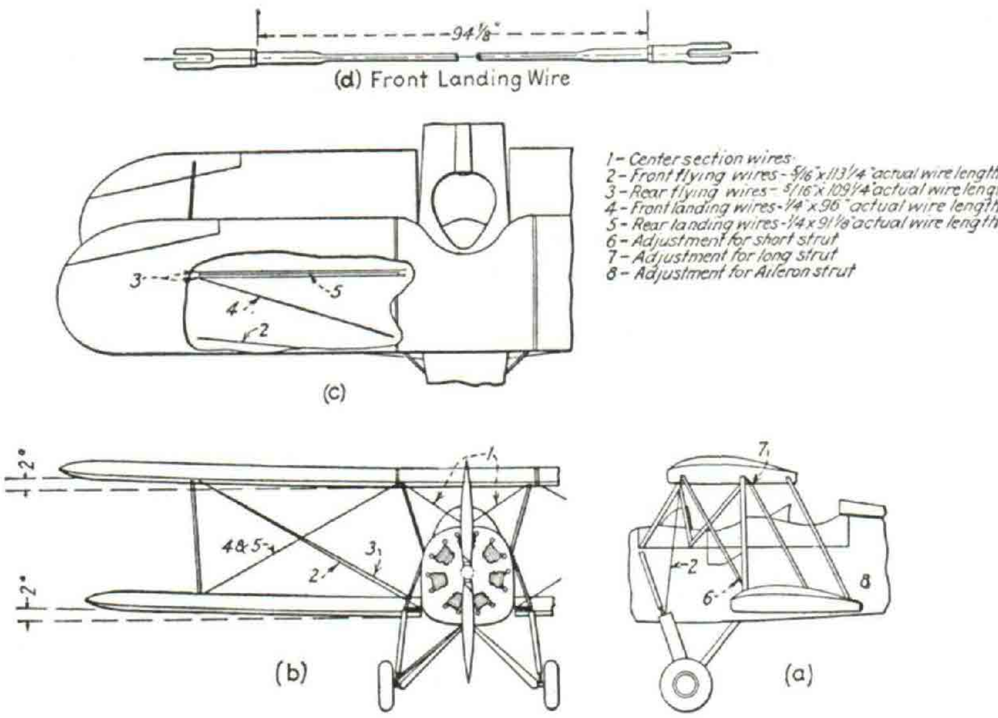

Fig. 9. Waco F rigging diagram.

17. Cotter all fastenings.
18. Connect aileron push tubes under fuselage so that both lower ailerons are even with the wing trailing edge when control stick is in neutral.
19. Adjust aileron struts so that upper and lower ailerons are even with wing.

Herewith is a table of rigging specifications for several biplanes, reprinted from CAA Aviation Safety Release No. 317, April 7, 1949. The gap figures given for the Great Lakes biplane do not make sense to the writer but they are printed as given in that official release.

MODEL	STAGGER	GAP	INCIDENCE degrees lower	INCIDENCE degrees upper	DIHEDRAL degrees lower	DIHEDRAL degrees upper
Eaglerock A-1	10"	5½' at tips	1¾	1¾	1½	1½
Fleet 1, 2, 7	23" ± ⅛"	**	0	0	4	0
Fairchild KR34C	9.63"	63¾"	2½	2½	1	0
Fairchild KR21	14"	63"	2	2	2½	¾
Great Lakes 2T1-A*	25"	25" CS 12.8" IS	3	3	2	3
Navy N3N-3	26-7/32"	65"	2	2	2	0
New Standard D-25	34"	**	**	**	4	2
Bird A, BK, CK	30"	58"	2	2	0	0
Stearman C3R	22½"	63" at root	1¾	1¾	2	1
Stearman PT-17	28"	72" at root	4	3	1½	1
Travel Air 2000 and 4000	25½"	58½" RS 55½" IS	3	3	1½	0
Travel Air E4000	29"	61½"	2½	2½	3¾	4
Waco GXE, ASO	10½"	62¼"	0	0	0	0
Waco RNF, INF	28½"	54"	0	0	2	2
Waco QDC	33-5/16"	55½"	0	0	1¾	1¾
Waco QCF	33¼"	55½"	0	0	2	2
Waco UEC	31-5/16"	55½"	0	0	2½	2½
Waco UIC	33½"	53⅛"	0	0	2½	2½
Waco UKC, VKC, VKS	31-5/16"	53-1/16"	0	0	2½	2½
Waco YKC, YKS, ZKS	31-5/16"	53-1/16"	0	0	2½	2½
Waco YOC***	38⅜"	49" RS	0	0	2½	2½

NOTE: RS = Root Section. IS = Interplane Struts. CS = Center Section.
* Great Lakes wing sweepback in degrees, lower 0, upper 9 deg. 30 sec.
** No data available.
*** Waco YOC wing sweepback in degrees, upper and lower, 2½.

BIBLIOGRAPHY

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"Aviation Service and Maintenance" by James G. Thompson, Aviation Press, Los Angeles, 1937, has service, adjustment and rigging chapters on Wacos, Fleets and Travel Airs. Travel Air chapter has detailed rigging chart for all models.

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"Airplane Construction and Repair", John E. Younger, McGraw-Hill Book Co., Vocational Texts series, 1931, has a good rigging chapter with data on Fairchild 71, Fleet, Waco F, Fokker Universal, Boeing 40.

"Aviation, Vol. 2" by American Technical Society, Chicago, 1945, has good rigging chapter including coverage of method of assembling wings on double-bay biplanes such as Jenny, Fledgling, etc.

A good source for used textbooks of all kinds is Barnes & Noble, 5th Ave. at 18th St., New York, N.Y. Also try book-finding services in classified ads of Popular Mechanics, etc.