PART 2

Further refinements for improved biplane performance

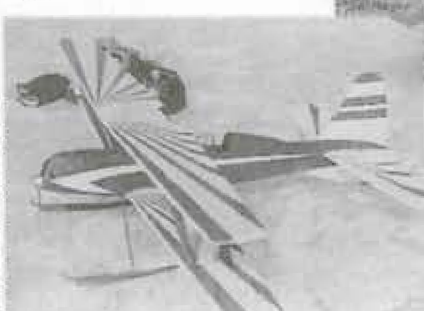
Biplane Secrets

by CARL RISTEEN

PART 1 OF this article briefly covered the evolution of airplanes, and how it led to biplanes, with their problem of mutual wing interference, and methods to combat it. Also covered were the effects of stagger, decalage, wing flaps and incidence. This part covers further refinements that have been shown to improve biplane performance. In Part 3, in the next issue, I'll look at triplanes and some angles on bipe fun-fly designs and more on interplane strut design.

Although long-time favorites of scale modelers, bipes have not, except for a few outstanding models, fared all that well against monoplanes in purely performance-oriented model competition. This is because of their inherent aerodynamic shortcomings. Many of these shortcomings can be offset by cunning design and construction, thereby permitting the bipe's unique, inherent strengths to shine through.

A 68-inch-span biplane designed by the author for .60 to .73 2-stroke power, shown here with a Webra .73 and quiet muffler. Doreen Armstrong holds the plane.*



A later modification of the same bipe included the addition of streamlined skis. Bipes are great on skis.

TAPERED WINGS: UNUSUAL BUT PERFORMANCE ENHANCING

At just about the apex of biplane development, some outstanding tapered-wing designs appeared. Two paramount examples were the deHavilland DH 86 Express and DH 89 Dragon Rapide of 1934. Four- and two-engine airliners, respectively, these were arguably the most gorgeous multi-engine bipes ever built. Both featured relatively high-aspect-ratio wings with a graceful and efficient semielliptical taper. The smaller DH 89 has also been considered almost as important as the DC-3 in advancing air travel. A total of 1260 DH 89s, including the military version, the Dominie, were built. Many remained in service for decades. Their excellent handling, reliability and short-field capability were particularly valuable in extending airline service to smaller communities serviced by crude, short airstrips. Al Williams' beautiful racing Gulf Hawk of the 1930s was another example of a superb tapered-wing bipe.

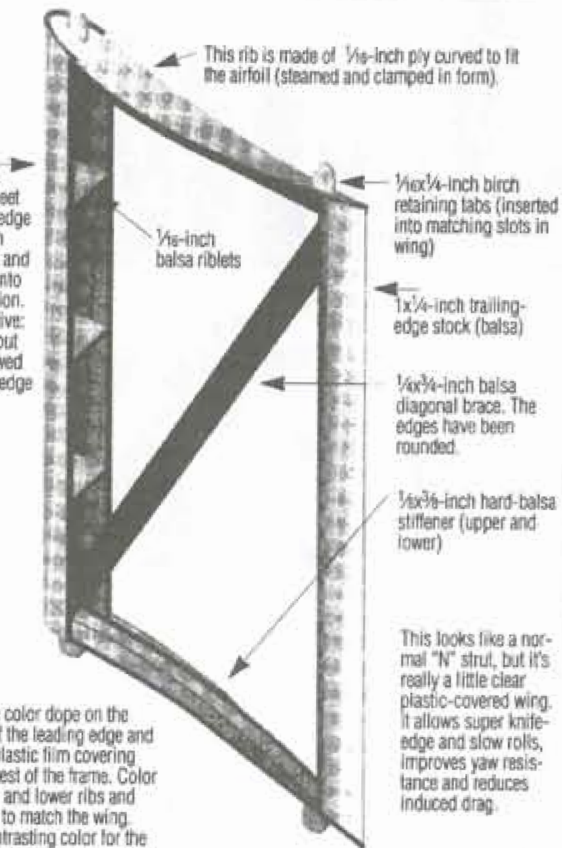
Tapered wings are something of a rarity on full-scale bipes. On an unbraced monoplane wing, taper can save a lot of weight. Taper makes the wing thicker near the fuselage, where bending moment is highest. This provides room for deeper spars that are much stronger for their weight. Taper also moves the center of aerodynamic loading closer to the fuselage, reducing the bending moment and further lightening the structure. Tapered wings require less aileron-control effort to produce a given roll rate, and they produce less aileron-induced yaw. In addition, both profile and induced drag are reduced, and lift is increased by a few percent. This combination of weight saving and increased efficiency can mean the difference between a so-so airplane and an outstanding one.

In most full-scale bipes, wire bracing carries the lion's share of the wing bending moment. This negates much of the incentive to create a costly tapered-wing structure, although taper would permit the use of thinner, and thus less "draggy," bracing wires. I switched to tapered wings on my model bipe designs and was pleased to obtain much more axial rolls, a higher roll rate with smaller servos and nicer all-around handling—not to mention a considerable weight reduction.

Tip-stall, a misdeed that tapered wings are frequently accused of, has never been a problem for me. If anything, I think that the reduced yawing couple produced by a smaller chord tip near stall may make inadvertent stall followed by a snap roll less likely. I should mention that all my bipes have full-span ailerons; shorter, barn-door ailerons would probably tend to produce a little more tip-stall misbehavior. I do use a degree or two of washout (twisting of the wings to achieve a lower incidence angle at the tips) to help keep the ailerons in business right up to deep stall.

The tips of moderately tapered wings, because of their smaller chord, *do* fly at a lower Reynolds number than the wider-chord inboard portions. They also fly in reduced downwash, slightly raising their effective angle of attack. The net result can be a tip-stall at an angle of attack that is half a degree or so lower than with a constant-chord wing, assuming that the airfoil section is constant along the entire span. I like to use a constant leading-edge radius all along the wing (it makes building easier), resulting in a tip section with a proportionally larger leading-edge radius. This kink may help to increase the stall angle of attack by half a degree or so at the tip.

I also like to use box-section main spars with close to ideal taper, with small turbulator spars in place of the more usual D-tube fully sheeted leading edge. This construction results in very light, strong, easy-to-repair wings that, on a monoplane, would probably have marginal torsional stiffness. They work well on a biplane, where the interplane struts provide a lot of additional torsional stiffening. Saving weight is one way to make the biplane layout work for you.



Detail of knife-edge "cheater" interplane strut

AILERONS: TWO OR FOUR?

My first bipe design had two, wide-chord, full-span ailerons on the lower wing and no ailerons on the upper wing. That didn't do the job. In desperation, I increased the aileron travel to nearly 45 degrees each way, but the roll rate, though fine for scale-like, gentle sport flying, was still too slow for snappy aerobatics. Full aileron deflection produced excessive, sloppy yawing and very noticeable drag. The model practically screamed for four ailerons.

You might think that two double-width ailerons would do the job of four narrower ones. They don't. Lowering an aileron on the lower wing of a bipe lowers the pressure, not only on the upper side of the lower wing, but also on much of the underside of the upper wing spanned by the aileron. This lowered pressure tends to pull the upper wing down and oppose the roll. The no-aileron wing also strongly resists being rolled. Rolling induces a change in effective angle of attack that results in a large lift force that opposes the roll. The result is something like trying to steer a car by only one front wheel, with the other wheel locked straight ahead.

As an experiment, rather than performing major surgery, I slipped a bunch of thin mini-hinges into the existing trailing edge of the upper wing, and I attached airfoil-sectioned ailerons. The model was transformed, and all of my bipes now sport four ailerons. Another bonus: four ailerons demand less than half as much servo effort to produce a given roll rate, reducing servo and battery weight.

Very small bipes may roll acceptably with only two ailerons, but anything with a wingspan of more than about 48 inches will probably need four ailerons to get anything like an aerobatic roll rate without excessive yaw and drag.

The deHavilland DH 89 Dragon Rapide. (Photo courtesy of Scale Model Research.)

Al Williams' racing Gulf Hawk of the late '30s. (Photo courtesy of Scale Model Research).

Using a little more travel on the lower wing's ailerons seems to help to keep the center of drag closer to the thrust line and produce rolls that are more axial. A little aileron differential travel (more up than down) will do pretty much the same job.

Bipes with upper and lower wings of unequal size with a lot of aileron area on the larger wing have less need for four ailerons. Roll resistance of the no-aileron wing decreases very rapidly as its dimensions shrink.

If one wing has a shorter span, for best efficiency, its chord should be proportionally reduced by at least as much as its span.

An 84-inch-span bipe with a piped HP120 engine. Another of the author's designs, this 12-pounder has 1,750 square inches of wing area.

DIHEDRAL

On my aerobatic designs, I like to use a little dihedral—something like 1½ degrees on the lower wing and a nearly equal amount of anhedral on the upper wing. This should give a net result of almost zero overall dihedral effect and remove virtually all the yaw/roll coupling, (the tendency for rudder deflection to cause unwanted roll). Building both wings with zero dihedral would probably have the same effect, but it would tend to give the lower wing an unusual, sagged appearance. I think the dihedral/anhedral combination looks better and, as a bonus, it gives the lower wingtips a little more ground clearance. I also use sheet nylon skids under the tips of the lower wing for additional insurance against asphalt rash.

BRACING WIRES: FUNCTIONAL OR JUST PRETTY?

Few modelers go to the trouble of equipping their bipes with bracing wires unless they are required for scale fidelity. Contrary to legend, bipe wings make poor birdcages. Fitting a bipe with the wires and all the paraphernalia they entail is very time-consuming, and the work does not stop when the model has been completed. Unless your vehicle can accommodate a fully assembled model, you can spend a lot of time at the flying field, fussing with the wires and fittings when you could be flying.

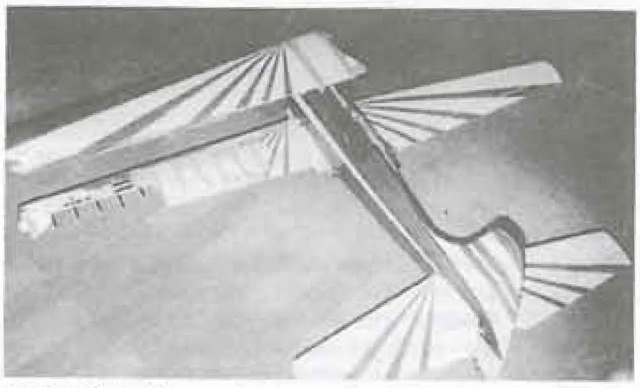
Having studied the effect of bracing wires on the weight of non-scale bipes with thick, symmetrical wing sections, I have concluded that little, if any, weight can be saved by using wires instead of incorporating an ideally tapered box-section spar. However, to avoid showering the flying field with assorted airplane pieces, scale models of thin-wing WW I bipes probably need wire bracing, or a lot of wing beef.

The drag of circular-section stranded-steel cable is very significant. At full speed, the drag of the wires and fittings may equal that of the wings. The necessary attachments for the wires are also difficult to build into the wing structure while minimizing weight. Streamlined solid wires can reduce the drag penalty by up to about 85 percent. *[Editor's note: Aero Scale miniature flying wires—high-quality, streamlined, model-size bracing wires— are available in five sizes from the Nelson Aircraft Co., 21550 N.W. Nicholas Ct., Unit D, Hillsboro, OR 97124; (800) 552-8065.]*

A close-up of the 84-inch sport bipe with the fuselage top removed to allow access to the tuned pipes and headers.

OTHER DRAG-PRODUCING THINGS FOUND ON BIPES

Cabane struts (for attaching the upper wing to the fuselage) made of round wire produce a lot more drag than you might think. Struts made of thin aluminum-alloy sheet or of thin aircraft plywood or hardwood, shaped and sanded to a smooth airfoil section, are far better, drag-wise. Interplane struts (between the two wings) slovenly fabricated of round dowels are sometimes seen on bipe models. These produce tremendous drag. Everything exposed to the air stream should be given a smooth, streamlined shape wherever possible. A motley bunch of little refinements have a way of adding up to produce a lot of drag reduction and reward you with a bipe that flies much better.



The wing flutter damage shown here occurred while the plane was flying straight and level at about 105mph. The flutter was second harmonic, caused by excess tip balance weight on long, flexible ailerons. The flutter was cured by adding mass dampers at the 40-percent-span position. The model landed safely with just one functional aileron. All damage occurred within 0.1 second. The additional wing on the bipe saved the model; this is one advantage of a biplane over a monoplane! On another occasion, the same bipe landed safely after losing the entire upper wing, part of the lower wing and half the stab in a midair collision!

UPPER AND LOWER WINGS OF UNEQUAL SIZE

Many designers of full-scale aircraft, observing that the lower wing always gets the short end of the stick, efficiency-wise, reduce its size and enlarge the upper wing. This raises overall wing efficiency while it retains the weight-saving advantage of wire bracing. Aerodynamically, such a bipe is a little closer to a more efficient monoplane. As you might expect, the greater the difference between the size of the two wings, the closer the combination approaches monoplane efficiency. This little ploy was simply one step down the road

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Note the cowl on this 68-inch-span, .60-size bipe. The rubber inlet air restricter prevents the engine from being over-cooled when flying during winter.

leading to strut-braced and, ultimately, unbraced monoplane wings, and it should be regarded with suspicion by dyed-in-the-wool biplane fanciers.

Enlarging the upper wing also raises the center of lift and drag. The result: a bipe that may handle more like a high-wing trainer (far from ideal for smooth, clean aerobatics). Enlarging the lower instead of the upper wing might make more sense for aerobatics, but it would produce a somewhat odd-looking bipe. This layout is rare in the full-scale world.

For a given maximum wingspan, wings with equal chords and spans have been found to be far superior to unequal-wing combinations. An equal-winged bipe with the same wingspan and wing area as a monoplane typically produces about 22 percent less induced drag than the monoplane. With a given wingspan, bipes can develop more lift with less induced drag than a monoplane—one of their strongest points. Their compact overall dimensions in relation to wing area is another bonus—a big help in making them more readily transportable in the average car.

If one wing has a shorter span, for best efficiency, its chord should be proportionally reduced by at least as much as its span. Theory says that the wing's chord should be reduced proportionally to the cube of its span, but, in many cases, this produces a chord that is too small to be practical. For example, if the shorter wingspan is reduced to 0.8 times the span of the longer wing, then the chord should be reduced to 0.8 to the third power, or about half the chord of the larger wing.

In the next installment, I'll look at triplane wings, bipe tail feathers, interplane strut design and offer tips on bipe fun-fly designs. See you then. ■