Flying a Brace of Ornithopters

This Note is culled from emails to Patricia, Dec 17/02, and to Gearge, Apr 9/03, with a few updates.

For a long time I have believed the lift unbalance of 2-wing ornithopters to be an unrecognized hazard. So much so, that I have been trying out a novel (?) four-wing arrangement.

Counter-phase four-wing layouts can reduce the vertical accelerations caused by two wings (0g to +3g in swallows and I don't know how huge in Big Bill). In biplane or tandem arrangements there are also secondary effects: both halve the overall aspect ratio; biplanes are tall for cross-wind operation; tandems introduce pitching moments (if fore wings flap in anti-phase with hind) or yawing moments (if rocking oppositely like Entomopter's). However, those side effects may be obviated if the rocking wings are set abreast of each other and flapped in counter-rotation. This layout is unlikely to be novel – although one knowledgeable modeller mistook it for the more familiar flapping tips, then realized and asked "but how does it lift if one wing is going up when the other is going down?"

Because the span is halved, the u/c legs can be shorter. (On Brace they were shorter than those required by the prop of the 1940's Wakefield whose shape the model was based on.) Unfortunately, they weren't as bendy as I'd intended for emphasizing boinging.

Boinging on take-off must be a particular pain! Just when you need a sensitive touch your arms would wave like branches in a storm. Not only would it be tricky to apply a damping input, it would be hard not to make the oscillation worse! How you'd flare-out for landing I can't imagine. Not only pilots but passengers (if we can find any) will tire of roller coasting, soon enough. They will choose a smooth ride in the smooth ornithopter (if we can offer any).

There are two additional safety advantages of Brace's aerodynamic balance over two-wingers. Firstly, the engine's peak loading is much less dependent on g, thus it will not be stalled at high g – as in an emergency. Secondly, a dead engine won't be motored over till the wings reach max dihedral like a two-winger's might be (try gliding then!). Indeed, Brace's wings could be declutched and then quite easily manually wound into a safe dihedral for glide (given time).

A possibility for yaw control is to vary the relative amplitudes of the port and starboard wings for "twin engine" steering. So far, I've used this only for correcting an in-built turning tendency. .Another is to vary the flap-axis incidence for roll control. That is more powerful than in a biplane or tandem, so Brace had to be braced in torsion (the cruciform in the centre).

On its first night out, the model flew smoothly. The first take-off it was underpowered so it trundled halfway across the hall before rising only about six inches. Other flyers urged more rubber but I was delighted: there was NO visible boinging! In fact, I'm not sure when it unstuck, it was such a smooth take off. TO's seemed smooth at higher powers, too. Also, there was none of the usual vertical tail-shake in flight but there was some cyclic roll due to a geometric error. For once, a trial went well.

And I was able to fly two ornithopters at once. What bliss! A brace of them, nearly a covey.

Brace currently has crude stub wings, attached to the original cantilever booms. I now think those wings interfere with transient flow over the inboard flappers. It flies at 0.227oz, 1.0oz/ft^2 (total area, inc lifting tail), and is 15.7" span with 75 degree amplitude. It needs 1 loop of 3/16" plus 1 of 1/8" of rubber, despite the small tip area.

For safer ground handling and taxiing in a cross-wind, I have used horizontal conrods. That allows a short u/c, but also means the inboard tips pass the body, so they are not sealed. That is likely to be less efficient than George's Hula Bird and I doubt that mine has ever done his 15 seconds – certainly not in early flights.

For assessing the effective aerodynamic balance, I have used springy u/c's and long take-offs to view the degree of that dreadful boinging that Patricia endured. None was evident! It has even taken off without any u/c, despite the inboard tips going subterranean (no, I don't know, either. It still scooted for yards before unsticking – though flapping much faster). Thus, even with a floor close by for reference, the flight appears to be smooth, just as George observed. (Not that we should be deluded by that. Although swallows appear to fly smoothly, they cycle from 0g (= free fall) to 3g at 25 Hz!)

My ornithopters always seem to require huge power. Brace is so battered now because it needs twice the power it was designed for and so explodes all over the hall every third flight (Brace n bits)! I suspect part of the high demand arises from the low AoA (so as not to stall those stub wings).

Brace's wings don't self-centre, so I shall try dihedrals later

I'm now trying out the stiffer 0.002" Polyester film shown, replacing condenser tissue, rigidly glued to the spars and (flat) root ribs. At first it was pre-tensioned by bending the spars back while gluing. The thrust was too low to sustain flight, so they have been re-covered with positive TE slack for the next trial. Another possible power loss resulted from angling the conrods forwards to the crank for a longer motor (6 1/4" between 4.1" centres), which led to structural deflections only partly fixed by adding the space frame. The motor stick was always separate from the tail boom to decouple flight trim from any bending and twisting.

Other flyers call the whole contraption "Diabolical". At least, I think that's what they said. But then, unlike us, they weren't aware of the need for smooth flight and aerodynamic balance.