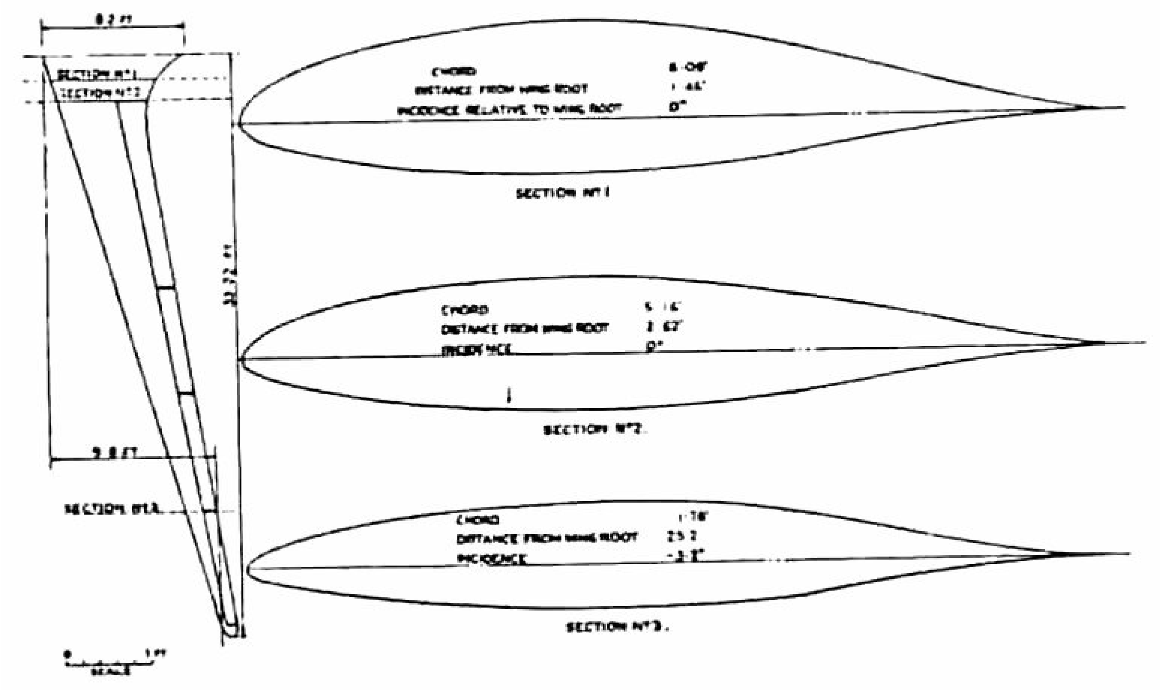
No. 205 JULY 2003

T.W.I.T.T. NEWSLETTER



Horten IVb Sections

T.W.I.T.T.
The Wing Is The Thing
P.O. Box 20430
El Cajon, CA 92021

CONTRATULATIONS ON 17 GREAT YEARS

The number after your name indicates the ending year and month of your current subscription, i.e., **0307** means this is your last issue unless renewed.

Next TWITT meeting: Saturday, July 19, 2003, beginning at 1:30 pm at hanger A-4, Gillespie Field, El Cajon, CA (first hanger row on Joe Crosson Drive - Southeast side of Gillespie).

THE WING IS THE THING (T.W.I.T.T.)

T.W.I.T.T. is a non-profit organization whose membership seeks to promote the research and development of flying wings and other tailless aircraft by providing a forum for the exchange of ideas and experiences on an international basis. T.W.I.T.T. is affiliated with The Hunsaker Foundation, which is dedicated to furthering education and research in a variety of disciplines.

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Meetings are held on the third Saturday of every other month (beginning with January), at 1:30 PM, at Hanger A-4, Gillespie Field, El Cajon, California (first row of hangers on the south end of Joe Crosson Drive (#1720), east side of Gillespie or Skid Row for those flying in).

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PRESIDENT'S CORNER

This month we will feature an article on flutter analysis and control written by Irv Culver that has a lot of very good information for all builders and home mechanics. It is another in a series we will do over the coming months to pass along Irv's insights into a number of subjects, some of which you have already seen. We were very fortunate to get his collective works, many of which had to do with his tailless theories.

We also received an update on Bob Hoey's latest project on a variable geometry Raven model. He has sent along some pictures that I think you will find interesting, along with his explanation on the do's and don'ts of building such a project.

I am looking forward to the July meeting. It will be an all Horten affair, so if you have any pictures or stories about any of the Horten designs, bring them along and share with the group.

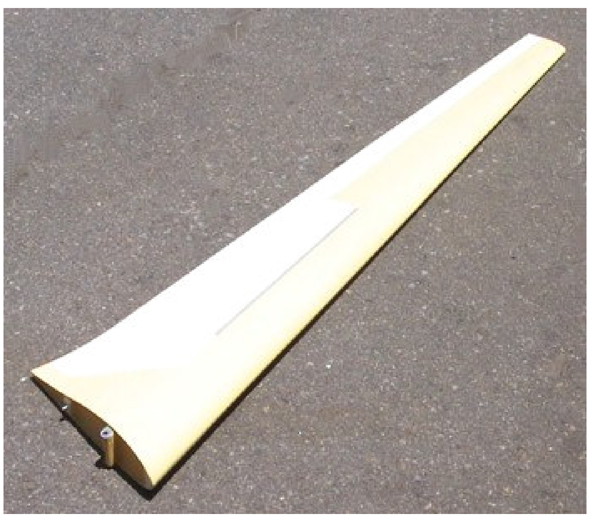
As you see from the cover, we have been bringing you information on flying wings for 17-years now. I have been editing the newsletter for a good many of those years and am amazed at the resiliency of our members in their dedication to this mode of flight. I am also amazed at the progress that has been made in the commercial arena for flying wings, as they are being considered more and more as an alternative to conventional aircraft in almost all areas of aviation.

Don't forget to set aside the Labor Day weekend for the SHA Western Workshop at Mountain Valley Airport in Tehachapi, CA. Make your hotel reservations early, since there will also be a vintage sailplane meet during the week leading up to the workshop. There is a good camp ground on the airport, if you are inclined towards the outdoor life. Bruce Carmichael has done his usual excellent job of putting together a variety of presentations, so don't miss it.

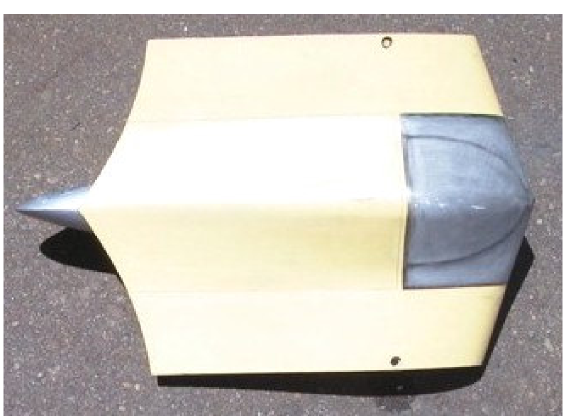
Andy

JULY 19, 2003 PROGRAM

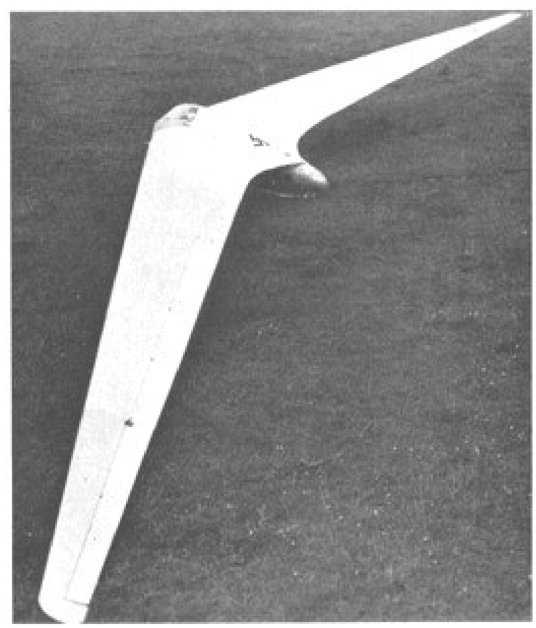
This should be a fun meeting. As you can see from the pictures below, Bob has received his scale model of the Horten IV that is supposed to fit inside the trailer that has been hanging on the wall for some time. The meeting will consist of discussing the Horten IV and putting this model together. The wings need to be mounted to the center section and the tips mounted to the outer end of the main wing section. Once all this is complete and everyone has all the pictures they want to take, we will use the group to hang it from the hanger rafters so everyone can enjoy it every time they come to the hanger.



Depending on the size of the group, we might even take the trailer down and see how well it will fit to confirm that Bob did the calculations correctly.



Although the markings on this model are not for the MSU aircraft, they do reflect this as Werk # 22 which was the first Horten IV built. It was first flown in May 1941 by Scheidhauer out of Konigsberg-Neuhausen, Germany, and was labeled as D-10-1359, LA-AA.



(Source: Nurflugel, Horten, Reimar, Peter F. Selinger, H. Weishaupt Verlag, Graz, 1983 pp. 93-94.)

Don't forget that this is our ***17th Anniversary*** party month, so there will be cake and ice cream for everyone. We will also be honoring Bob Fronius' birthday (TWITT founder), which occurred the previous week.

LETTERS TO THE EDITOR

Jun 19, 2003

Subject: Simplified Primary Glider

I am interested in feedback about a hair brained scheme which nags me daily: a simplified primary glider. By simplified I mean a flying plank with rudder and elevator - no ailerons.

I realize this imposes control limitations. Yet the planform interests me. After all, every design compromises.

Opinions invited. Reasoning welcomed.

Fly right.
Nicholas Cafarelli
nc@zapo.net

(ed. – This was the original message from Nicholas to the Nurflugel mailing list. In another message to TWITT he also expressed an interest in basing his design on one of the older "midget" sailplanes like the Rigid Midget or Lil' Doggie". The following are responses he has received so far from the Nurflugel group, so if you have something to add, please contact him and include TWITT as a cc: in your message or send us a copy of you letter.)

June 19, 2003

Why reinvent the wheel? Take a look at Mike Sandlin's "Bug" and "Goat" ultralight glider designs. They both fly very well and the best part is the drawings are free on the web and quite well done. These are about as "simple" as it gets but like all things aviation, there is no such thing as a "simple" aircraft they are all a pain in the a** to build. <grin>. http://home.att.net/~m--sandlin/bug.htm

Albert Robinson
arobins1@midsouth.rr.com

June 19, 2003

I've seen photos of a tailless primary glider, I believe from the 20s that was nothing more than a straight wing with framework underneath. Kind of like an SG-38 that the builders lost interest in 2/3 the way through.

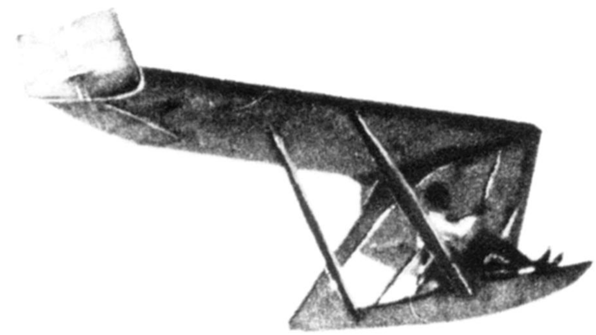
Does anyone have identification, background or more info?

Still, let's not let our obsessions for a layout push our judgment into a corner. Is there any advantage to a non-traditional format? Especially with unconventional controls that can only reinforce bad habits?

Cheers,
Bob Storck
bstorck@sprynet.com

June 22, 2003

This craft approachs the flavor I have in mind: http://www.nurflugel.com/Nurflugel/Lippisch_Nurflugels/Storch_IX/lippisch_stork_ix_1.jpg



I intend to avoid rearward sweep preferring a straight leading edge. Wing taper might be incorporated implying a slight forward sweep. The planform closest to what I have in mind is the Marske series.

By using the construction techniques analogous to the Sky Pup - foam spar webs, wood spar caps and longerons - I might dispense with struts and be able to afford a number of full size iterations into a corner.

I have found obsessions sometimes lead to unexpected successes. When they do not the journey is filled with inspirations for further artful excesses.

The advantages: simple, strong fuse; fewer control linkages; quicker rigging; less material to purchase; possibly identical ribs and simpler wing structure. (The Sky Pup uses only the D-cell to handle torsion for the bulk of the wing.)

The challenge: find the sizing and planform, which results in "good" pilot feel and safe operation throughout the flight envelope.

Thank you for raising questions. I appreciate it. Can you amplify you opinion on "reinforcing bad habits"?

I agree that control coordination will vary from normal"...

Yet aircraft vary widely in handling even when they appear outwardly identical. Small differences in linkages, airfoils, control surface gaps, surface finish, rigging, and center of gravity can make for huge differences. And control coordination thus varies widely between aircraft of all kinds.

I am very interested in the groups opinion on how a AILERONLESS, rudder and elevator only aircraft might best be approached.

Again, thank you for your input. I look forward to hearing more.

Nicholas

June 22, 2003

I love the primaries as well. I have looked at that glider (Lippisch) a lot (some years ago). Yes, it might be a good project. But ... why change it into a straight edge design. It did perform good at those days. Why change a winning design? I guess there is enough data on this glider to have it rebuilt in modern materials. All I want to add is that if you go for a primary, it should be meant for beginners. The straight edge gliders I know are very sensitive in pitch. I guess it is not beginners' material. A swept wing might have less pitch sensitivity. Just a thought.

Anyway, continue your quest for that primary. Keep it simple, keep it cheap and it will get more people in the air.

Keep that brain spawning wings,

Koen Van de Kerckhove
nestofdragons@hotmail.com

June 22, 2003

(Nick) <This craft approaches the flavor I have in mind:http://www.nurflugel.com/Nurflugel/Lippisch_Nurflugels/Storch_IX/lippisch_stork_ix_1.jpg>

(Storck) No, the one that I saw the flight photos of appeared to be a pure, Backstrom type Plank primary. As I said, like a SG38 that never was finished.

<. . . The planform closest to what I have in mind is the Marske series.>

Why? Without explanation, it seems to be personal reference and aesthetics over proven aero solutions. At that, the Monarch works very well. Why reinvent the wheel?

<… I might dispense with struts and be able to afford a number of full size iterations.>

Are you sure about that? Some of the cheapest and quickest to build aircraft I've done involved built up, jig built spruce/fir strip ribs, and nasty old spars.

<… When they do not the journey is filled with inspirations for further artful excesses.>

I can count more that wound up with unfinished projects, endless reworks, and even a lot of tragedies. I don't discourage innovation and new ideas, but make sure there is more than some "Big Chief" scribbling and fantasies as background.

<…The advantages: simple, strong fuse;>

So? What is wrong with most Conventional primary fuses?

<…fewer control linkages;>

The wings I have built have had some of the most complex and hard to tune control systems.

<…quicker rigging;>

OK, if built as a one piece wing without disassembly. If the wings come apart, there is no advantage to a primary with non-removable tail.

<…less material to purchase;>

Marginally. Still have the extra mixer and control complexity.

<…possibly identical ribs and simpler wing structure.>

Only if you have a Hershey bar wing. But this creates some control issues that even you have alluded to.

<The challenge: find the sizing and planform which results in "good" pilot feel and safe operation throughout the flight envelope.>

Aha!!

<Thank you for raising questions. I appreciate it. Can you amplify you opinion on "reinforcing bad habits"?>

I'm glad to have learned on sailplanes, as I've flown with too many power pilots who ignore the ailerons or rudder. Especially valuable when doing combat maneuvering in the Navy. Always surprised folks when I had a few extra knots to play with after a mirror series like a climbing scissors, etc.

<I agree that control coordination will vary from "normal"...>

OK, what's the advantage here. This really puzzles me. We don't need any more Ercoupe pilots.

<I am very interested in the groups opinion on how a AILERONLESS, rudder and elevator only aircraft might best be approached.>

Again, why?

Cheers

Bob Storck

June 22, 2003

Bob Stork has asked why I am interested in a rudder and elevator controlled flying plank primary glider. My reasoning follows.

I wish to simplify controls while simplifying wing structure. By having only an elevator inboard on the wing I hope to reduce the need for drag struts. I will use a D-Cell to handle torsion. My thinking is that without outboard ailerons the wing will undergo less torsion.

An aircraft exists which is controlled by rudder and elevator only, which takes advantage of this simplification. The Sky Pup has only 66" out of 373" with internal drag strutting. The outboard wing panels - each over 153" use only their respective D-Cells to resist torsion. In these 153" outer panels rear ribs are 24" apart. Nose ribs are 8" apart.

The Sky Pup has a remarkably good structural record given its very simple wing.

I have no qualms about an all wood wing. However the foam spar webs used in the Sky Pup conserve wood and make material procurement easier. I like wood truss ribs. Yet foam webbed wood capped ribs make sense too.

Now why forward sweep? Or no sweep? This is to avoid washout. Sure you can jig washout. If I can eliminate it I prefer to do so. A slight forward sweep - that is a leading edge perpendicular to the flight path coupled with moderate taper - has been demonstrated to obviate the need for washout. I could also eliminate taper and just go with mild forward sweep and still need no washout.

The Marske wings demonstrate that inboard elevators gradually lose their effectiveness with increasing AOA. This is believed to reduce the likelihood of stalls and spins.

I do not seek to reinvent the wheel. I seek to explore the wheel, possibly giving it slightly different form.

I may have confused you. If so, I apologize. You mention control mixing and I get the impression you imagine control coupling analogous to the Ercoupe. My intentions have not included mechanical control coordination. There will be no mixer. Just like in conventional aircraft the pilot is the intelligent mixer. Some Sky Pup builders use the stick to control both elevator and rudder substituting the rudder connection for the aileron connection. Plans built Sky Pups use a foot bar for rudder actuation.

Flying Planks fly. Rudder only models fly. Marske Monarchs fly. Sky Pups fly. My only innovation seems to be in combining attributes of "proven" machines.

Please do not mistake my attempts to explain myself as denigration of your ideas. You have raised valid questions. I hope to learn more from your further questions. I respect your ideas and will continue to try to clarify my concept.

It may be a dead end. As of right now, I continue to advocate investigating it. Please do not imagine I believe it will break some great barrier. I hope it will be another baby step in the right direction. We stand on the shoulders of all those aviators before us. I just want to tiptoe up a tiny bit without falling.

Every failure can be a learning experience. Some argue the ability to fail quickly, to fail often, and to consistently recover to try again is key to success. I agree. Let me know if I have left something unexplained or if my explanation needs amplification.

Nicholas

June 23, 2003

Hallo Nicholas,

Help remind me to give you the address and email of the friend of Jean Claude Debreyer. At my last contact he mentioned he was working on an amateur built version of the Pelican. I guess you can work together. You both share a lot of things (flying wing, unswept, light, easy, ...).

I think that I lost contact with Jean Claude Debreyer and David Thivet due to some major error from my part.

Well, I am at my work now. I will try to give you that address this week. But if anybody has it too, please, can you give it. Otherwise I need to depend on my memory and it is exam time in my school. Bad timing for memory training. ;^)

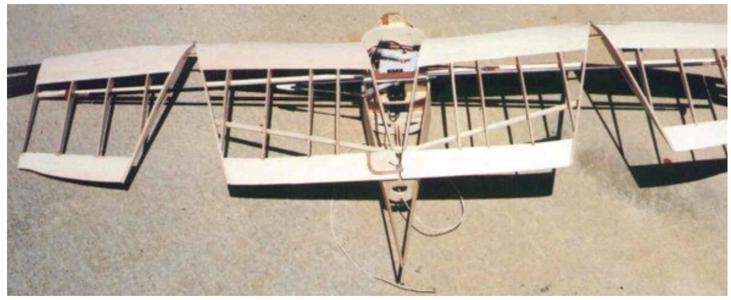
Keep that brain spawning wings,

Koen

July 3, 2003

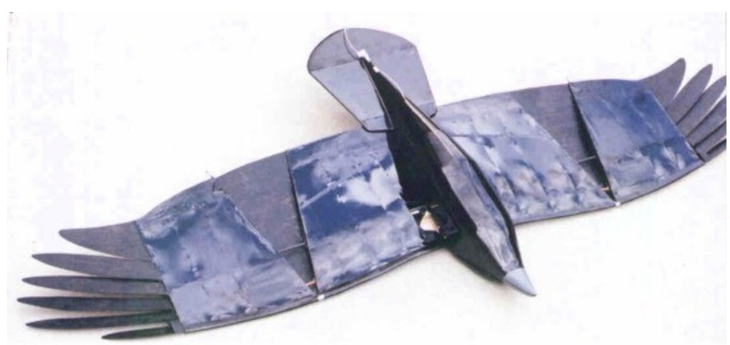
TWITT:

I have made a few flights on the variable-geometry Raven model. The first flights were really puzzling, but thankfully, not catastrophic. I finally figured out the problem and have since made some successful flights. I have attached photos showing the structure, mechanism and the completed wing. I am using two carbon tubes as push-pull-rods to accomplish the wing change. These rods also serve as main wing spars and carry the primary bending loads. The bottom view was taken before the covers were added over the open area to show the amount of area change.



During the original layout I had located the pivot points to try to maximize the amount of span and area reduction (about 14% for both). As you can see in the photos, the fore-and-aft area distribution looks roughly equivalent. Sometimes you shouldn't trust your eyeballs!! I finally recalculated the

aerodynamic center for the as-built configuration and found that the aerodynamic center of the retracted wing is about half an inch farther forward than the extended wing. As a result the extended wing is too stable and requires a whopping 20 degrees of up elevator for a normal glide. The retracted wing is just barely stable and flies with zero elevator. The retracted wing does have a fast, flat glide, so it seems to be performing as expected.



The airfoil that I am using is also different (no under-camber and no reflex - in order to improve high speed performance). This partly explains the large elevator deflection. The short-coupled tail requires a lot of up-elevator trim to replace the strong nose-up moment, which was provided by the wing reflex in earlier Raven models. (You flying wing designers know all about that!)

I intend to build another wing, but will move the wrist pivot points inboard about 2.5 " from the current location. That should reduce the amount of wing area moving forward, and increase the amount moving aft. And this time I'll do the aerodynamic center calculations BEFORE starting construction. Changing the wing configuration in flight with a single servo is also marginal. I have to nudge it by pushing over a little to unload the wing. May try a jack screw next time.

Bob Hoey
bobh@antelecom.net

(ed. – Thanks for the update and pictures on your latest project. I knew you would find the solutions to your initial problems. The model looks great in both configurations. I asked Bob to send us some video of it, or the successor, in flight so we can see the differences in flight performance as the configuration is changed.)

PHYSICS OF FLUTTER

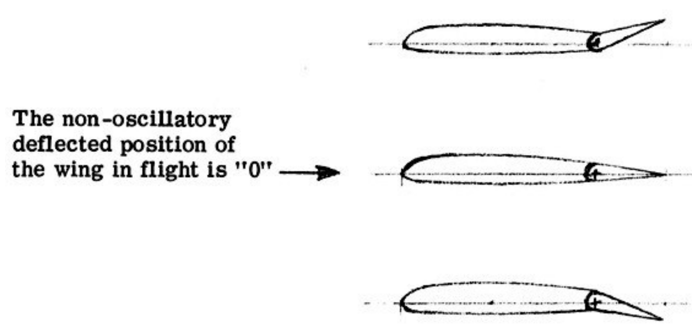
I. H. CULVER

There appears to be a general lack of understanding of flutter among aircraft designers; even many flutter analysts are mathematicians with little physical understanding of the subject. Therefore it would seem appropriate that more papers on the subject of the physics of flutter are in order. This paper is on cantilever configurations, no struts or wires.

We chose a simple first case like first mode symmetrical flapping with aileron symmetrical rotation, both ailerons up and both down. Before we get into the details let's make a simple single degree of freedom oscillatory system. Hang a weight from the rafters in your garage on a long string so the weight is close to the floor. This will make the frequency low enough so that you can excite it by pushing on the weight. Never mind that the stiffness for this system is provided by gravity rather than structural stiffness as in the case of flutter. You will find that pushing on the weight while it is moving will change the amplitude. Pushing with the motion will increase the amplitude of the motion while pushing against the motion will decrease the amplitude. In flutter these are called driving and damping forces. What do we learn from this? First, the excitation must have the same frequency (cycles per second (cps)) as the swinging motion, and pushing in the same direction as the motion increases the amplitude. The relation between the experiment and the flapping motion of a wing is that both are mass stiffness oscillatory systems. The only difference is that for the weight on the string the stiffness is due to gravity while for the wing the stiffness is due to structural stiffness and maybe some aerodynamic stiffness.

From the above it is apparent that if I push up on the wing tip while it is moving up, and down while it is moving down, the amplitude will increase (called excitation or driving). If I push down while the tip is moving up the result is damping. Where could the force come from that can push up while the wing is moving up, and down when the wing is moving down at the same frequency as the wing is flapping? First, we all know that we can raise and Lower a wing with the ailerons, so if both ailerons went trailing edge down while the wing was moving up with sufficient amplitude and at the same frequency as the wing flapping we would have flutter.

If the ailerons are trailing edge heavy, the inertia forces of the ailerons will tend to deflect the aileron up when the wing flaps up and comes to a stop. So when the wing is in the full up position, just before it starts down, the aileron will be in the full up angular position that is trailing op edge up. And of course the trailing edge of the aileron will be down when the wing is down.



At first look it appears that this just stiffens the wing in flapping. That is, the aerodynamic forces on the wing are in phase with the flapping motion so the aero forces only add to the structural flapping stiffness. This only raises the flapping frequency. However there are other effects.

The simplest effects first. Friction in the hinge pins and other parts phase-shifts the aileron motion to later; that is, the aileron is still moving up slightly when the wing is fully flapped up. So that when the wing is passing through "0" on the way down, the TE of the aileron is still up a little, pushing down on the wing while the wing is moving down.

The next effect is aerodynamic damping of the angular motion of the aileron. The wind is blowing by while the TE is moving. This causes a retarding or damping force similar to friction in the hinges and adds to the phase shift.

Next: aerodynamic lag of non-steady aerodynamics. There are two explanations worthy of consideration. Both are correct and non-conflicting. We are all familiar with the fact that as aspect ratio increases the induced drag decreases. This is due to the fact that at ∞ aspect ratio the up-wash ahead of the wing is equal to the down-wash aft of the wing and that the slope of the lift curve is 2 π per radian of α. Now if we reason that deflecting the air down aft produces one half the lift and the other half comes from the up-wash ahead of the wing, then if we suddenly change the angle of attack from 0 lift angle to some +angle, the air flowing off the TE will come off at the new angle of attack thereby creating one half the final lift. However the up-wash ahead of the wing takes time to develop since, as Newton said, a body in motion tends to stay in motion in a straight line unless acted upon by an external force. The air ahead of the wing is flowing straight at the wing when it is at 0 lift angle. When we suddenly change the angle to some +angle the pressure rises on the lower surface and drops on the upper surface. This causes an up pressure gradient ahead of the wing, and, as Newton said, this pressure gradient will cause the flow approaching the wing to start to curve up, and as it curves up it causes the pressure difference on the wing to rise, which strengthens the pressure signal telling the air to curve up more ahead of the wing until the up-wash ahead of the wing is equal to the down-wash aft of the wing.

Now for the classical explanation: A sudden change in angle of attack creates a circulation (or vortex) around the wing and a vortex of opposite sign and equal strength at the TE of the wing. The net result is that the vortex at the TE cancels one half the lift; however the TE vortex floats off downstream allowing the lift to grow to its full static value.

Now back to flutter. We have the wing flapping up and down. When the wing is flapped up the aileron TE is up, creating downlift. Now if the downlift due to the aileron TE being up lags in time, then when the wing passes through 0 on the way down, there will still be some downlift left. Result: some driving force. Remember, pushing in the direction of motion adds energy to the oscillatory system.

The above leaves several questions. First, how does the aileron natural frequency get close to the flapping frequency? The answer is that if the aileron natural frequency on the ground is below the wing flapping frequency, then as you increase speed the aerodynamic stiffening raises the natural frequency up to the flapping frequency or slightly above; the result is flutter,

A more detailed explanation is, the aerodynamic center of the control surf2ce is alt of the hinge line so as the dynamic pressure $q = \frac{\rho V^2}{2}$ (insert figure) rises, the stiffness around the hinge line increases, resulting in an increase in the natural frequency of the control surface.

ω = FREQUENCY

I = MOMENT OF INERTIA AROUND H.L.

$K_{\alpha o}$ = 0 SPEED ANGULAR STIFFNESS

$K_{\alpha a}$ = AERODYNAMIC ANGULAR STIFFNESS

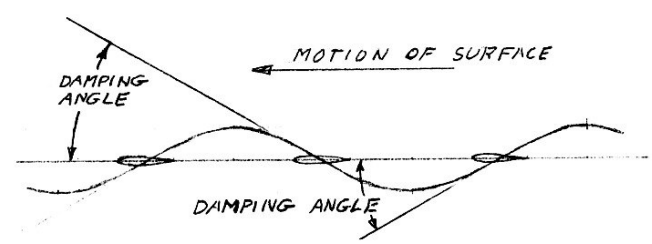
$$\Sigma K_\alpha = K_{\alpha o} + K_{\alpha a}$$

$$\omega_A = \left(\frac{\Sigma K_\alpha}{I}\right)^{\frac{1}{2}} \quad \text{RADIANS PER SEC. (AVIS)}$$

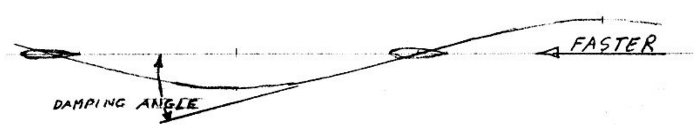
$$\omega_H = \frac{\left(\frac{\Sigma K_\alpha}{I}\right)^{\frac{1}{2}}}{2\pi} \quad \text{CYCLES PER SEC. (HERTZ)}$$

It should be noted that control cables can be loose due to thermal expansion differences between the airframe and the cables, or neglecting to keep the cables tight. Also, push-pull systems have some lost motion so that the frequency of the control surface is a function of amplitude so that up to some amplitude you can have flutter (limited amplitude flutter). Even though the amplitude is limited the damage causes to the system by limited cycle flutter can result in increased lost motion. It is not smart to rely on control systems to prevent flutter.

You should note that we had two degrees of motion available, one that moved normal to the air stream and one that changed incidence or angle relative to the air stream. If we had flapped the wing up and down only, while traveling through the air, we would have generated a damping angle.

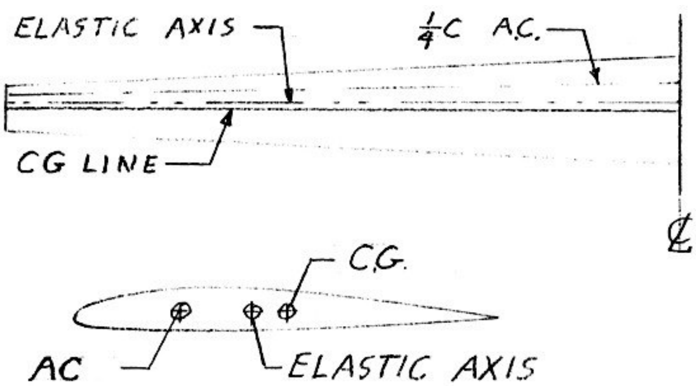


Suppose that for the same dynamic pressure (insert figure) we go to altitude where the density $P = \frac{\rho V^2}{2}$ is lower so that we must go faster to get the same airspeed reading. Then for the same flapping amplitude and frequency we have less damping angle.



Now for the same flapping amplitude and the same control surface response the flutter problem is worse. That is, flutter will occur at a lower indicated airspeed at altitude. If one likes geometry, when the change in the angle of 0 lift line due to moving of the control surface is equal to the damping angle, then we have reached the 0 stability (neutral) flutter point.

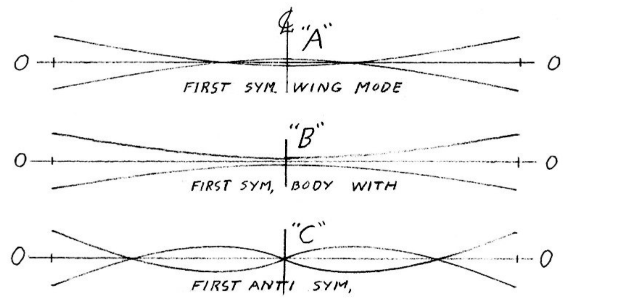
We should next look at another 2-degree-of-motion flutter problem that is not likely to occur with today's designs. This is wing flapping and wing torsion. Assuming that we had mass-balanced the ailerons so that they would not contribute to flutter, it is still possible to have flutter. As we know, in the early days of aviation some machines used wing warping for aileron control. This would indicate that wing twisting gives similar effects to aileron motion.
Most wings have the C. G. of the airfoil aft of the elastic axis and both of these are aft of the aerodynamic center, which is approximately at the 1/4 chord. The elastic axis (or shear center) is the spanwise line that is defined by: if you push up or down on this line the wing will not twist.



It is easy to see that this is similar to the aileron case with the C. G. aft of the hinge line. The elastic axis acts like a hinge line and the C.G. is aft, so when the wing is flapped up and comes to a stop it tends to deflect the TE up the same as for the aileron case. The difference is that for the wing torsion flapping case the wing torsion starts out at 0 speed at a considerably higher frequency than the flapping frequency. However the aerodynamic stiffness is negative in torsion instead of positive like the aileron case. That is, the aero-dynamic center is ahead of the elastic axis so if we increase the dynamic pressure the torsional moment caused by deflecting the wing in torsion gives a negative stiffness that is opposite to the case of the aileron. So although we start with the torsion frequency way above the flapping frequency, increasing dynamic pressure can reduce the torsional frequency until it is just above the flapping frequency (flutter).

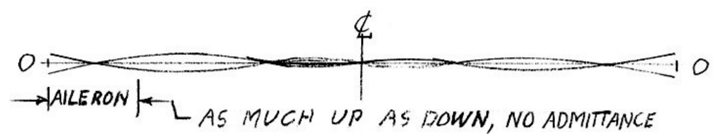
It should be noted that at flutter the wing is being stiffened in flapping by aero lift forces at the a. c. due to twisting. Also note that if the elastic axis is on or aft of the C. G. and aft of the a. c. then the wing will not flutter but it can diverge staticly (non-oscillatory divergence). Of course if the a.c., C G. and elastic axis are all together then nothing happens. Most modern surfaces are so stiff in torsion that there is low probability that wing torsion flapping flutter or static divergence is a problem within the useful speed range of sailplanes or light aircraft today.

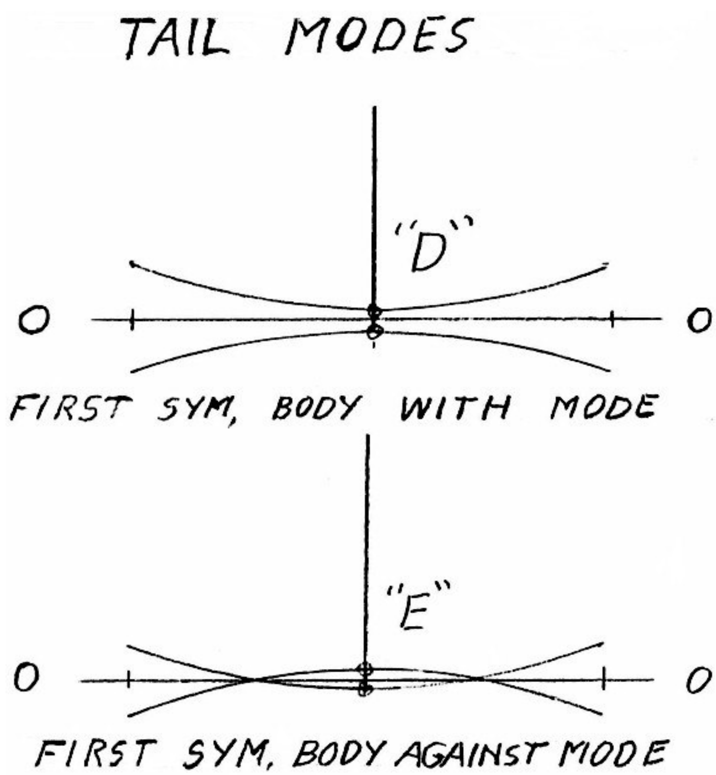
Some flapping mode shapes:

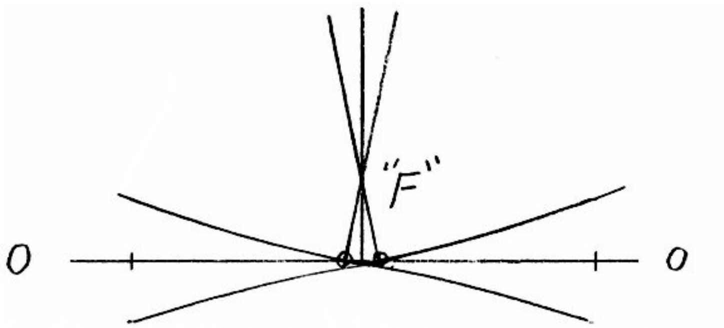


It should be noted that Case B symmetrical (body with) mode is highly improbable due to the requirement that the body bending first mode must be very low to match the wing frequency and the nose and tail must deflect a long way to make the C. G. of the airplane not plunge up and down while flapping (as required by Sir Isaac). Case B requires a very elastic fuselage.

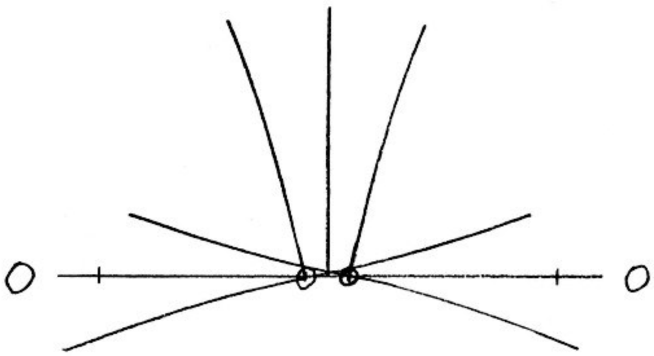
Second or higher modes of flapping are not considered since the chord lengths per cycle are so low that flutter could not occur. Also the admittance factor would be low.







FIRST TORSION BODY AGAINST MODE

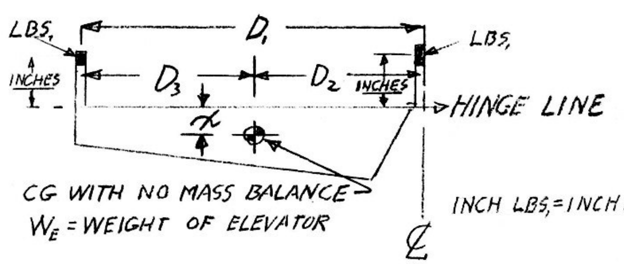


FIRST TORSION BODY WITH MODE

For tail surfaces all the body with and against modes are probable since the tail is generally small compared to the wing and the tail frequencies are close to the fuselage bending and torsional frequencies.

So the safest answer for tail surfaces that must fly at reasonably high speeds is to balance such that all first modes are balanced dynamically. This can be accomplished on the elevator by 3 mass balances, I on each tip and 1 in the center.

First estimate or measure the spanwise C.G. of one elevator.



The inch lbs. of balance at the tip is $= \frac{D_2}{D_1} \times (\chi \times W_E)$

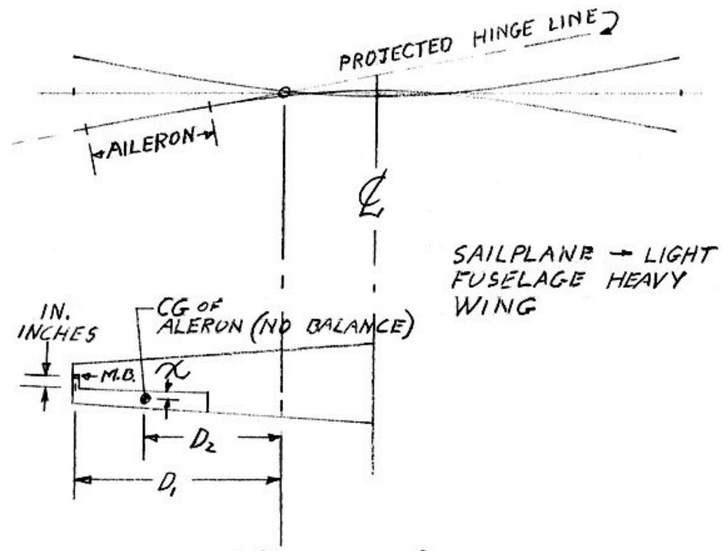
and the inch lbs. at the center balance is $= \frac{D_3}{D_1} \times (\chi \times W_E)$

If the center balance weight is one weight for both elevators then of course the center balance is 2 TIMES THE ABOVE. Note inch lbs. of mass balance is the distance from the hinge line to the C.G. of the mass balance times the weight of the mass balance.

If possible use the same technique on the rudder; you will not have the doubling up in the center. It is of course OK to distribute the mass balance spanwise along the surface proportional to the chordwise unbalance distribution.

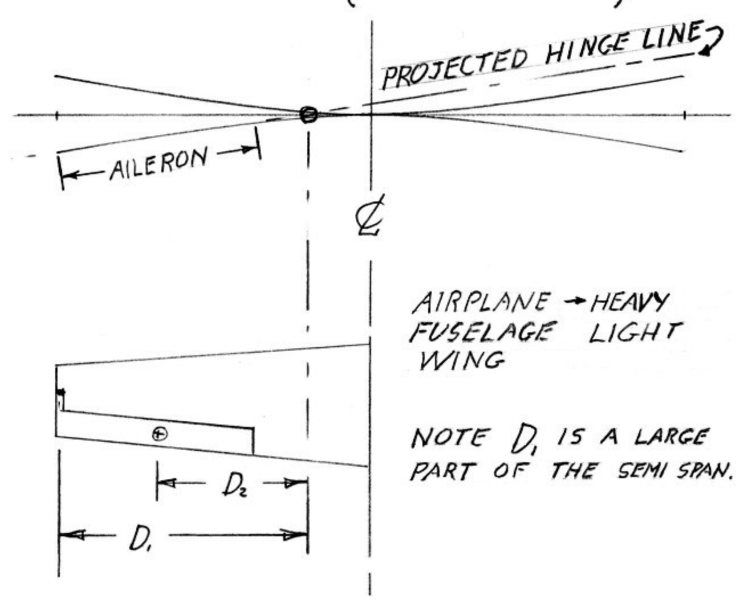
Aileron balance is a much simpler problem than tail surface balancing since ailerons do not generally run all the way in to the fuselage from the tip and the body motion even for Case B is small compared to the wing-flapping excursion. Some high-speed airplanes (Mach .8+) have balances only at the aileron tip. This is OK if the aileron torsional stiffness is high. (Natural frequency of the aileron in torsion including mass balance is considerably above the wing flapping frequency.)

Of course distributed mass balance proportional to the distributed mass unbalance is always OK. A full span aileron could have the same problem in the A mode as an elevator in the E mode if the wing were extremely heavy and the body light, but also the body mode in bending would have to be close in frequency to the wing flapping mode frequency. The likelihood of the above is essentially zero. So generally if the mass balance is sufficient to satisfy the following, the system will not flutter due to aileron unbalance.



THE MIN. M.B. (MASS BALANCE) WEIGHT IS

$$M.B. \times IN. = \frac{D_2}{D_1} \times \chi \times \left(\text{WEIGHT OF AILERON WITHOUT M.B.}\right)$$



Some words of warning about mass balancing. First, mass balances must be attached to the surface sufficiently strong to stand buffeting due to stall at high speed and stiff enough so that the mass balance resonating against the surface being balanced produces a frequency considerably above the expected flapping frequency of the surface that the control surface is attached to.

Some notes on flight flutter testing: My advice is to cross-exam the design to make sure that there is no possibility of flutter at 1.5 x VNE of the machine, then make a flight flutter demonstration, not a test. There is only one case where over balancing of control surfaces will cause flutter and that is where the over balance causes an apparent unbalance.

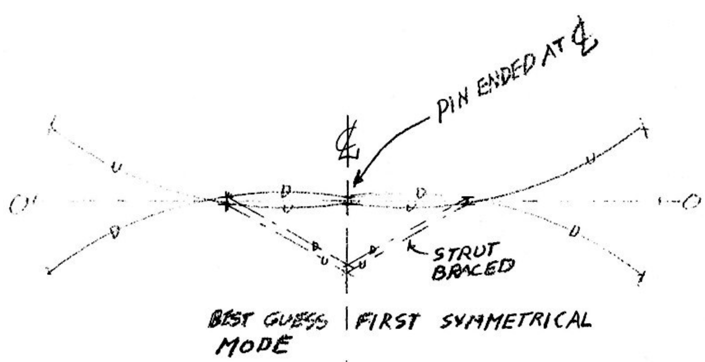
Look at case E: a tail with full static balance on the elevator all at the tip with a light aft fuselage so the fuselage motion is large. The inboard largest part of the elevator sees the mass balance at the tip as if it were on the trailing edge of the elevator die to its opposite motion. (Explanation of above: Full static balance means that you balance around the hinge line and in this example put all the balance at the tips.) Full static balance does not mean that you do not have a flutter problem.

Afterthoughts

There are many effects not covered in this overview of the physics of flutter:

1 – The effects of structural damping.
2 – Transonic effects (imbedded supersonic enclosures with shock down to subsonic) causing non-linear aerodynamics.
3- Body pitching coupling with flapping & torsion and/or control surface motion.
4- Separated flow and stall flutter
5- Never balance a tab more than 95%.

These effects are not generally problems with sailplanes and light aircraft.



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