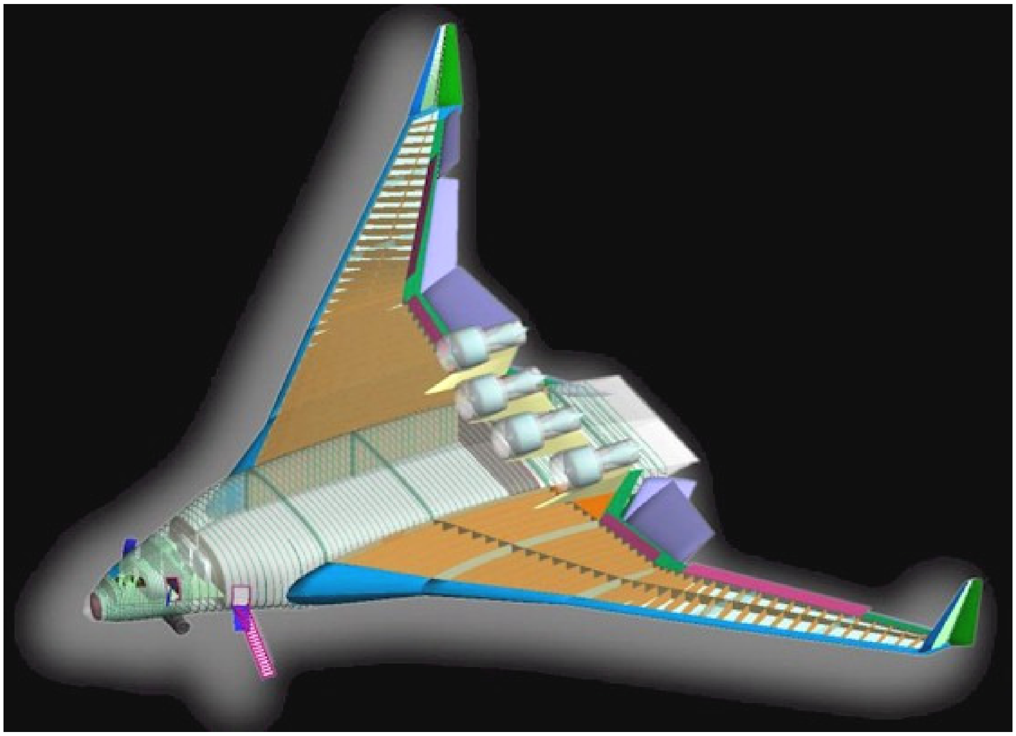
No. 300 JUNE 2011

T.W.I.T.T. NEWSLETTER



Long Range flying wing aircraft, showing internal details. Source: http://www.mh-aerotools.de/company/paper_9/global_transport_aircraft.htm Unclassified Paper - presented at the RTO-Symposium on Unconventional Vehicles and Emerging Technologies, Bruxelles, 2003. *(ed. – This might not show up in the printed version, but looks great in the electronic version of the newsletter.)*

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

The number after your name indicates the ending year and month of your current subscription, i.e., **1106** means this is your last issue unless renewed.

Next TWITT meeting: Saturday, July 16, 2011, 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.

T.W.I.T.T. Officers:

President: Andy Kecskes **(619) 589-1898**
Treasurer:
Editor: Andy Kecskes
Archivist: Gavin Slater

The **T.W.I.T.T.** office is located at:
Hanger A-4, Gillespie Field, El Cajon, California.
Mailing address: P.O. Box 20430
El Cajon, CA 92021

(619) 447-0460 (Evenings – Pacific Time)
E-Mail: twitt@pobox.com
Internet: http://www.twitt.org
Members only section: ID – **20issues10**
Password – **twittmbr**

Subscription Rates: $20 per year (US)
$30 per year (Foreign)
$23 per year US electronic
$33 per year foreign electronic

Information Packages: $3.00 ($4 foreign)
(includes one newsletter)

Single Issues of Newsletter: $1.50 each (US) PP
Multiple Back Issues of the newsletter:
$1.00 ea + bulk postage

Foreign mailings: $0.75 each plus postage

Wt/#Issues	FRG	AUSTRALIA	AFRICA
1oz/1	1.75	1.75	1.00
12oz/12	11.00	12.00	8.00
24oz/24	20.00	22.00	15.00
36oz/36	30.00	32.00	22.00
48oz/48	40.00	42.00	30.00
60oz/60	50.00	53.00	37.00

PERMISSION IS GRANTED to reproduce this publication or any portion thereof, provided credit is given to the author, publisher & TWITT. If an author disapproves of reproduction, so state in your article.

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).

TABLE OF CONTENTS

PRESIDENT'S CORNER

Even though there weren't very many letters or e-mails this month to work from I managed to find some material for you I think you will enjoy.

I have put in Part V of the continuing Weyl article on stalling phenomenon of tailless aircraft, which only leaves two more chapters plus references to finish up.

I have also included some material from Al Bowers covering a talk he gave to the AIAA Los Angeles chapter in August 2010 on minimum induced drag that he had been asked about through the Nurflugel group. What he included was a breakdown on what was in each segment and a link to a series of slides that go with it. It is not the complete story since there is some material from the presentation missing in his synopsis, but it is still some good information on the subject.

Now that the summer is rapidly approaching I hope some of our members will be able to get out and do some flying whether it is full size or scale aircraft. If you have some extra time, don't forget to take a few pictures and send them my way so I can share your experiences with the others in the group. Unfortunately, I am still a long way from having my sailplane in the air, but made some major progress over the past few weeks that have set the stage for rapid progress in the weeks ahead.

Happy flying.

Andy

LETTERS TO THE EDITOR

May 12, 2011

Hi Andy.

In the members only section the March & April issues for 2011 do not have valid links. This is they are not reachable via this part of the website.

Warren Bean
<warren.bean@gmail.com>

(ed. Warren was right about the links and they have been fixed. If anyone should happen to find a link on the web site that doesn't work, please let me know. I don't go back through the material on the site very often checking of broken links so I sort of depend on viewers to let me know through an e-mail.)

May 17, 2011

I was searching for information on vortex street forcing functions and came across an AIAA paper on bird wings that may be of interest to some members. It includes geometric information on 4 birds and some airfoil analysis. It may be found at: http://ntrs.nasa.gov. Enter the search term "Avian Wings" in parenthesis and 3 documents should show up with one of them being the AIAA paper. I have not checked out the other two, but they may be of interest also.

James McLellan
<jwmcl@q.com>

(ed. – I didn't read all of this since one of the papers is 425 pages with the others being between 25-35 pages with illustrations and images. They look very interesting for those of you who enjoy the technical side. Thanks James for thinking of our bird flight enthusiasts.)

Nurflugel Bulletin Board Threads

I have been following this group for a while. I joined because of my interest in flying wing aircraft. This interest and my passion for model airplanes led me to rediscover a 63-year-old article I remembered as a kid about a flying wing model. The original magazine's plans were inaccurate, typical of the era, so I redesigned them in AutoCad. I would like to submit a few items (attached) that you may find interesting. I posted the magazine article a while back on a flying wing model airplane group and someone sent me a recent picture of Bernie Gross and his homebuilt flying wing.

Bill Froeb
<wfroeb@optonline.net>

Is this the photo of Bernie and his recently finished Pioneer 2 he built back in the mid 1970's? He called this glider, "The Deaf Hawk", but referred to is as "My Beloved". Somewhere I have a photo he took of himself flying his Pioneer at 10,000 ft.

Jim Marske
<jim@marskeaircraft.com>

(ed. The image Bill included with the original message to Nurflugel was cut out by the program, but it looks like you can see everything he was talking about at this link. The PDF image in the upper center should be page 1 of several pages you can see by clicking on the ≥ link under the second from right PDF image. I have included a sample image at the top of the next page.
http://www.rcgroups.com/forums/attachment.php?attachmentid=3913337)

"On the Minimum Induced Drag of Wings"

...or why Al Bowers ("that idiot again! What makes him think he's so smart!") thinks the Hortens are important...

http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110003576_2011000927.pdf

Chart 1: I stole the talk title from Ludwig Prandtl. The ideas here are Prandtl's, not mine. I am simply the guy connecting the dots, the really BIG idea came from Prandtl. Munk, Horten, Jones, Klein & Viswanathan, and Whitcomb reiterated it.

Chart 2: Just an outline of the talk. I will give a SHORT history of spanload and why its important ("what is the optimum spanload?") and the implications of spanload (flight mechanics and adverse yaw), and finally close with a few concluding remarks.

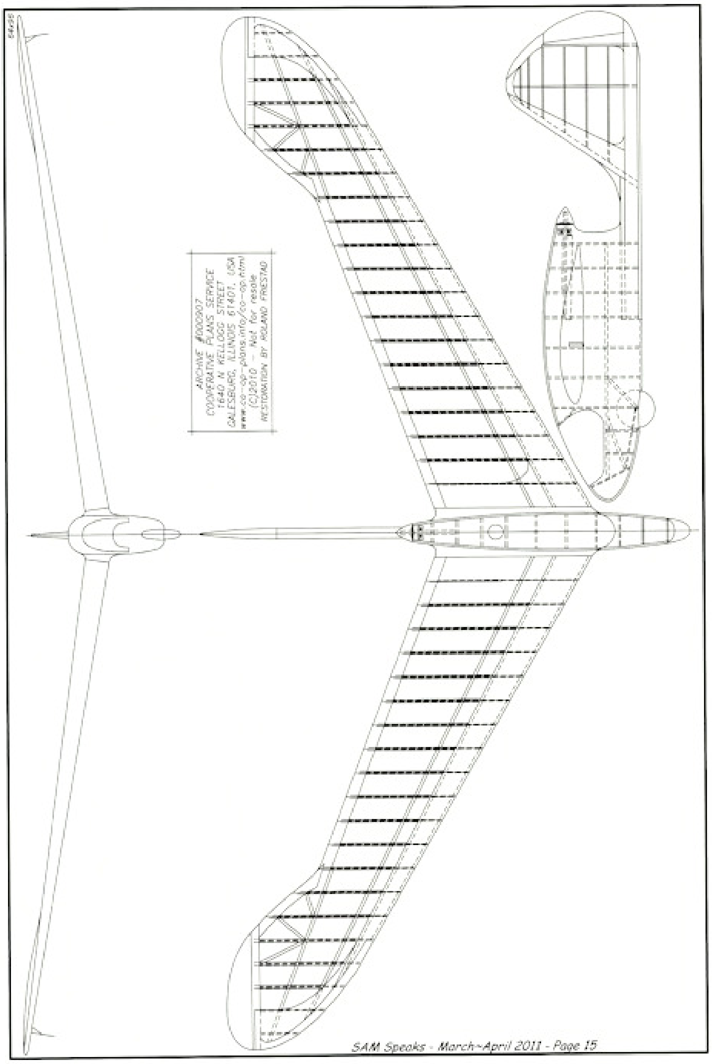


Chart 3: History of spanload. We started with the bird as out model of flight. And we had some success with that, but we departed from a bird model with a more mechanistic model (which is what we still do today), and we got away from the holistic and organic model for flight. At about the same time, we got the first analytical tools to evaluate spanload and the ability to optimize it.

Chart 4: Birds are the ultimate organic and holistic model for flight. I like the use of the Great Wandering Albatross (~11 ft span) simply because it is the most efficient soaring bird. The albatross in the upper right is cheating, note his left wingtip is in contact with the water, so he has no induced drag on that wing!

Chart 5: So what is it about the bird flight model that is so great? One of the things I noticed along the way, birds don't have vertical tails. Why not? How do they control yaw? 1/ Birds also flap their wings for propulsion (a WHOLE 'nother topic and area of exploration!). The figure (lower right) is of a high performance aircraft model in a wind tunnel being driven in a cyclic pitching maneuver. The solid line shows that on the up-stroke the aircraft follows the upper arc of the loop, and develops a great deal of lift. On the down-stroke of the cycle the lift falls to a rather low level. The dotted line is the steady state solution.

(ed. – Below is an example of the slides included in the on-line link at the beginning of the article.)

Note that the cyclic motion results in lift ABOVE AND BEYOND what can be sustained in steady flight. This is dynamic lift, and it is an interaction between the momentum transferred from the wings of the aircraft to the air, and the momentary momentum transfer of the energy back to the aircraft (this is caused by the start-up vortex and is related to the Strouhal number). 2/ there is a stability and control aspect to birds we don't understand (I have yet to see this explained well in the literature). How do birds get away without vertical surfaces? 3/ Birds are an integrated system that combines minimum structure, optimal propulsion, optimal flight performance, and optimal flying qualities. How do they do that?

Chart 6: The departure from the organic model to the mechanistic model happened with the success of the Wright Brothers (another topic of considerable discussion). The key dates of the departure are all in October of 1902, 10 Oct, 12 Oct, and 24 Oct. Prior to this time, birds were the model of flight. You can see this in the 1900 and 1901 gliders, as neither of these gliders, or the 1899 kite (down the left side of the chart), had vertical tails. But they discovered adverse yaw and the lack of vertical surfaces was causing considerable distress to their ability to fly. The 1902 Glider had vertical surfaces. Initially the vertical surfaces were fixed (top row, second from left). But on 10 Oct, Orville suggested to Wilbur that the vertical be made movable. The first flights of this new "three-axis control" glider was 12 Oct. By 24 Oct they had gained considerable confidence and made their first deeply banked turns, and photographed such (bottom right). Tow images were made on 24 Oct, and both were from the rear showing steeply banked flight, considerable wing warping for roll control, and rudder deflection to control adverse yaw. At this point they embarked on adding power for the first successful power, controlled manned flight (top row, second from right) on 17 Dec 1903. And finally by solving the issues with control harmony and propulsion reliability they flew the first practical aircraft (top row, right) on 04 Oct 1905. Their patent of 1906 is about the use of wing warping for roll control, and rudder deflection for control of adverse yaw (propulsion is NOT part of their patent for aircraft). This is the foundation for the mechanistic model of flight, and it is a model for which we still use today almost without fail. And we ALWAYS use vertical surfaces or some other method (usually DRAG) for yaw control.

Chart 7: But 1903 was a good year for another reason. Prandtl finished his doctoral thesis on boundary layers. And from this development, he could separate the viscous from the inviscid flows. And in that simplifying development he came up with the lifting line theory. From lifting line, you can calculate the induced drag from the circulation around a wing. In about 1917, Prandtl calculated the span load for the minimum induced drag of a wing for a given span (the elliptical spanload). This was published by him in the open literature in 1920 (NACA Report No 120). Albert Betz (a brilliant researcher and student of Prandtl) published the first known description of the elliptical spanload. Betz made it clear that the idea and solution was all Prandtl's. BTW, Betz would later solve the problem of how to measure the profile drag of a wing (the wake momentum deficit).

Chart 8: Max Munk (another of Prandtl's students) solved a general solution for the optimum spanload for a wing of a given span, as well as for multiple wings (usually called the Munk Stagger Biplane Theorum). This was published in 1920 (NACA Report No 121). Notably, Munk was the Chief Scientist of the NACA Langley Research Laboratory in Hampton VA [insert funny story of Munk here]. Up to now, all the solution sets were for the minimum induced drag for a wing of a given span (elliptical spanload). It is in 1932 that the "breakthrough" happens when Prandtl revisits the solution to the question of what is "optimal." In his 1932 paper, titled "On the Minimum Induced Drag of Wings" (when translated to English) Prandtl imposes a different constraint than the use of the given wingspan. Prandtl uses the constraint as the equivalent wing root bending moment of the elliptical spanload. Prandtl's question (which he answers) is: "is there a different spanload with the same lift and the same wing root bending moment as the elliptical spanload that results in less induced drag? Prandtl solves this new problem.

Chart 9: Reimar Horten hears of Prandtl's new solution and applies it to his sailplane designs. He later writes his own PhD dissertation on the practical implementation of the new Prandtl spanload. In the Horten implementation, there is induced thrust at the wingtips. He postulates (and later solves) the application to eliminate adverse yaw using Prandtl's spanload solution. Horten calls this spanload the "bell shaped spanload distribution" (BSLD). An American researcher, Robert T Jones, discovers the same solution as Prandtl did in 1950. This solution is entirely independent of Prandtl, Jones was unaware of Prandtl's solution until many years later. Jones' formulation was for the general case, not just the optimal spanload for a given lift and given wing root bending moment. Finally in 1975, Armin Klein and Sathy Viswanathan add an additional constraint, the shear. Using this formulation the resulting wing should produce the minimum induced drag for a given wing weight.

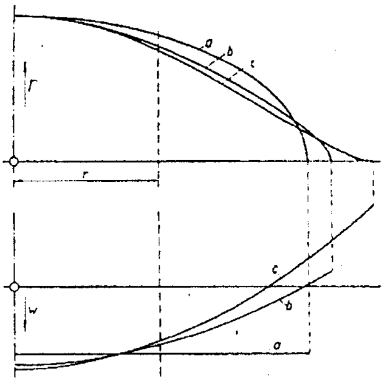
Chart 10: Prandtl's original lifting line theory was characterized by Prandtl as "vortex ribbons." Note in the drawing that the spanload is depicted as elliptical (also note that circulation is defined as a vector with the origin at the span centerline, we have discarded this notation today and use circulation only as a scalar, so it is always shown as positive now). From Prandtl's 1920 paper: the downwash behind the wing is constant (y=c, a zeroth order polynomial).

Chart 11: Using Prandtl's lifting line theory, we can also apply the theory to the question "what is the minimum drag for a given control input?" The solution is the half-lemniscate. Dr Richard Eppler applied this idea to the ailerons of the fs-24 Phoenix sailplane.

Chart 12: Examples of elliptical planforms with elliptical spanloads, the fs-24 and the Supermarine Spitfire.

Chart 13: This *(next page)* is from Prandtl's 1932 paper on induced drag. It was an outstanding piece of work, only two pages, eleven equations, two tables, and two figures long. The figures are reproduced here. The top is the spanload, Curve a is the elliptical spanload. Curve b is a spanload with equal wing root bending moment as the elliptical but less induced drag. And the optimal solution, again with the same lift and wing root bending moment as the elliptical, is curve c. The spanload for Curve c has 22% more span, and has 11% less induced drag. The lower figure is the non-dimensional induced drag for the same three curves as above. Note the induced drag becomes negative (note: negative drag) at the wingtips.

Minimum Induced Drag & Bending Moment



- Prandtl (1932)
  Constrain minimum induced drag
  Constrain bending moment
  22% increase in span with 11% decrease in induced drag!

Chart 14: Horten applies Prandtl's theory to his family of sailplanes. Horten is interested in the structural weight savings at this point. He has not solved the problem of the adverse yaw from control input, and this is a noted characteristic in his designs at this time (from 1933 through 1945). The figures show the elliptical spanload and the bell shaped spanload in the upper figure, and in the lower figure is the dimensional induced drag as a function of span (again: note the negative drag at the wingtips for the bell shaped spanload).

(ed. – There are 31 charts to this presentation so I will put the rest of this synopsis by Al in the next issue.)

THE AEROPLANE JUNE 27, 1947

AERONAUTICAL ENGINEERING

Stalling Phenomena and the Tailless Aeroplane IV

By A. R. Weyl,: A.F.R.Ac.S,

THE N.A.C.A. tests, discussed in the previous installment, were made with an NACA 23012 aerofoil section on the following plan shapes:—

Angle of effective sweep	Aspect ratio
60 degrees	2.52
45	3.56
30	4.36
0	5.0

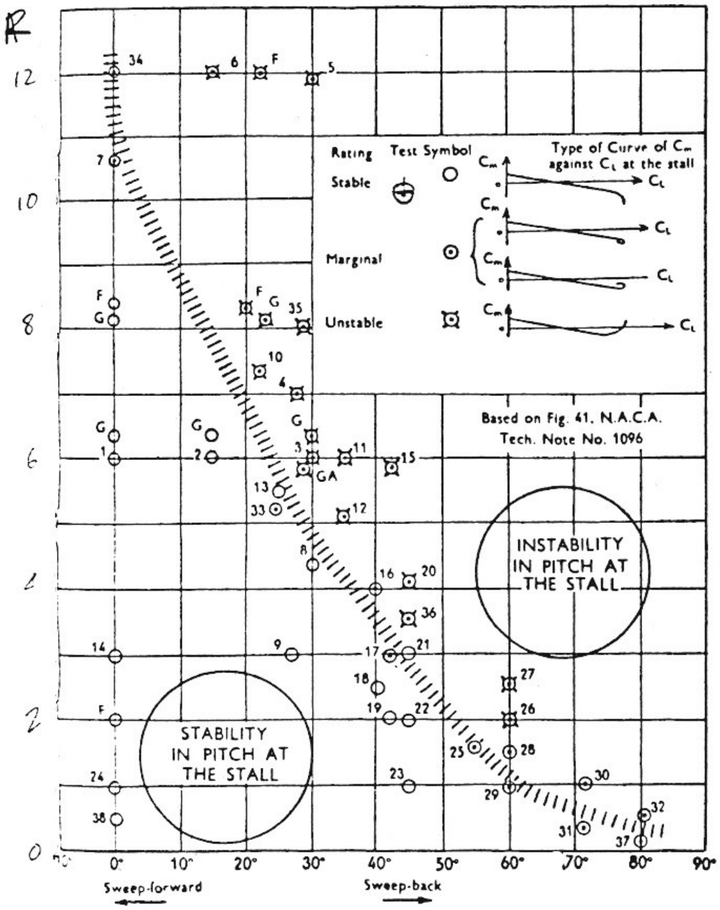


Fig. 8.—Longitudinal stability of swept-back, untwisted wing systems at the stall, as a function of sweep and aspect ratio (experimental results).

The wingspan and the wing width (normal to the leading edge) were in all cases the same. The Reynolds Number of the tests was between 1.0 and 2.0×10^6.

The stalling behavior is characterized by the shape of the pitching-moment wing-incidence curve. The influence of the stall development on swept wings is very informative. But in basing design considerations on these qualitative results, it ought not to be overlooked that the effect of the change in aspect ratio is as well marked as that of sweep.

For the unswept wing with an aspect ratio of 5, the pitching-moment curve is straight, tip to the incipient stall. After this point it turns steeply towards negative (nose-heavy) pitching moments, and a tendency to decrease the incidence (i.e., stability) is experienced. For the wing with 30 degrees of sweepback, however, the curve turns up when the stall develops. Even a substantial amount of washout does not constitute a complete cure.

An experimental tailless research glider of General Aircraft, Ltd. had 28.4 degrees effective sweep-back, RAF.34 aerofoil, an aspect ratio of 5.8 and 5 degrees washout. During flight tests with this aircraft it was found that, when made to stall, the nose rose a few degrees (i.e., proof of instability), but then dropped again when the stall spread along the span.

F. Anderson, of the N.A.C.A., found in earlier wind-tunnel tests (Ref. 77) that 30 degrees sweep with an aspect ratio of 6, a taper ratio of 2 and 8.5 degrees washout, proved unstable at the stall, while a wing system having 15 degrees sweep gave stability at the stall without any washout

For larger angles of sweep, and consequently lower aspect ratios, the somewhat surprising phenomenon was observed that a negative slope of the pitching-moment curve appeared at incidences well below the stall. This unexpected increase of the longitudinal stability occurred at sweep angles of 60 degrees or more, even at incidences, which correspond to those of high-speed flight.

Although this phenomenon has nothing directly to do with what is commonly understood as a stall, not only is it characteristic for the combination of sweep and aspect ratio investigated, but in addition, may well constitute a certain measure of danger. The pronounced increase in the static longitudinal stability (due to the backwards shift of the aerodynamic center) means not only a sudden appearance of nose-heavy trim, but also a reduction in the effectiveness of the elevator control ("frozen control" at high speed). Soule has also pointed out that the phenomenon may be responsible for the diving tendency when flying at speeds near to that corresponding to the critical Mach Number of the aircraft, this is, however, not quite true.

At higher incidences the shape of the pitching-moment curve for the wing of pronounced sweep again shows the tendency to increase the incidence. Obviously, the instability at the stall arising from the change in the slope of the pitching-moment curve is connected with the effective sweep as well as with the aspect ratio. The sweep, however, seems to be the main factor, judging from other tests than the N.A.C.A. tests, when the sweep alone was varied (e.g., Ref. 71). But from the comparative N.A.C.A. investigations it is established that the higher the aspect ratio (i.e., the slimmer the wing plan), the smaller becomes the angle of sweepback at which instability at the stall becomes apparent.

The comparison made by Shortal and Maggin (Ref. 76) proves (for aerofoils without twist or any other devices curing the wing-tip stall) that with a sweep-back of 15 degrees and an aspect ratio of 6, the wing system is stable at the stall, while with the same sweep but an aspect ratio of 12, instability in pitch at the stall becomes apparent. This reflects badly on the properties of tailless sailplanes like those of the Horten brothers, which consequently require an undue amount of twist in order that the stall shall become innocuous.

On the other hand, a wing system with 30 degrees sweep and an aspect ratio of 6 was unstable, while with an aspect ratio of 4.36, the same angle of sweep-back resulted in a stable pitching-moment curve. The American results tally well, both qualitatively and quantitatively, with earlier German experiments at Goettingen and with the results found by Ferrari at Turin on the Piana-Canova tailless development (Ref. 78).

Seemingly, the combination of sweepback and aspect ratio forms the major factor for the shape of the pitching-moment curve at the stall. Since the "stick-free" stability at the stall is important for the safety and the flying qualities of tailless aeroplanes, the designer will have to take this into account.

Soule and his collaborators at the N.A.C.A, have condensed their experimental results in a helpful diagram, which relates to aerofoils without any wing twist. The boundary indicated in this diagram should, however, be accepted with care. Only the influence of sweep and of aspect ratio have been taken into account. The choice of the aerofoil section will also be important, to an extent, which is hitherto still unexplored. Moreover, however important the stick-free stability at the stall is, it does by no means reflect completely the nature and qualities of the path of flight and the attitude of the aeroplane when the incipient stall takes place.

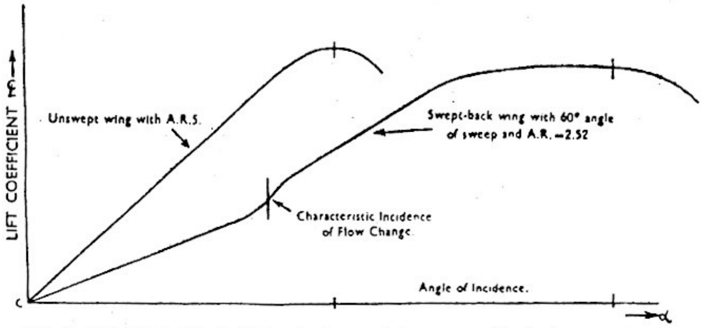


Fig. 9.—Lift curve for an unswept wing and for a swept-back low aspect-ratio wing of equal aerofoil section (N.A.C.A) [from N.A.C.A. Tech. Note No. 1088]. The variation in $\frac{dC_L}{d\alpha}$ at the characteristic incidence is worth noting.

So, for instance, there might be a nose-heavy (stable) tendency at the incipient stall. The corresponding slope in the pitching-moment curve may, however, be so abrupt and severe that the aeroplane tends to dive away suddenly without the possibility of control, rendering a quick recovery impossible. This is, indeed, the fact with many conventional, so-called “safety" aeroplanes, and has given rise to a large number of severe accidents. The stall, too, may spread so suddenly span-wise and chord-wise that it becomes relatively unimportant for the pilot whether the feel of the stick is nose- or tail-heavy; the question of control effectiveness is of paramount importance at that instant. Hence, the N.A.C.A, diagram will form a useful guide for the designer, but it should not be deemed conclusive for a final decision on the wing plan.

The taper ratio (root chord/tip chord), too, has an effect on trim and stability at the stall. Its increase, i.e., a pronounced taper, aggravates the occurrence of the premature tip stall at equal effective angles of sweep. The reasons are the same as those valid for the unswept tapered wing. Hence, taper promotes stick-free instability at the stall.

For low-aspect ratios, however, taper may have just the opposite effect. In free-flight tunnel experiments of the N.A.C.A., wing systems having 42 degrees sweepback and aspect ratios between 2 and 3, a taper ratio of 1.4 gave erratic stability at the stall, while pointed wings indicated clear stability at the stall, though with curvature of the pitching-moment curve at sub-critical incidences.

The presence of a fuselage does not seem to exert a great influence on the characteristics of the pitching-moment-curve slope at the stall.

There is reason to presume that, when the aspect ratio is too large for a given sweepback, unstable pitching moments will occur during and after the incipient stall. If the aspect ratio is too small, the aerodynamic center will shift at all speeds of flight and, at the stall, the longitudinal stability will be so excessive as to impair seriously the controllability. The reason for this is the influence of the tip vortices on the flow over the wing; with decreasing aspect ratio this influence increases, but taper seems to reduce it.

The slope of the lift curve (dC_L/d_α) generally decreases with decrease of the aspect ratio. But wing combinations of the kind investigated by the N.A.C.A. (as, for instance, sweep of 45 degrees combined with an aspect ratio of 3.56, or sweep of 60 degrees combined with an aspect ratio of 2.52) exhibit distinct kinks in their lift curves, with noticeable increases of the lift-curve slope at higher incidences beyond a "characteristic" incidence.

This is an indication that a change in the state of flow in the boundary layer is taking place at this "characteristic" incidence. Indeed, in the N.A.C.A. tests an observation of silk tufts showed that the flow change at the "characteristic" incidence was accompanied by a slight ruffling of the tufts near the leading edge in a region at about 40 percent of the semi-span from the root. The provision of a small barrier to span-wise flow at this region (mid-span fin disc) exerted an appreciable effect, both on the lift-curve slope and on the pitching-moment slope (both with respect to the wing incidence). This observation may have some bearing on the flow mechanics, causing unorthodox behavior over the certain laminar-flow aerofoils mentioned earlier.

The flow change also exerts an influence on the static directional ("weathercock stability (dN/dβ) and on the rolling moment, due to side-slip (dL/dβ) of the wing. Both stability derivatives (of which the former is critical for the design of "flying wings") assume reversals in their moment/incidence curves for some wing incidences, quite distinct from the influence of tip stall.

Apart from the peculiarities in longitudinal stability at the stall, sweepback is also prone to give trouble in lateral stability at higher incidences of flight. At high incidences, sweepback has the same effect on the lateral motions as dihedral, and pronounced sweep gives the characteristics of excessive dihedral. The consequences are unstable or badly damped lateral oscillations. This is very noticeable at incidences near the stall, and the flying qualities at take-off and landing may be badly affected by it. How far the aspect ratio has an influence does not yet seem to be experimentally established, but may be presumed as present. The resulting motion arising from the deficient lateral oscillatory instability may easily take the form of “Dutch Roll," i.e., a non-damped yawing and rolling motion due to the excessive dihedral effect. This effect is not remedied by devices intended to avert the premature tip stall, but is directly connected with the sweepback.

The experience that sweepback can lead to lateral instability at high incidences is actually a very old one, but apparently forgotten. Nearly 35 years ago pilots and designers became well aware of it. Probably Dunne, experienced the trouble before anybody else, but there is no conclusive evidence of it. Bomhard in Vienna, who originated the swept-back Lohner biplanes from 1910, began with a sweep of 23 degrees. He reduced it on subsequent models to only 12 degrees because too much sweepback was found to cause lateral oscillatory instability during take-off and landing. The adoption of staggered biplane arrangements and of pronounced wash-out, which was finally adopted for the Lohner biplanes, according to a 1911 patent of Bomhard, did not prove a remedy (Ref. 83). From Austria, the swept-back biplane fashion spread to Germany, and there again designers began with angles of sweep of 30 degrees and more (L.F.G., Union-Bomhard, etc.). The same results were found and the angles of sweep were subsequently reduced on all these biplanes.

Parallel with this, Fokker had identical experience with his first monoplanes. Though the angle of sweepback was only about 9.5 degrees, the addition of a dihedral of 9 degrees rendered the Fokker "Spider" troublesome and vicious during take-off and landing. The effect was so much felt that the Prussian military authorities refused to accept the design for this very reason. Thirteen years later Fokker returned with the D.XIV fighter with his original features combining an effective sweepback of 14 degrees with 7 degrees dihedral. The design was not satisfactory, though the fatal crash experienced with it was most probably due to premature tip stall leading to a flat spin.

In more recent times, "Dutch Roll" instability had been predicted by R.A.E. tests for the de Havilland D.H.108 experimental tailless aircraft for incidences below the actual stall. In practice the disturbance seems to have been observed, but has not proved troublesome.

The Remedies of the High Incidence Tip Stall

The stalling phenomena discussed can be varied by devices, to remedy the premature flow-separation in the region of the wing tips. Devices which have been found practicable for this purpose can be divided into two categories. They are either those by which the increase of the section lift at the tips (which follows from the sweepback) is directly reduced, or those which delay the stall at the wing-tip and make it occur at higher effective incidences.

To the first kind belongs the remedy of wing twist, i.e., a washing-out of the effective incidence towards the tips. This changes the lift grading over the span (i.e., the section lifts) it all incidences.

Consider a stable swept-back wing system with tips so twisted that their local incidences are essentially smaller than that of the wing at the root. Such a wing will obviously reach the critical incidence first at a region of the span, inboard of the tips. Obviously, when such a twisted wing system approaches the stall it will provide "stick-free" stability, i.e., a tendency to decrease the incidence, because the lift contribution of the tips will then give a nose-heavy trim. Such "wash-out," moreover, is coincident with the fundamental condition for static longitudinal stability at all incidences of normal flight.

This coincidence is, however, only a qualitative one. Actually, for the achievement of static stability in pitch for normal positions of the center of gravity, less wing-twist is required than for the prevention of tip stall. Both requisite depend upon the amount of sweep for their magnitude, but only the former is directly related to the center-of-gravity location

Even a very substantial amount of wash-out is not sufficient to exclude the occurrence of premature tip stall entirely. A considerable degree of wing twist may easily be neutralized by a rolling motion, with the result that one wing-tip stalls before the other one.

In any case, wing twist is not very desirable; it is wasteful in drag. Not only does it increase the profile drag, but by modifying the lift grading from that of an elliptical one the induced drag, too, is increased. Wing twist reduces the critical Mach number and is presumed bad for the compressibility-stall. Moreover, with pronounced angles of sweep, wing twist alone is not sufficient to prevent tip stall, even in straight flight.

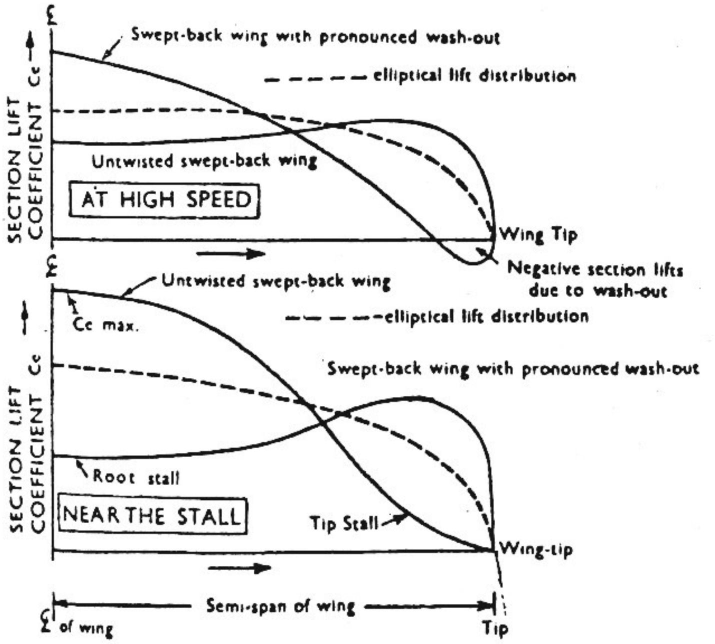
Thus, obviously the device of wash-out has only limited scope and will remain restricted for small angles of sweepback only. When wash-out is employed as a device against premature tip stall, two considerations should be borne in mind. One is that, however pronounced the twist may be, it will not form an absolute safeguard for the reason stated. To consider the incidence-change induced by a rolling motion would lead to abnormal and quite uneconomical wing twists. The Dunne biplane had 45 degrees wing twist between the "bustle" and the tip.

Secondly, twist is best distributed along the span. If the wing is shaped with wash-out over the tips only, the adjoining regions of the span will have large differences in pressures and lift; consequently, high span-wise pressure gradients will be formed. The result is that premature separation will be induced at such regions of different lifts; these are likely to upset the beneficial influence of the wash-out. The least penalties are erratic stability qualities.

The same consideration also applies to tips with variable incidence. As soon as regions with different section lifts occur at neighboring strips of the span, the pressure gradient becomes easily large enough to promote a premature separation of the flow. This restricts the range of utilization for variable-incidence wing tips. Flow separation has actually been observed immediately inboard of wing-tip controllers.

Although even somewhat more limited in scope, the increase of section camber towards the tips, which the author introduced as a remedy against premature tip stall on tapered wings in 1936 (Ref. 28), is more efficient against premature tip stall. Flight tests at the R.A.E. have since proved that the increase in section camber slows up the breakaway of the airflow. In addition, the loss in lift sustained beyond the critical incidence is less catastrophic, and this would allow the retention of some measure of control at the stall. Of all the simple remedies for tip stall, this seems still the best; its influence on the induced drag is smaller than that caused by geometric twist and the increase in profile drag, due to span-wise pressure gradients, can be made exceedingly small. M. A. Garbell (Ref. 79) has recently given a method of aerofoil selection for highly tapered and swept-back wings based on the device of highly cambered wing-tip sections. The effectiveness of this has been experimentally proved for taper ratios of 4 and angles of sweepback at the leading edge of up to 15 degrees.

For tailless aeroplanes with moderate sweepback, a combination of twist with increased section camber towards the tips would, hence, seem to have prospects. For larger angles of sweep, however, none of these simple devices appears as a practicable method of effecting a cure.



Among the stall-delaying devices belong the wing-tip slot and the provision of leading-edge flaps near the wing tips. Slots delay the stall for the span region covered by them, up to very high incidences. Since they retain the same value of the lift-curve slope over the extended range of incidence, their use results in a higher maximum lift. However, considering the maximum lift of the entire wing system, the effect of wing-tip slots is but small and, on swept-back wings, marred by the effect of the sweep. Slots—even those of the full-span variety—give a small increase in the maximum lift if span-wise flow components, arising from sweep-back of the leading edge, are present.

In spite of this, wing-tip slots are rather efficient in delaying the stall at the tips of a swept-back wing and in curing the premature tip stall, even at substantial angles of sweep. As the thickness of the boundary layer has much to do with the effectiveness of a slot, it is vital to have the slot as far forward toward the leading edge as possible.

With automatically actuating slats of the Handley Page type, the profile-drag increase, caused by the provision of slots at high incidences, becomes very small indeed for flying at high and cruising speeds. "Letter-box" slots are not as effective, besides giving higher profile drag. The loss of efficiency is not only due to the slot interruptions, which are necessitated for structural reasons; as the slots are farther back on the chord, the thicker boundary layer in that region impairs their action. On swept-back wings, the slot proportions and location tend to become critical. Nevertheless, the Me.163 rocket-fighter of Lippisch, which has proved to have satisfactory flying qualities at Farnborough, had been equipped with rather crude-looking slots of the "letter-box" variety.

The effectiveness of wing-tip slots for the prevention of premature tip stall and for the retention of aileron control beyond the stall, was discovered and investigated in this country more than 20 years ago. After it had become common knowledge that such slots could be designed to fit all reasonable demands for safe and effective flying, unstalled and stalled, wing-tip slots were—with few notable exceptions—practically ignored. To day they return for tailless aeroplanes as one of the devices, which may become a necessity.

First to experiment with wing-tip slots for the prevention of tip stall on swept-back tailless aeroplanes was G. T. R. Hill (Ref. 30). The necessity for this arose on the Pterodactyl Mk. V military biplane (1933-34). The shape of the larger upper wing resembled that of the U-wing of Mk. IV, but to give a better field of vision the centre section of the wing had a narrower chord and a thinner aerofoil section. In order to equalize the corresponding local loss of lift, it had been given a larger incidence, i.e., a wash-in. This resulted in premature stall at the center section, i.e., in a (desirable) root stall. In flight with engine on, however, the slipstream of the tractor airscrew unstalled the center section again, which rendered trim and stability difficult in powered flight. A remedy was found in the provision of automatic slots at the wingtips. These were coupled to a lift-spoiler, which emerged from the upper surface of the center section as soon as the slots opened at high incidences. The slots began to open at an incidence of 10 degrees; they were fully open at 15 degrees.

As mentioned, wing-tip slots contribute little to the wing's maximum lift. But since they permit safe flight at the incidence at which the maximum lift of the entire wing system occurs, they allow a swept-back wing to reach a higher value of maximum lift than it would attain when no slots were provided. Wingtip slots are, therefore, welcome accessories to high-lift devices for tailless aeroplanes.

With tailless aeroplanes and gliders several kinds of wing-tip slots have hitherto been used, such as (a) permanently open slots or fixed slats; (b) fixed slots with automatically operated shutters; and (c) automatic slots of the Handley Page type.

Fixed slats were experimented with in wind-tunnel tests by the N.A.C.A. a number of years ago, and the "letter-box" slots of the Lippisch Me. 163 have already been mentioned. The latter arrangement, consisting of one slot row interrupted by rib members of the wing structure, proved simple and effective. But it is open to doubt whether the increase of the profile drag caused by such slots can be considered tolerable at small incidences and high lift. Even if the direct loss in profile drag should be small, due to the influence of sweep—there are no experiments yet accessible of tests in this direction—it would seem obvious that the laminar flow over the region concerned is spoiled. In view of the somewhat crude execution of the arrangement, this is, perhaps, a feature the designer wanted in order to safeguard controllability and stability.

The Handley Page auto-slot has been successfully applied to the second version of the de Havilland D.H.108 tailless research type. It is actuated by the negative pressures over the wing leading edge, which assume high values, producing an upward, forward-directed resultant force on the slat when the lift assumes higher values. These high local negative pressures are the result of the adherence of the boundary layer to the wing, and a thin and vigorous boundary layer is a necessary requisite. The span-wise flow component on a swept-back wing causes the accumulation of a thick layer of stale boundary material at the wing tips. At the tips of wings with 45 degrees sweep, a boundary-layer thickness of between 30 and 50 percent of the local wing chord has actually been measured near the leading edge. Such a very thick boundary layer is lacking flow energy to provide high negative pressure, especially when the wing has some wash-out for stability. The experience with the second version of the D.H.108

has, however, proved that automatic tip slots operate quite normally.

AVAILABLE PLANS & REFERENCE MATERIAL

Coming Soon: Tailless Aircraft Bibliography
Edition 1-g

Edition 1-f, which is sold out, contained over 5600 annotated tailless aircraft and related listings: reports, papers, books, articles, patents, etc. of 1867 - present, listed chronologically and supported by introductory material, 3 Appendices, and other helpful information. Historical overview. Information on sources, location and acquisition of material. Alphabetical listing of 370 creators of tailless and related aircraft, including dates and configurations. More. Only a limited number printed. Not cross referenced: 342 pages. It was spiral bound in plain black vinyl. By far the largest ever of its kind - a unique source of hardcore information.

But don't despair, Edition 1-g is in the works and will be bigger and better than ever. It will also include a very extensive listing of the relevant U.S. patents, which may be the most comprehensive one ever put together. A publication date has not been set yet, so check back here once in a while.

Prices: To Be Announced

Serge Krauss, Jr. skrauss@earthlink.net
3114 Edgehill Road
Cleveland Hts., OH 44118 (216) 321-5743

Books by Bruce Carmichael:
Personal Aircraft Drag Reduction: $30 pp + $17 postage outside USA: Low drag R&D history, laminar aircraft design, 300 mph on 100 hp.
Ultralight & Light Self Launching Sailplanes: $20 pp: 23 ultralights, 16 lights, 18 sustainer engines, 56 self launch engines, history, safety, prop drag reduction, performance.
Collected Sailplane Articles & Soaring Mishaps: $30 pp: 72 articles incl. 6 misadventures, future predictions, ULSP, dynamic soaring, 20 years SHA workshop.
Collected Aircraft Performance Improvements: $30 pp: 14 articles, 7 lectures, Oshkosh Appraisal, AR-5 and VMAX Probe Drag Analysis, fuselage drag & propeller location studies.

Bruce Carmichael brucehcarmichael@aol.com
34795 Camino Capistrano
Capistrano Beach, CA 92624 (949) 496-5191

VIDEOS AND AUDIO TAPES

(ed. – These videos are also now available on DVD, at the buyer's choice.)

VHS tape containing First Flights "Flying Wings," Discovery Channel's The Wing Will Fly, and ME-163, SWIFT flight footage, Paragliding, and other miscellaneous items (approximately 3½+ hours of material).
Cost: $8.00 postage paid
Add: $2.00 for foreign postage

VHS tape of Al Bowers' September 19, 1998 presentation on "The Horten H X Series: Ultra Light Flying Wing Sailplanes." The package includes Al's 20 pages of slides so you won't have to squint at the TV screen trying to read what he is explaining. This was an excellent presentation covering Horten history and an analysis of bell and elliptical lift distributions.
Cost: $10.00 postage paid
Add: $ 2.00 for foreign postage

VHS tape of July 15, 2000 presentation by Stefanie Brochocki on the design history of the BKB-1 (Brochocki,Kasper,Bodek) as related by her father Stefan. The second part of this program was conducted by Henry Jex on the design and flights of the radio controlled Quetzalcoatlus northropi (pterodactyl) used in the Smithsonian IMAX film. This was an Aerovironment project led by Dr. Paul MacCready.
Cost: $8.00 postage paid
Add: $2.00 for foreign postage

An Overview of Composite Design Properties, by Alex Kozloff, as presented at the TWITT Meeting 3/19/94. Includes pamphlet of charts and graphs on composite characteristics, and audio cassette tape of Alex's presentation explaining the material.
Cost: $5.00 postage paid
Add: $1.50 for foreign postage

VHS of Paul MacCready's presentation on March 21,1998, covering his experiences with flying wings and how flying wings occur in nature. Tape includes Aerovironment's "Doing More With Much Less", and the presentations by Rudy Opitz, Dez George-Falvy and Jim Marske at the 1997 Flying Wing Symposiums at Harris Hill, plus some other miscellaneous "stuff".
Cost: $8.00 postage paid in US
Add: $2.00 for foreign postage

VHS of Robert Hoey's presentation on November 20, 1999, covering his group's experimentation with radio controlled bird models being used to explore the control and performance parameters of birds. Tape comes with a complete set of the overhead slides used in the presentation.
Cost : $10.00 postage paid in US
$15.00 foreign orders

FLYING WING SALES

BLUEPRINTS – Available for the Mitchell Wing Model U-2 Superwing Experimental motor glider and the B-10 Ultralight motor glider. These two aircraft were designed by Don Mitchell and are considered by many to be the finest flying wing airplanes available. The complete drawings, which include instructions, constructions photos and a flight manual cost $250 US delivery, $280 foreign delivery, postage paid.

U.S. Pacific (559) 834-9107
8104 S. Cherry Avenue mitchellwing@earthlink.net
San Bruno, CA 93725 http://home.earthlink.net/~mitchellwing/

COMPANION AVIATION PUBLICATIONS

EXPERIMENTAL SOARING ASSOCIATION

The purpose of ESA is to foster progress in sailplane design and construction,which will produce the highest return in performance and safety for a given investment by the builder. They encourage innovation and builder cooperation as a means of achieving their goal. Membership Dues: (payable in U.S. currency)

United States	$24 /yr	Canada	$40 /yr
So/Cntrl Amer.	$40 /yr	Europe	$45 /yr
Pacific Rim	$50 /yr	U.S. Students	$18 /yr

(includes 4 issues of SAILPLANE BUILDER)

Make checks payable to: Sailplane Homebuilders Association, & mail to Murry Rozansky, Treasurer, 23165 Smith Road, Chatsworth, CA 91311.