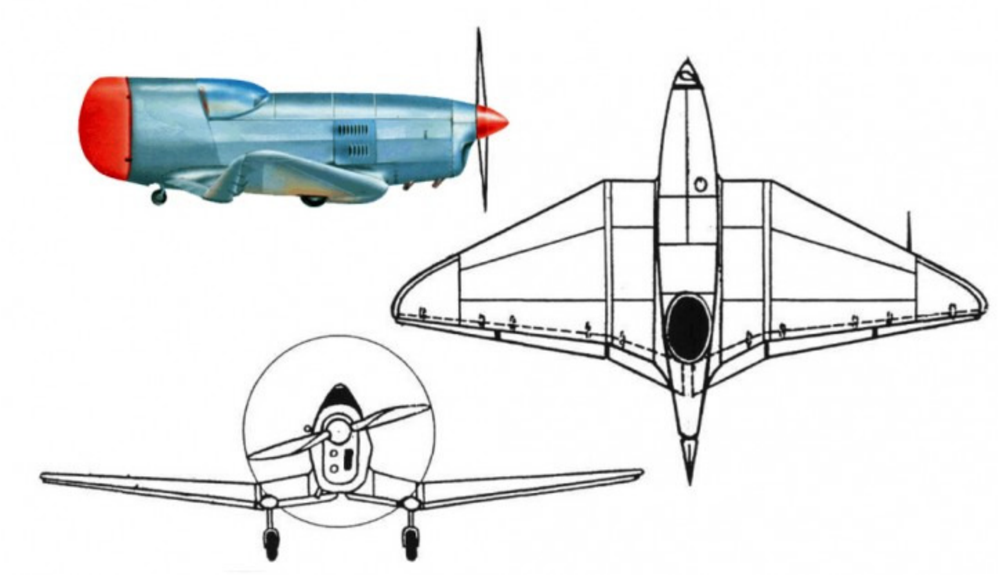
No. 350 AUGUST 2015

T.W.I.T.T. NEWSLETTER



Designed and built by the celebrated Soviet aircraft designer Boris Cheranovsky, the BICh-21 was an extremely compact racing plane which used an innovative tail-less layout. The aircraft was completed by 1940, however it wasn't until 1941 that the aircraft was first flown. Source: http://www.diseno-art.com/news_content/2014/06/chyeranovskii-bich-21/

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

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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.

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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 will finish the paper on “Aerodynamic Investigations on Tailless Effects in Birds” by D. Hummel originally published in 1992. This was donated to TWITT by our long time member Karl Sanders, who was a constant contributor until his passing some years ago.

Next month we will have an article on dynamic soaring contributed by our member Phil Barnes. This is a technical piece so I know many of you will enjoy it.

I will be continuing to digitize some of the technical articles that we have in the archives and putting them out through the newsletter. These are generally photocopies of the originals or other copies so they are not perfectly clear. I have made whatever adjusts I could with my available software to make them as readable as possible. If you have trouble with the printed version you can always go to the members only section of the website and open up the PDF version. You can then push it out to about 125% to make it easier to read. The user ID and password on in the column to the left so it is easy to gain access to the electronic version.

Andy

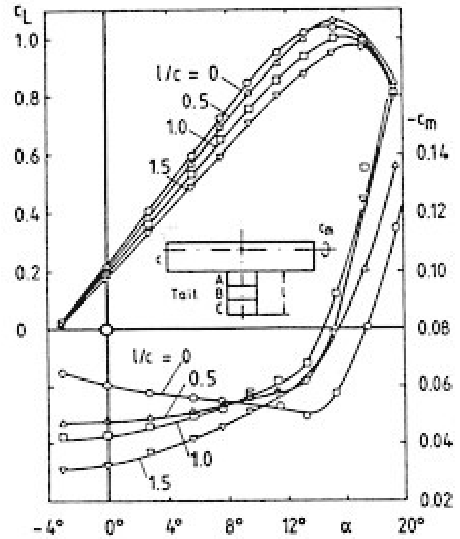

Fig. 8. Effect of tail length l/c on the lift and pitching moment characteristics. Rectangular wing $A = 5$, tails A, B, C ($a/c = 0.5$; $f/a = 1.0$; $\varepsilon = 0°$; l/c variable), symmetrical flow

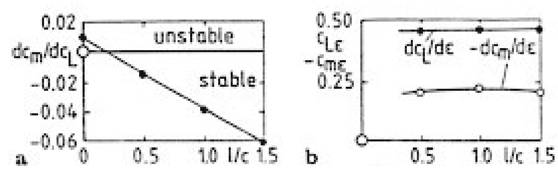

Fig. 9. Effect of tail length on (a) stability and (b) control effectiveness. Rectangular wing $A = 5$, tails A, B, C ($a/c = 0.5$; $f/a = 1.0$; $\varepsilon = 0°$; l/c variable), symmetrical flow

The latter result is somehow unexpected. It can be understood, however, bearing in mind that the tail works in the wing's downwash field. Long tails experience large downwash effects which compensate the length effects. For all tails according to Figs. 8 and 9 the base width and hence the length of the kink in the airfoils slope in the case of a deflection ε is constant. Therefore long tails are means to increase stability rather than control effectiveness.

3.1.3 Effect of tail's trailing-edge shape

In the tail configurations D and E according to Fig. 4 the shape of the trailing-edge of the tail has been varied. A wedged and a forked tail with the same area $S/S_W = 1.25$ have been tested. It turned out that this modification of the tail shape has no effect on the aerodynamic coefficients. Therefore it is not significant whether the largest chord length of the tail is located at $y = 0$ or at $y = a$. The results for the tail configurations D and E are identical with those of a square cut tail of the same area which can be interpolated between the tail configurations B and C. Therefore stability and control effectiveness of the configurations D and E may also be taken from Fig. 9 for $l/c = 1.25$.

3.1.4 Effect of tail's spreading and base width

In this section the results for the wing-tail-configurations G to S, Z, AA and AB will be discussed in comparison with

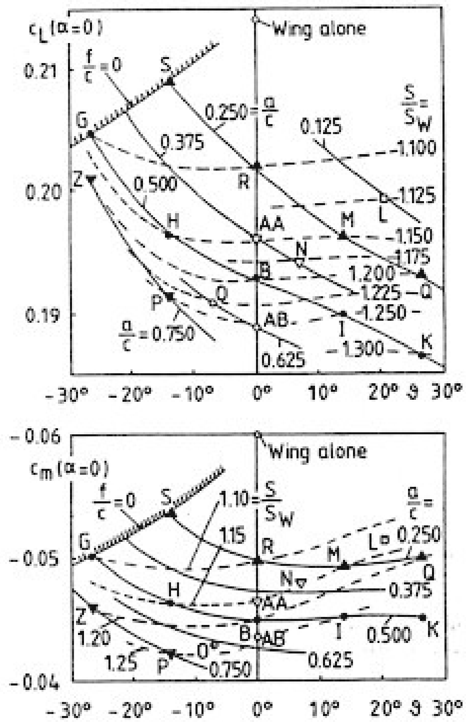

Fig. 10. Effects of tail spreading ϑ and base width a/c on the lift and pitching moment characteristics. Rectangular wing $A = 5$, various tails ($l/c = 1.0$; $\varepsilon = 0°$), symmetrical flow

the wing alone. For all these wing-tail-configurations the tail length and the deflection angle ε were constant, $l/c = 1.0$ and $\varepsilon = 0°$. Two parameters, the sweep angle ϑ and the base width a/c or the area S/S_W, are varied independently in this geometric series and the third parameter, S/S_W or a/c, is a dependent one.

For the whole series of wing-tail-configurations the zero lift angle of attack α_0 is virtually constant. Therefore the lift coefficient for a certain angle of attack represents the slope of the lift curve $c_L(\alpha)$. In Fig. 10 the lift coefficient $c_L(\alpha = 0°)$ is plotted as a function of the spreading angle ϑ for all wing-tail-configurations of this series. Within the diagram lines of constant parameters area S/S_W and base width a/c are given.

Adding an unspread tail $\vartheta = 0°$ to the wing leads to a reduction of $c_L(\alpha = 0°)$ which increases with increasing base width (Subseries $R/AA/B/AB$). This effect can be explained by means of the increasing tail area S/S_W which corresponds to a decrease of the aspect ratio of the configurations in this subseries. Positive spreading (outwards) of the tail at constant base width a/c leads to another reduction of $c_L(\alpha = 0°)$ which again can be related to the area increase and the corresponding reduction of the aspect ratio of the configurations. For constant area S/S_W, however, there exists a remarkable difference between positive and negative spreading of the tail, which can be seen e.g. for the sub-series of tails $Z/B/Q$. The wedge-shaped tail Z, see Fig. 4, produces larger lift than tail B due to the relatively high loading in the region of the large base width of the tail. The outwards-spread tail Q has a narrow base width and the lift should be reduced therefore. However for tails with a positive spreading angle ϑ the highly swept side-edge of the tail becomes a leading-edge with considerable local loading. In addition the flow separates from the highly swept side-edge of the tail and forms spiral-shaped vortices on the upper surface of the tail. Such a vortex formation is well known from delta wings, see e.g. [9], and it has been found also for tails with $\vartheta \geq 0°$ from oilflow patterns which have been set up during the present wind tunnel tests. Due to the vortex formation the outwards-spread tails produce additional lift which compensates the lift loss due to the narrow base width. It is this effect by which the lines S/S_W = const. in Fig. 10 are unsymmetrical with respect to $\vartheta = 0°$.

A detailed comparison of the subseries of tails *R/AA/B/AB* and *A/B/C* shows that for unswept tails $\vartheta = 0°$ of constant area S/S_W = const. the broader and shorter tail with the larger base width (tail *A*) produces less lift than the narrower and longer tail with the smaller base width (tail *R*). According to the load distribution in the region of the base width the opposite should turn out. The actual result is due to the fact that already for unspread tails $\vartheta = 0°$ side-edge vortices are formed over the upper surface of the tail which lead to an increase of the tail's lift. For the short tail *A* the extension of the side-edge is small and the vortex effect is not very important, but for the long tail *R* the extension of the side edge is large and the vortex effect becomes predominant. Oilflow patterns for the wing-tail-configuration *B* clearly indicate the presence of side-edge vortices over the upper surface of the tail.

Concerning the pitching moment derivatives Fig. 10 contains also $c_m(\alpha = 0°)$ as function of the spreading angle ϑ for all wing-tail-configurations of this series. Again lines of constant parameters area S/S_W and base width a/c are given. The results are similar to those for the lift coefficient c_L $(\alpha = 0°)$ and they may be discussed in the same way as for the lift coefficient. In addition from the measured pitching moment curves the slopes dc_m/dc_L have been determined. The result is shown in Fig. 11 for the present series of tails and again lines of constant parameters area S/S_W and base width a/c are given.

By adding all these tails to the wing stability is achieved. Tail *S* is the smallest shape to establish stability. For all spreading angles ϑ the stability increases with increasing area S/S_W or with increasing base width a/c of the tail. For constant base width a/c the stability increases rapidly by spreading the tail outwards. The rearward shift of the aerodynamic centre takes place due to the variation of planform area and shape by adding the tails to the wing.

From the measurements for different deflection angles ε the control effectivenesses with respect to lift $c_{L\varepsilon} = dc_L/d\varepsilon$ and with respect to pitching moment $c_{m\varepsilon} = dc_m/d\varepsilon$ have been evaluated. Similar results turn out and the one for the control effectiveness related to pitching moment is shown in Fig. 11.

The control effectiveness increases with increasing area of the tail. At a first glance this results seems to contradict the outcome of Fig. 9. If the area is increased by increasing the length of the tail, the control effectiveness remains constant because of the fact that the downwash effect becomes more and more important as discussed in Sect. 3.1.2. In the present series, however, the area is increased by an enlargement of the tail's width at constant length. In this situation the downwash effect is virtually constant and the enlargement of the area leads to an improvement of the tail's effectiveness. For constant base width a/c the control effectiveness increases with increasing spreading angle ϑ which is due to the enlargement of the area. For constant area S/S_W, see subseries *Z/B/Q*, a remarkable effect of spreading angle turns out. For negative spreading angles, tail shape *Z*, a large base width a/c exists. In the case of deflections ε the high loading in the vicinity of the kink in the airfoil's slope covers a broad region and this leads to a high control effectiveness. For positive spreading angles, tail shape *Q*, the base width is narrow and correspondingly the control effectiveness should be low. On the other hand for positive spreading angles high suction is present along the swept leading-edge of the tail and flow separations lead to additional suction in this region. These effects are predominant and therefore the control effectiveness is also high for large spreading angles ϑ.

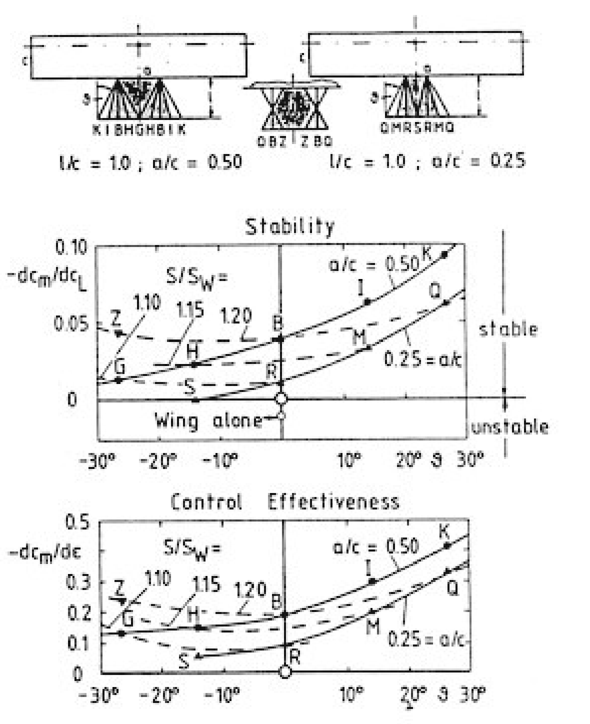

Fig. 11. Effect of tail spreading ϑ and base width a/c on longitudinal stability and control effectiveness. Rectangular wing $\Lambda = 5$, various tails ($l/c = 1.0$; $\varepsilon = 0°$), symmetrical flow

3.1.5 Effect of tail's spreading and fork deepness

In this section the results for the wing-tail-configuratons with forked tails *T* to *Y* will be discussed and compared with the unforked tails *R/M/Q* according to Sect. 3.1.4.

For this series of wing-tail-configurations the zero lift angle of attack α_0 is again virtually constant. Therefore $c_L(\alpha = 0°)$ represents the slope of the lift curve. Fig. 12 shows the results for different spreading angles ϑ and for three values of the fork deepness d/l. Lift and nose-down (negative) pitching moment reduce with decreasing fork deepness. For increasing spreading angle ϑ and constant fork deepness the lift is also reduced but the pitching moment remains virtually

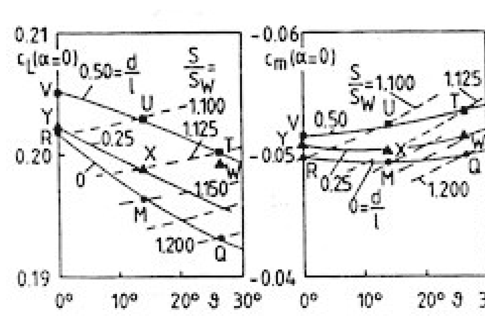

Fig. 12. Effect of spreading ϑ of forked tails on the lift and pitching moment characteristics. Rectangular wing $\Lambda = 5$, various tails ($l/c = 1.0$; $a/c = 0.25$; $\varepsilon = 0°$; d/l variable), symmetrical flow

constant. This behaviour can be explained generally by the increase of the tail area which reduces the aspect ratio of the configuration. On the other hand for constant area S/S_W more deeply forked tails are more spread and they experience larger lift and nose-down pitching moments. This is again the leading-edge effect of the outwards-swept side-edge of the tail which produces high local loading on the tail.

The stability of forked tail configurations may be taken from Fig. 13. For constant fork deepness d/l the stability increases rapidly by spreading the tail outwards. Due to the increasing tail area the aerodynamic centre is shifted rearwards. For constant spreading angle ϑ the stability reduces with increasing fork deepness because of the corresponding reduction of the tail's area. Configurations with forked tails are less stable than those with unforked tails. If the tail is not spread ($\vartheta = 0°$) there exists a small amount of longitudinal stability. For the unforked tail its value is larger than for the forked tail. If these tails are spread outwards at constant base width a/c, the ratio of stabilities of the spread and the unspread tail is much larger for the forked tail than for the unforked one. This means that a forked tail is a device to increase the longitudinal stability rapidly by means of spreading.

Concerning the control effectivenesses similar results turn out for the lift and the pitching moment. In Fig. 13 the control effectiveness related to the pitching moment, $c_{m\varepsilon} = dc_m/d\varepsilon$, is shown for different spreading angles ϑ and for three values of the fork deepness d/l. The control effectiveness increases with increasing spreading angle ϑ and with decreasing fork deepness d/l. As in the longitudinal stability the reasons for this behaviour are two-fold. On the one hand an increase in area leads to a high control effectiveness for constant tail length. On the other hand the swept leading-edges of the outwards-spread tails produce additional contributions to lift and nose-down pitching moment. This latter effect is predominant for the configurations under consideration in Fig. 13.

3.2 Lateral motion

The wing alone as well as the wing with an untwisted ($\delta = 0°$) and with a twisted ($\delta = 30°$) tail of shape B according to Fig. 4 have also been tested in unsymmetrical free stream flow. Some results are shown in Fig. 14 in which the coefficients for rolling moment c_l, yawing moment c_n and sideforce c_Y are plotted against the angle of sideslip β for a constant angle of attack $\alpha = 9.5°$.

The results for the wing alone are described first. In symmetrical free stream ($\beta = 0°$) all coefficients are zero. For positive angles of sideslip $\beta > 0°$ the lift on the windward side is larger than on the leeward side of the wing. This leads to negative rolling moments and the derivative is $c_{l\beta} = dc_l/d\beta < 0$. Since the local drag is correlated with the local lift positive yawing moments turn out and the derivative is $c_{n\beta} = dc_n/d\beta > 0$. This means that for the wing alone a stable situation with a small amount of directional stability is present. Concerning the sideforce the windtunnel model under consideration showed a very small positive sideforce with a derivative $c_{Y\beta} = dc_Y/d\beta > 0$ which is due to the local shape of the wing tips.

Adding an untwisted ($\delta = 0°$) tail of shape B to the wing leads to the same lateral aerodynamic characteristics as for the wing alone. Therefore an untwisted tail has virtually no effect at all on stability and control of the lateral motion.

If the tail is twisted ($\varepsilon = 30°$) even in symmetrical free stream flow $\beta = 0°$ a negative rolling moment turns out which has already been described in the literature [5, 8]. In addition to this, however, a positive sideforce occurs which acts at the tail and therefore also a corresponding negative yawing moment is found. This means that twisting the tail is a measure to produce rolling moments, yawing moments and sideforces simultaneously. The magnitude of these forces and moments depends on the angle of twist of the tail. If the

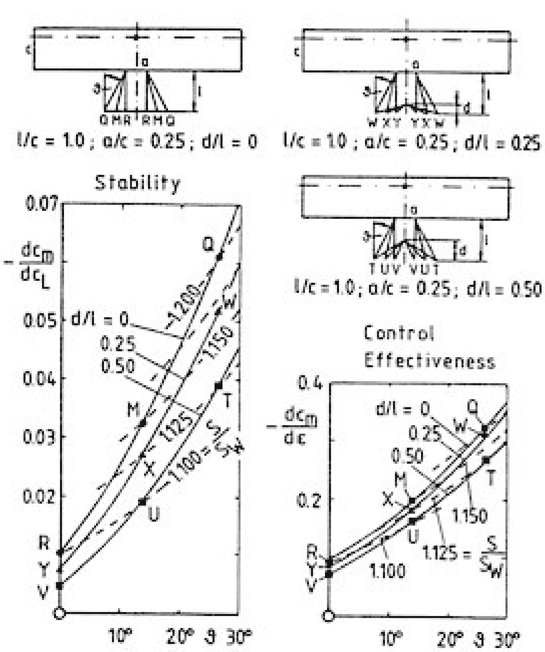

Fig. 13. Effect of spreading ϑ of forked tails on longitudinal stability and control effectiveness. Rectangular wing $A = 5$, different tails ($l/c = 1.0$; $a/c = 0.25$; d/l variable), symmetrical flow

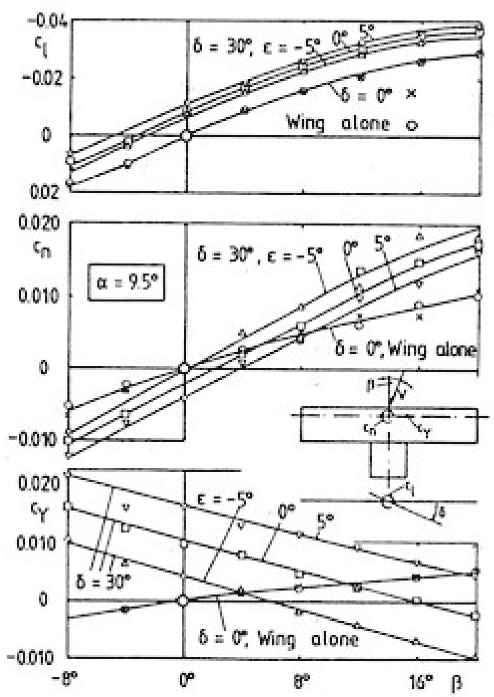

Fig. 14. Aerodynamic characteristics of the rectangular wing $A = 5$ alone and with an untwisted ($\delta = 0°$) and a twisted ($\delta = 30°$) tail (shape B; $l/c = 1.0$; $a/c = 0.5$; $\varepsilon = 0°$) in unsymmetrical flow ($\alpha = 9.5°$, β variable)

direction of the twist would be altered (e.g. to $\delta = -30°$) the sign of all three lateral derivatives c_l, c_n and c_Y at zero angle of sideslip $\beta = 0°$ would change as well. If the twisted tail is deflected up ($\varepsilon = -5°$) and down ($\varepsilon = +5°$) in symmetrical free stream flow $\beta = 0°$ the lateral derivatives vary considerably. Due to the deflection ε the loading of the tail is changed primarily: For increasing deflection angle ε the sideforce as well as the corresponding negative yawing moment increase also. The slight variation of the rolling moment due to changes of the deflection angle ε is caused by the sideforce acting below the moments reference point. The results of the present investigations for symmetrical free stream flow $\beta = 0°$ show that a tail twisted in both directions and deflected up and down acts as a device to control the lateral motion.

Other effects of twisting the tail may also be taken from Fig. 14 if the variations of the lateral derivatives with the angle of sideslip are taken into account. Concerning the rolling moment the $c_l(\beta)$ curves for all twisted tails ($\varepsilon = -5°$, $0°$, $+5°$) are shifted parallel as compared with the untwisted tail or the wing alone. The stability derivative $c_{l\beta}$ is not changed by twist δ and deflection ε. For yawing moment and sideforce, however, the situation is different. For a twisted tail ($\delta = 30°$) the sideforce decreases linearly with increasing angle of sideslip. The stability derivative is $c_{Y\beta} < 0$ and its value is independent of the angle ε. This means that the slightly unstable situation for the wing alone and the untwisted tail has changed towards a stable behaviour of the configuration with a twisted tail. Similar effects can be seen from the yawing moment results $c_n(\beta)$. The reduction of the sideforce leads to additional positive yawing moments with increasing angles of sideslip. This means that the stability derivative $c_{n\beta}$ is increased in comparison with the wing alone and the untwisted tail. In the present case the directional stability is considerably improved by the twisted tail and the amount of stability is the same for all deflection angles ε. This is due to the fact that only the variation of the aerodynamic coefficients with the angle of sideslip has to be taken into account. At an angle of sideslip $\beta > 0$ a crossflow in the $-y$ direction takes place which causes an additional positive lift on the tail for negative twist $\delta < 0$ and additional negative lift on the tail for positive twist $\delta > 0$. The reduction of the sideforce with increasing angle of sideslip is caused by the "cross flow drag force" which acts at the tail in $-y$ direction in both cases $\delta > 0$ and $\delta < 0$. This means that twisting the tail leads to increased lateral stability and this improvement is independent of the direction of twist.

3.3 Discussion

Concerning the longitudinal motion the present results indicate that the tail in birds acts as horizontal stabilizer and elevator in the same way as in conventional airplanes. Both stability and control effectiveness are governed by size and planform shape of the tail. In comparison with aircraft some peculiarities may be mentioned and discussed.

Birds are also able to fly without their tail. If all tail feathers are removed at once static longitudinal stability is lost. In this case the situation is the same as in statically unstable aircraft. Disturbances in the flight attitude are now amplified, but if the time constants of the corresponding dynamic process are large enough active control can be applied to achieve damping. In birds this active control is effected by intensive motions of the wing. In this situation the ability to perform flight manoeuvres is considerably reduced and the wing motions are mainly used to overcome the static instability. Many juvenile birds start flying in a configuration without any tail or with a reduced tail only. Their wings are mainly used for dynamic stabilization and the flight manoeuvres are rather clumsy. With increasing tail formation the static stability increases. The wings are no longer necessary to overcome static instability and the flight manoeuvres which are now possible become adapted to the way of life of the adult bird. If the tail feathers are lost by an accident the ability of the wings to overcome static instability is again used for survival. The first bird archaeopterix lithographica had a very long tail. This means that the evolution of flight started with a relatively stable configuration.

The balance of moments about the centre of gravity according to Eq. (1), which is necessary for an equilibrium state, can be written as

$$c_m = c_{m0}(\vartheta, \varepsilon = 0°) + \frac{d c_{m0}}{d\varepsilon}(\vartheta)\varepsilon + \frac{d c_m}{d c_L}(\vartheta) c_L = 0. \qquad (2)$$

In conventional aircraft with $\vartheta = \text{const.}$ Eq. (2) is fulfilled for different values c_L by means of a proper adjustment of the elevator deflection angle ε. This can be performed in the same way also by birds. In aircraft the planform shape of the tail is fixed. In birds, however, the spreading angle ϑ can be varied for constant base width a/c. The subseries $G/H/B/I/K$ and $S/R/M/Q$ of tails in the present investigations are realistic examples for such variations. Eq. (2) can be fulfilled for different lift coefficients c_L and constant deflection angle ε by means of a proper adjustment of the spreading angle ϑ. This kind of control by variation of the position of the aerodynamic centre is not possible in aircraft since a variable tail geometry, e.g. a telescope tail, would be necessary. In birds, however, control by tail spreading is widely used: For high lift coefficients the tail is usually spread whereas for low lift coefficients the tail is folded to a narrow shape. Control by spreading the tail means that the static longitudinal stability is varied simultaneously. Investigations on the performance aspects of this kind of control on the basis of the present windtunnel results are in progress.

Concerning the lateral motion the present results indicate that a tail for which a certain projection area is seen in the plane $y = 0$ increases the directional stability. Twisted tails of either sense of rotation fulfill this condition and other cross section shapes like the slightly V-shaped tails of petrels and gulls lead to the same effect. Due to the absence of a vertical fin birds normally have a low amount of lateral stability but the latter can be increased easily by twisting the tail in any direction. Concerning lateral control twisting of the tail has been explained [5, 7, 8] to be a device to produce rolling moments. This has to be considered as a side effect since rolling moments are much more easily generated by aileron deflections at the wing. The main purpose of a twisted tail is to produce sideforces and yawing moments. To achieve this the tail has to carry some loading in order to be effective. For a positive tail loading positive twisting leads to a positive sideforce and to a negative yawing moment. An unloaded twisted tail produces no sideforce and no yawing moment. For a negative tail loading which is achieved for very large negative deflection angles ε negative twisting leads again to a positive sideforce and to a negative yawing moment. Both ways to produce a positive sideforce at the tail are related to different pitching moment characteristics which influence again the longitudinal control. It has to be born in mind, however, that also a variation of the spreading angle ϑ can be used at a prescribed deflection angle ε to establish an equilibrium state according to Eq. (2). It is this mechanism which leads to a close coupling of longitudinal and lateral motion in birds. Further investigations on this subject are necessary.

168 Z. Flugwiss. Weltraumforsch. 16 (1992)

4 Conclusions

Comprehensive windtunnel experiments on an $A = 5$ rectangular wing with a large variety of plane tails with deflections up and down have been carried out in symmetrical flow. In addition for one tail shape plane and twisted tails without and with deflections up and down have been tested in unsymmetrical free stream flow. In comparison with conventional aircraft the following results have been found:

1) The presence of a tail in birds increases the stability of the longitudinal motion as in airplanes.
2) The tail in birds acts as an elevator as in airplanes.
3) Long tails are devices to increase longitudinal stability rather than control effectiveness.
4) Spreading a tail at constant base width increases stability and control effectiveness of the longitudinal motion.
5) Configurations with forked tails are less stable than those with unforked tails. Spreading of forked tails at constant base width leads to a larger increase of longitudinal stability than spreading of unforked tails.
6) Twisting a tail in any direction increases the directional stability of the lateral motion. This measure is used by birds instead of the vertical fin of airplanes.
7) Twisting of a loaded tail leads to a sideforce and to a yawing moment. Their directions depend on the combination of loading and twist. This measure is used by birds instead of the rudder on the vertical fin of airplanes.

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Received September 30, 1991

LETTERS TO THE EDITOR

Dear Chuck Bixel:

Would you have any dihedral to maintain roll stability? Possibly 2 to 3 degrees? What about chord angle? AoA? Assuming a flat wing or small camber.

I am currently designing (5 years now) a crossover using 2 wings (box style) to prevent lift loss similar to winglets, to connect both upper and lower wings and a hovercraft bag skirt to lower surface drag before attaining GE. as well as 2 sponts, to add floatation (rear wing tips of delta) to add stability while on the water. and possibly a canard if necessary for pitch stability, rather than a large stabilizer, and a hinged wing to increase wing span if necessary and also better close quarter maneuvering on the water. I like some of your ideas but am hoping to produce for myself a personal use up to 1200 lb, useful load plus fuel etc.. looking for 150-200 kts, 6 passenger, 600 mile range, under 200 hp.

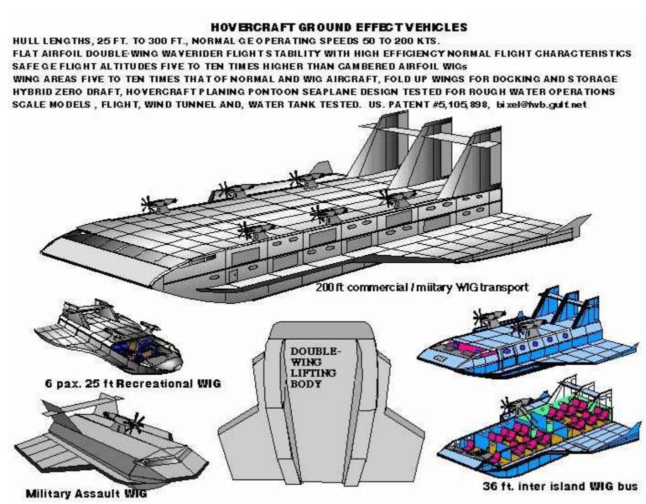
Any suggestions?

John Eshleman
excalun@hotmail.com

(ed. – This was a letter to Chuck based on information on flat airfoils we have on the TWITT website at: http://www.twitt.org/Bixel_WIG.html#top

I haven't heard anything from either John or Chuck to know if they made a connection.

If you are interested in the flat airfoil type or wing in ground effect and have an opinion, please chime in directly to John and copy TWITT so we know there is something going on.)



AVAILABLE PLANS & REFERENCE MATERIAL

Tailless Aircraft Bibliography

My book containing several thousand annotated entries and appendices listing well over three hundred tailless designers/creators and their aircraft is no longer in print. I expect *eventually* to make available on disc a fairly comprehensive annotated and perhaps illustrated listing of pre-21st century tailless and related-interest aircraft documents in PDF format. Meanwhile, I will continue to provide information from my files to serious researchers. I'm sorry for the continuing delay, but life happens.

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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.

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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
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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
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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.

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