Some Thoughts on Nature and Sailplane Design

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1. Introduction

Once again glider performance appears to be approaching a new technical frontier, as suggested by the present trend to ever increasing wingspan. To cross this frontier we will need to change some of our present habits of thinking, and nature seems to be showing us some new directions to try. One of the possibilities is some sort of acoustical boundary layer control device to improve laminar flow, as suggested by the scales of fish and the feathers of birds. Another is the use of short tailed or all wing configurations such as those of soaring birds, which should provide energy gains and performance improvements.

2. The Evolution Boundary

In nearly all scientific branches, progress is made continuously, but along what we could call evolution boundaries. Fig. 1 and 2 show the progress of the energy of man-made particle accelerators and the evolution of 'things and beings' on the earth.

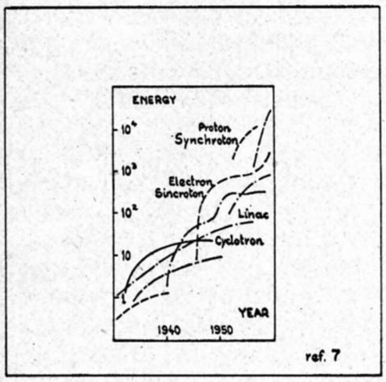


Fig. 1. Energy of artificial particles.

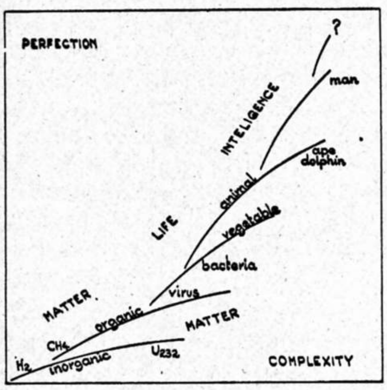


Fig. 2. Evolution of things on earth.

An evolution frontier is met whenever only small progress results from great increments in complexity or extreme changes in known parameters, and the only way to cross it is by innovation or the discovery of new parameters.
Gliding seems to be no exception to this 'evolutionist behaviour' and the most evident symptom of approaching the evolution boundary is the trend toward increasing span and aspect ratio, as illustrated in fig. 3.
The British SIGMA project today and the Darmstadt D-30 in the past are distinct examples in which the best technical knowledge was applied in an attempt to cross the frontier by stretching to unbearable limits existing techniques. Whenever this happens what is needed is a 'jump' or a 'break through', which might be found if we study the way nature, during aeons, has dealt with its aerodynamic problems.

3. Nature is Right

The present shark-like shape of glider fuselages (see fig. 4) seems to confirm the statement that 'nature is right' as pointed out explicitly in Ref. 6. The shark must not stop still or it will either die of lack of oxygen, because its gills need flowing water to work, or it will sink to the ocean bottom, because unlike other fish it has no flotation bag to control its depth. As a consequence its body shape is perfected to give minimum drag, and its forebody short-span lifting wings have elliptical delta planforms, in order to minimize its energy requirements for perpetual flight through the water.
Another interesting example of nature's wisdom is furnished by insect flight. Let us consider the 'drag rotor' or 'drag propeller' (fig. 5), which is a device having four blades whose pitch can be varied by 90 degrees. Such a rotor with four elliptical blades and the pitch-changing mechanism was patented many years ago in Brazil by Alden-car da Silva Peixoto. He had obtained encouraging results and hovering flights with a small model propelled by four such rotors driven by electric motors.
Neglecting the drag of the blades at zero pitch and adopting a unity drag coefficient for the blade at 90 degree pitch during its quarter of turn travel, we have for a stationary rotor:

$$\text{Thrust} \cong \frac{\rho}{2} \cdot \omega^2 r^2 S \text{ and}$$

$$\text{Power} \cong \frac{\rho}{2} \cdot \omega^3 r^3 S$$

The thrust-to-power ratio is then:

$$T/P \cong 1/(\omega r)$$

This shows why the small model worked so well, but also why any normal sized man carrying vehicle will need too much surface and horsepower to be practical if propelled by drag rotors.
However, this same device is amazingly efficient if we go down in the scale of size and force to that of insects.

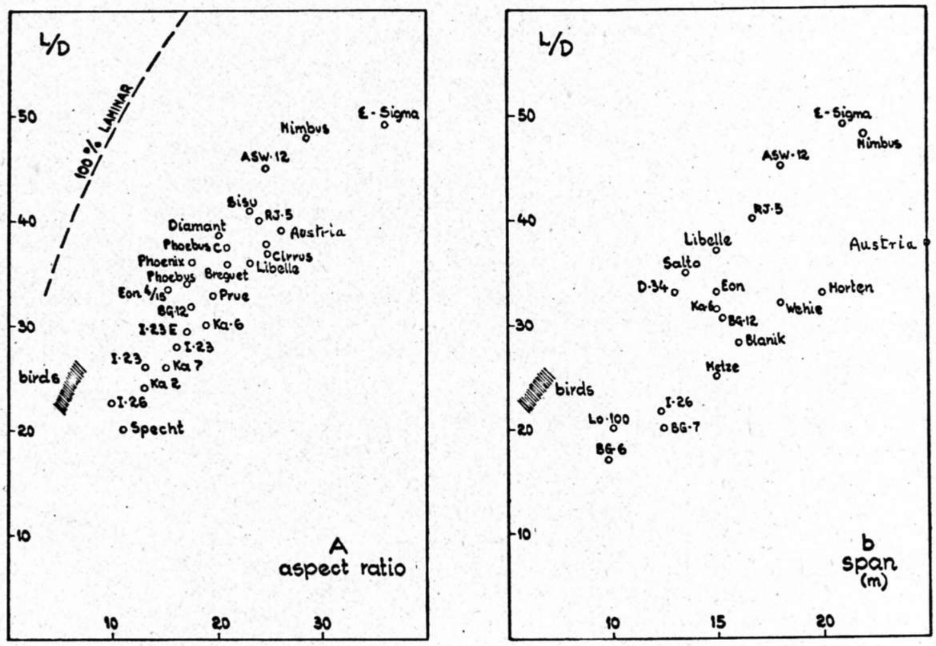


Fig. 3. Evolution boundary of gliders

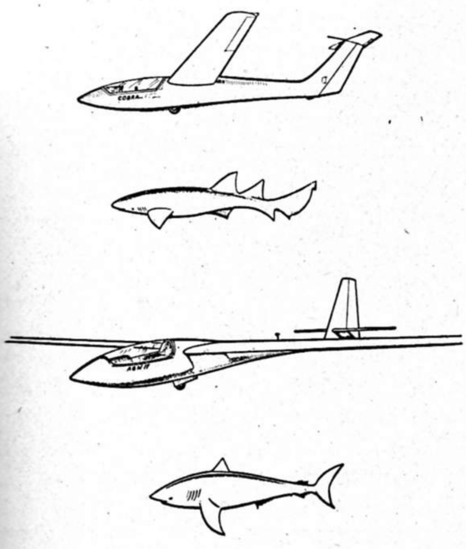


Fig. 4. Fuselayes and sharks shapes.

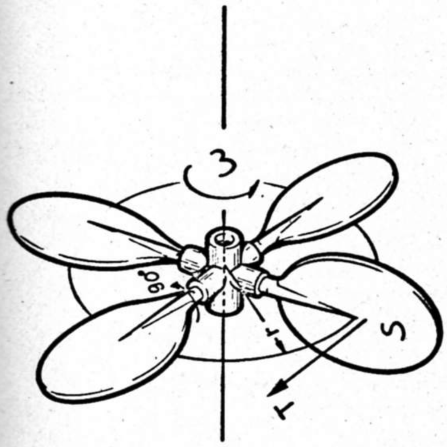


Fig. 5. The 'dray' rotor

	r	ω	L/P
	mean radius meter	frequency rad/sec	lift/power kgf/H.P.
Butterfly ∾	.05	2.0	750.
Honeybee ∾	.005	20.0	750.

Such figures were never attained by helicopters and propellers! Thus it is evident that insect wings are not lifting surfaces but rather dragging surfaces and people who say that the honeybee flies only because it knows no aerodynamics are really wrong.
Nature seems always to choose the most efficient way of doing things. While in air the drag rotor is adequate only for inverse applications such as the windmill, its uses in water, such as the oar, the Pelton wheel, and the paddle wheel for boats, are human applications of the 'dragging principle' used by nature for the propulsion of fish. Had Earth the gravity and atmosphere of Venus, nature and evolution might have given us beautiful drag wings with

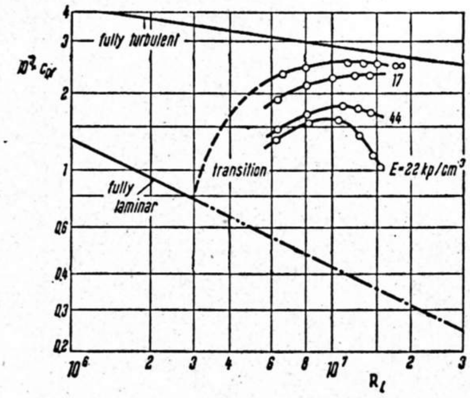


Fig. 6. Skin-friction coefficients for circular cylinders provided with elastically deformable skins and placed in a stream parallel to the axis at varying values of the elastic constant E. Measurements by M. O. Kramer.
E = ∞ corresponds to a rigid skin

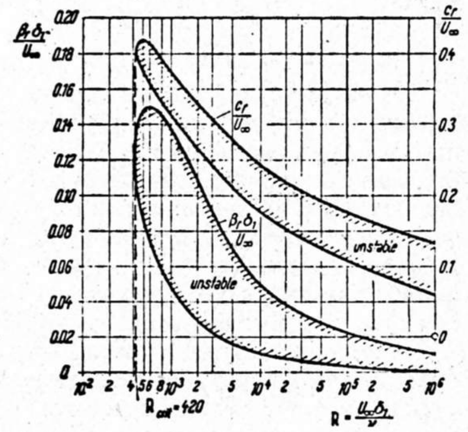


Fig. 7. Curve of neutral stability for the frequency β_r of the disturbances and wave propagation velocity c_r for the boundnary layer on a flat plate at zero incidence (Blasius profile), after W. Tollmien.

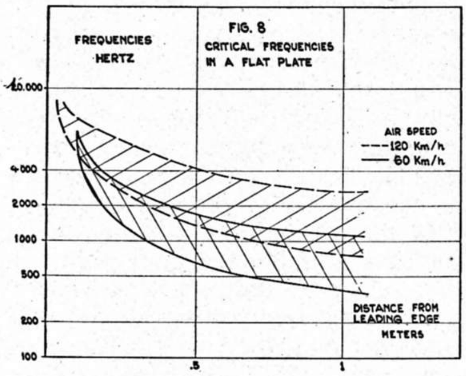


Fig. 8

which we might fly like angels on our own power. I hope someday our astronauts may do so on Venus.

4. Scales, Feathers, etc.

Birds are feathered, fish are scaled or have flexible skins, bats have hair and so did the prehistoric «pterosaurus». Submarine and hydrodynamic research have already shown the boundary layer control properties of the dolphin's ski. Flexible walls were shown by Kramer (Ref. 3), Landahl (Ref. 4) and others to cause transition delay and drag reduction (fig. 6). However, the real role of scales and feathers has yet to be completely understood. At first thought it seems that, like elastic skins, they are very ingenious devices for creating e smooth surface in the flow direction; a surface in fact that remains smooth even after bending or flexing. But is this the only role of scales and feathers or are they also devised to control the boundary layer, delaying transition or avoiding separation and flow reversals?
The well known diagram for laminar boundary layer neutral stability (see figs. 7 and 8) shows that for each Reynolds Number, there is only a critical band of 'deleterious' frequencies or 'noises' that may start the transition to turbulence.
In fig. 9, we see how these critical oscillations become less and less damped, degenerating into the random turbulent spectrum, as measured in the classical work of Schubauer and Skramstad. It is possible that scales and feathers may act as acoustical dampers for these critical frequencies; their orderly variation in size in the flow direction seems to substantiate this supposition.
Unfortunately acoustics and aerodynamics, although closely related, have not often been studied together, unless in aircraft noise suppression and in some sonic aerodynamic phenomena, but it is evident that a vast field of development is open for research in this area. I will not be surprised if it is shown that the aerodynamic cleanness of glass fibre ships is due not only to their superb surface finish but also to the acoustic properties of the fiber resin combination. It is known that as acoustic absorbers, glass fibre and sandwich materials are better than wood panels, and these better than bare metal skins. Otherwise-similar gliders made of these materials seems also to exhibit a small performance variation in the same sense. In my

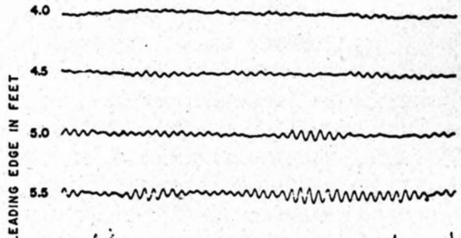


Fig. 9. Oscillograms showing laminar boundary-layer oscillation in boundary layere of flat plate. Distance from surface = 0.023 in.; U_0 = 80 ft. per sec.; time interval between dots = 1/30 sec.

country such investigation will be difficult but I believe that elsewhere a well coordinated team of biology, acoustics, aerodynamics and plastics experts could develop a light acoustic damper material, an artificial equivalent to scales and feathers, to be applied over glider external surfaces, which could yield a performance breakthrough.
The performance of 100% laminar gliders has already been calculated by Raspet, Carmichel (Ref. 8 and 9), and others. Although this 100% figure can hardly be achieved, any improvement in this direction would represent a milestone in gliding. Other methods such as boundary layer aspiration could be used but up to now we do not have any really simple use of them, and I doubt that we will. If anything so simpleas the application of a 'scale and feather' material over glider surfaces shows some possibilities in this sense, it deserves theoretical and practical research.

5. Short Tailed Gliders

While we are waiting for the 100% laminar glider, it is worthwhile to look at other ways suggested by nature to our natural intelligence.
The majority of soaring birds do not exhibit long 'tail cones' supporting any Vee, Cross, or Tee tails! A long tail means a long nose, and a pilot seated away from the aerodynamic center of the ship, with consequent large c. g. travel for different pilot weights! The net result is larger stability and control requirements with larger tail area, greater fuselage bending moments, larger wetted surface. Worst of all is the greater fuselage weight. For each pound added in the fuselage weight we need another pound in the wing structure to support it! Since low weight means low cost to build and low cost to fly, nature, alway economical whenever preservation is not involved, restrained tails to minimum size.
Tailess designs are always lighter than equivalent tailed ones as shown by the 120 kg Fauvel AV-22 of 22 square meter wing area. I have many hours of flying an AV-36 and, other than its low performance and weak yaw control, I have no complaint about its flight characteristics. Its low longitudinal static stability and low pitch inertia make it excellent for hands off or blind flying. The all wing layout has some drag reduction aspects due to the fact that the local skin friction in an already turbulent boundary layer can be lower than the mean friction of a layer partially laminar but of lower Reynolds Number, as shown in fig. 10. In consequence, a tail surface placed behind a fuselage or a wing trailing edge may have less drag than the same surface placed in a free stream.

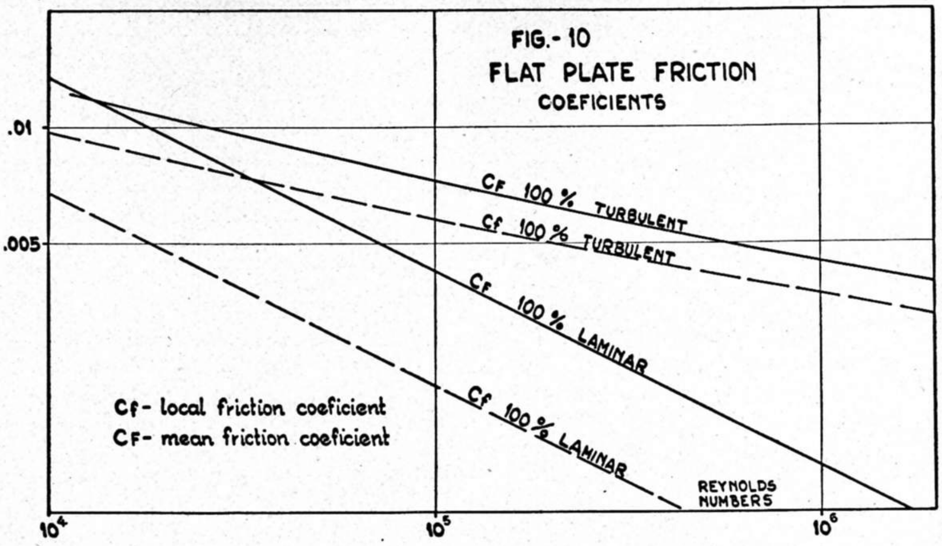
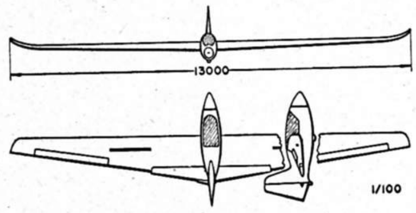


Fig. 10

Comparing a 200 kg AV-36 with the old 300 kg Meise we see that although they have the same performance (L/D $\approx$ 23) the overall drag of the Fauvel is only two thirds of the Meise drag and is slightly lower than that of a Ka-6. This in spite of its low wing loading, interference, and thick nosed airfoil.
Low drag and low weight lead to very low power requirements. Birds, better classed as powered gliders than pure gliders, adopt the all wing layout that seems to be unsurpassed for powered gliders.
For pure gliders the problem with flying wings is that their main drawbacks (trim drag, weak pitch damping, and poor yaw control) increase with increasing aspect ratio unless a backward or forward sweep is used, destroying the design lightness and simplicity. For very high aspect ratios, the longitudinal equations of motion show that the lack of pitch damping may lead to dangerous short period oscillations and that with rearward C. G. positions even a startling 'spin' around pitch axis can occur. Thus only a pure glider of moderate aspect ratio and performance, some kind of a modern fiberglass equivalent of the Fauvel, can be designed with many weight, drag, structural and economical advantages.
A slight forward sweep and better planform, as shown in fig. 11, can minimize trim drag due to elevator deflection, and even with an airfoil of moderate thickness the spar depth at the root can be considerable. With such a layout tip airfoils need not be reflexed (birds' airfoils are not) and for the center section many helicopter (8 H 12, 8 H 15), Wortmann and Eppler laminar airfoils with low negative or slightly positive pitching moment are now available.
A complete family of under, over, or self-balanced airfoils can be obtained by simple combination of two usual



A modern plastic equivalent of the "Fauvel" as medium performance club glider.

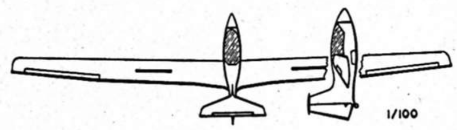


Fig. 11 A short tailed high performance low weight glider

NACA airfoils of different thicknesses, the thicker one for the upper surface and the thinner one for the lower surface, as exemplified by the airfoil 64 12109 shown in fig. 12. An infinite combination number is possible with symmetrical or cambered airfoils, but care must be taken to use the same 'mean line' and a unique leading edge radius or the pressure distribution will be distorted. The same process used in the inverse sense over highly cambered 'mean lines' leads to 'super critical type' airfoils with flat pressure distributions in the upper surface but having strong negative pitching moments as exemplified by the airfoil 64 70921 in fig. 12. In fig. 13, 14 and 15 an in table 1, are shown the velocity distributions, the drag polars and the main theoretical two-dimensional characteristics of the above-mentioned airfoils compared with a normal NACA section (64 415) and a Wortmann section.

All these results were obtained with a computer program based on the numerical Riegels methods (ref. 10) using only 11 computing stations and supposing a fully attached boundary layer. This is questionable with respect to drag coefficients, but it simplifies computation.
For the flapped center section of flying wings, the conditions to be matched, flap (elevator) down, low angle high speed flap up cruising, and high angle low speed thermal flight, are so diverse, that I am doubtful if laminar flow can be maintained simultaneously on both surfaces with any already designed airfoil. So the challenge is open.

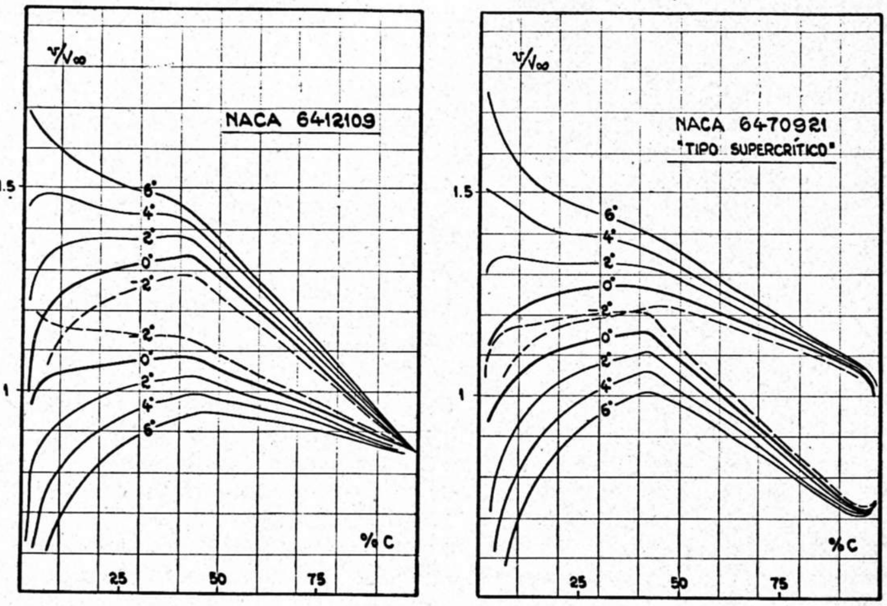


Fig. 14 Velocity distribution computed for the airfoils obtained from different thickness NACA airfoils.

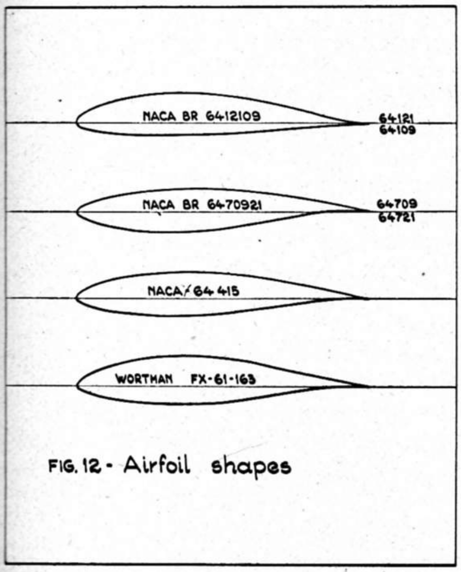


Fig. 12

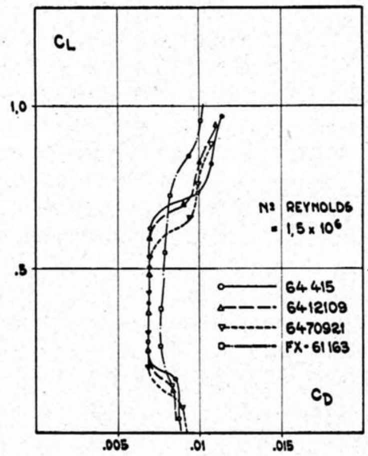


Fig. 15 Airfoil computed polars (theoretical)

Table 1. Computed Airfoil Characteristics

	64415	6412109	6470921	FX-61163
$dC_L/d\alpha$	0.1213	0.1214	0.1210	0.1217
$\alpha_{CL=0}$	−3.3613	−2.7680	−3.9557	−5.2986
X/c c.a.	26.271	26.257	26.422	26.586
c_m c.a.	−0.0907	−0.0538	−0.1274	−0.1416
α ideal	0.4699	2.8704	−1.8328	0.5245
Cl ideal	0.4201	0.6183	0.2327	0.6383

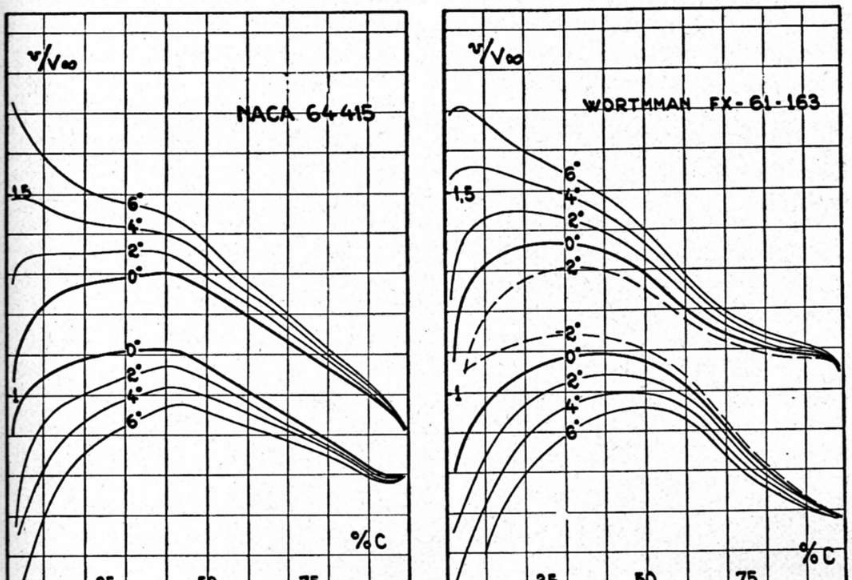


Fig. 13 Velocity distribution computed for the normal NACA and wortman airfoils

If performance is the main target, the high aspect ratios needed will prevent the all wing layout for pure gliders, but n o t, and this is the point, not the use of a short tailed configuration!
A short tailed design as exemplified in fig. 12 will keep some advantages of flying wings such as low weight and low drag and also permit the use of high aspect ratios. A nice handling ship can result if spoilers are used to assist the rudder in yaw control. With a semi-reclined pilot seated with the ships against the spar, the C. G. shift for different pilot weights, as well as longitudinal stability and control problems, will be minimized, and horizontal (or Vee?!) tail size would be determined by pitch damping and trim drag considerations.
The combination of factors such as low weight, high performance and low inertia in pitch may provide some unusual forms of soaring flight, utilijing low-energy lift sources such as vertical bubbles, horizontal gusts, and wind gradients. With all this, the long-envied dynamical flight of the birds will become available also for soaring people!

6. Conclusion

Glider designers as well as all creative men must bear in mind that they themselves have been designed, and nature can be the best model to follow i f nature's purpose and objectives (which are not always evident) are coincident with their own. In fields other than those discussed in this paper, nature has many other not yet understood solutions to problems closely related to gliding activities, e. g. navigation, thermal detection and dynamic flight techniques.

OSTIV should encourage and promote, in addition to technical and meteorological papers, any biological research related to gliding activities. If this happens I suspect that in the XXVII World Gliding Championship over the Brasilia plateau it will be a hard task indeed to distinguish a gaggle of gliders from a flock of 'urubus', the Brazilian vultures equivalent to the European buzzards!

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Réflexions sur la nature et le dessin du planeur

Résumé

Le progrès de la Science tend à être continu (fig. 1 et 2) et ceci s'applique au dessin du planeur. La figure 3 montre la tendance à l'augmentation de l'envergure et de l'allongement. Mais à partir d'un certain point, chaque petite amélioration demande de grands efforts. Alors une innovation est nécessaire pour réaliser un progrès notable.

Est-ce que la Nature nous donnera des leçons? Nous copions déjà le requin pour la forme du fuselage (fig. 4).

Le «rotor», figure 5, utilisé par les insectes fonctionne bien à petite échelle mais le rapport poussée/puissance est inversement proportionnel au rayon et ce propulseur ne conviendrait pas à des véhicules à l'échelle humaine.

Les plumes d'oiseaux, les écailles de poissons, la peau flexible du dauphin sont là uniquement pour leur douceur ou pour réduire la traînée en retardant la transition (fig. 6 et 10). Il est possible que la stabilité de la couche limite (fig. 7 et 8) et l'amortissement des oscillations soient dues à un effet acoustique. Il est aussi possible que la souplesse du revêtement contribue à la propreté des planeurs en fibre de verre. Des recherches simultanées en aérodynamique et en acoustique sont nécessaires.

Les oiseaux voiliers ont des empennages arrière peu éloignés de la voilure. Des planeurs conçus de cette manière présenteraient une traînée plus faible et un déplacement moins important du centre de gravité en fonction du poids du pilote. Les planeurs Fauvel sont légers, leurs caractéristiques de vol sont bonnes sauf pour le contrôle en lacet. Un compromis, figure 11, peut donner un planeur à faible traînée. Ce serait un planeur équipé d'un empennage situé à faible distance de l'aile plutôt qu'un planeur sans queue de façon à réaliser un grand allongement tout en conservant un bon amortissement en tangage. Les profils utilisés pour la partie centrale de la voilure peuvent être des Eppler ou des Wortmann, ou une combinaison de différents profils pour l'extrados et l'intrados. Des comparaisons sont montrées sur le tableau 1 et les figures 12 à 15.

La compétition est ouverte!!!

Einige Gedanken über die Natur und den Segelflugzeug-Entwurf

Zusammenfassung

Der Fortschritt in der Wissenschaft neigt zu einer Stetigkeit (Fig. 1 und 2); das gilt auch für den Segelflugzeug-Entwurf, was durch Figur 3 mit dem Trend zu vergrösserter Spannweite und vergrössertem Seitenverhältnis gezeigt wird. Es wird aber bald ein Punkt erreicht werden, wo eine grosse Anstrengung nur noch eine kleine Verbesserung erzeugt; denn viele Innovationen werden benötigt, um einen Durchbruch zu erzielen.

Wird die Kenntnis von der Natur helfen können? Wir formen den Rumpf fast immer wie den des Haies (Fig. 4). Der «Widerstandsrotor» (Fig. 5), wie er bei Insekten vorkommt, arbeitete gut an einem kleinen Modell, aber das Schub-Leistungs-Verhältnis ist umgekehrt proportional dem Radius, und die Anordnung würde für manntragende Fahrzeuge unbrauchbar sein.

Die Feder der Vögel, die Schuppen der Fische, die flexible Haut der Delphine – sind sie nur «Glätte», oder vermindern sie auch den Widerstand durch Vergrösserung des Umschlages (Fig. 6 und 10)? Vielleicht sind die Stabilität der Grenzschicht (Fig. 7 und 8) und die Dämpfung der Schwingungen (Fig. 9) eingeschlossen durch akustische Wirkung. Vielleicht trägt auch die Flexibilität der Flügelhaut zur Sauberkeit der Glasfaser-Segelflugzeuge bei (?). Zusammenwirkende aerodynamische und akustische Forschung ist notwendig.

Segelnde Vögel haben kurze Leitwerks-Hebelarme. Kurzrümpfige Segelflugzeuge würden niedrigeren Widerstand und kleineres Gewicht haben und auch eine geringere Schwerpunktswanderung mit verschiedenen Pilotengewichten (?). Die Fauvel-Entwürfe sind leicht und die Flugeigenschaften sind gut, mit Ausnahme der Steuerung um die Hochachse. Moderne, widerstandsarme Gegenstücke könnten aussehen wie in Figur 11. Sie würden besser kurze Rümpfe als gar keine haben, um hohes Seitenverhältnis zu erlauben, aber noch eine Nickdämpfung zu erzeugen. Flügelprofile für den inneren Teil des Flügels könnten von Eppler oder Wortmann sein, oder auch Kombinationen von verschiedenen Profilen für die obere und untere Oberfläche (?). Einige Vergleiche sind in Tab. 1 und in Figur 12 bis 15 gezeigt.

Der Wettbewerb ist eröffnet!