Inauguration lecture by Prof. Dr. Eng. Wladyslaw Fiszdon

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Some aeroelastic problems of sailplane design trends

Beginning the scientific and technical meetings of the XI OSTIV Congress, it seems appropriate to recall the aims of this international organization which were formulated by its long time President L. A. de Lange during a recent F. A. I. Conference, i. e.

a) «To foster and coordinate efforts to seek new scientific knowledge by means of the sailplane as well as to gain scientific knowledge for the development of soaring».

b) «To foster and coordinate efforts to improve the training methods, the design, construction and operation of sailplanes and accessories, particularly with a view to increasing proficiency, performance, flying qualities, safety and comfort for the benefit of soaring and for aviation in general».

During our meetings of the technical section we will have the opportunity to acquaint ourselves with different problems connected with these aims which may be briefly described as the advancement of soaring.

In the time available, I would like briefly and (please excuse me for it) superficially, to discuss only one property of sailplanes which perhaps is not sufficiently appreciated and made use of for the improvement of sailplanes, that is, the flexibility or, to emphasized, the effects due to the deformations of the sailplane structure.

This property of sailplanes, leading to aeroelastic effects, becomes more important as their speed increases. Continuous aerodynamic improvements in sailplanes, particularly the introduction in the last 15 years of aerofoils and the reduction of drag in the last 50 years of their development led, as we know well, to a large increase in their maximum lift to drag ratio and not only to a reduction of the minimum rate of descent but also to a very large increase of the lift to drag ratio at high velocities. This is shown clearly on fig. 1, where performance curves for selected gliders built between 1921 and 1967 are collected (1). Trends of the increase of flight velocities for rates of descent of 1, 2, 3, 4 m/sec are given in fig. 2. A large increase of flight speed for the same rate of sink is noticed and e. g. for a rate of sink of 3 m/sec this increase is about threefold. This points to possibilities of flight at higher velocities in the same atmospheric conditions.

For example: using the rule of thumb given by Niehuss (2) at the IX OSTIV Congress that «under good thermal conditions and negligible wind the optimum sink rate outside the thermal is almost half as great as the experi-

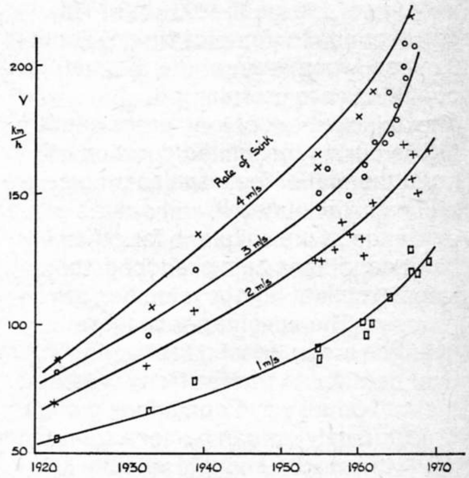
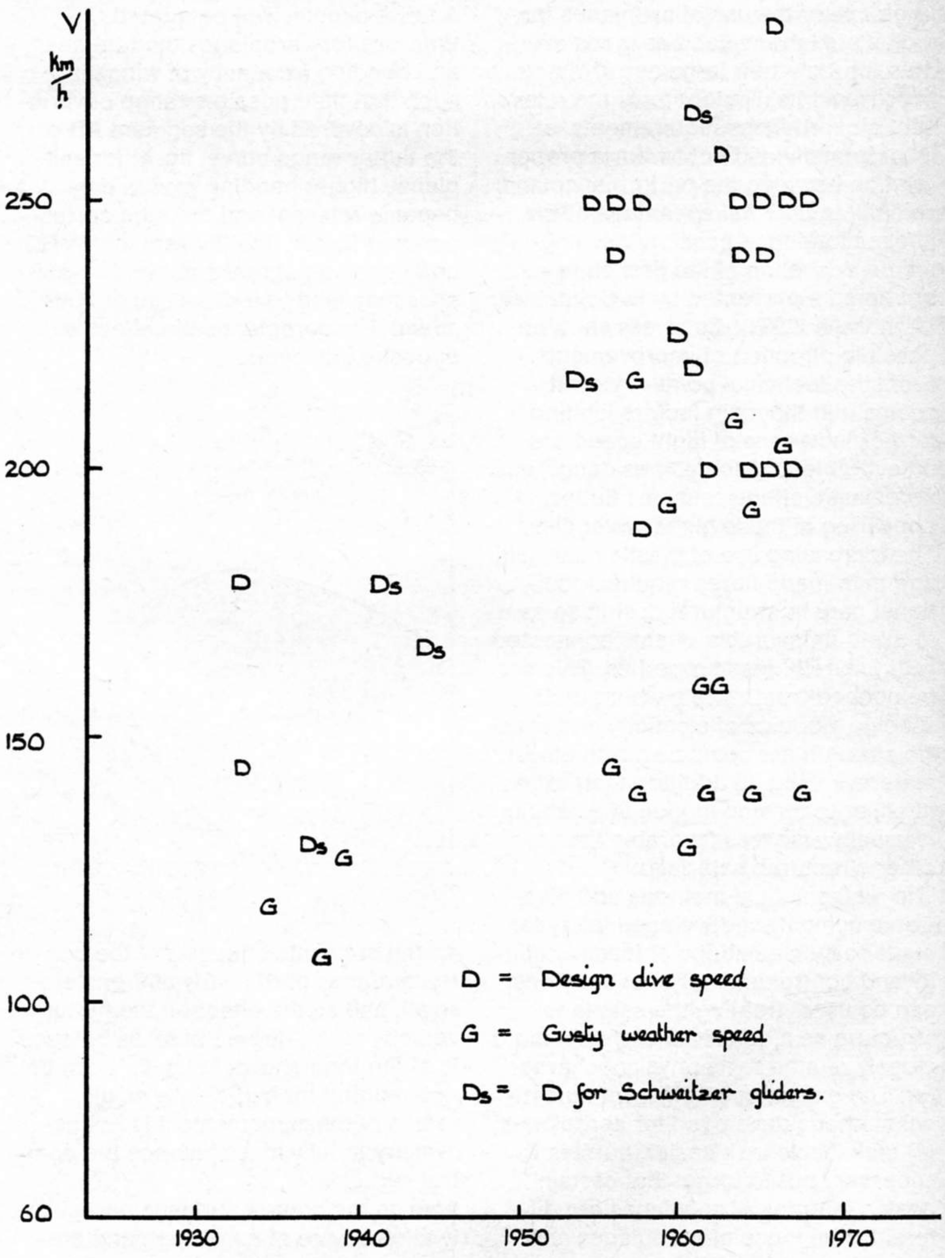


Fig. 2

Fig. 3



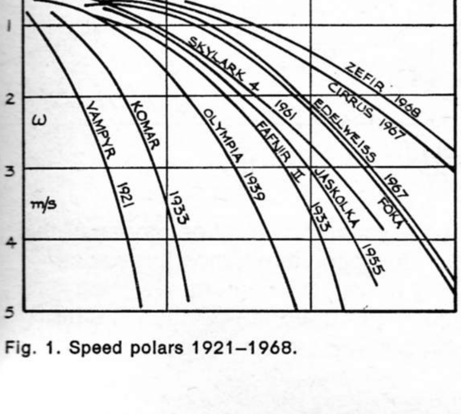


Fig. 1. Speed polars 1921–1968.

enced climb rate during thermal flight,» the maximum velocity to achieve a minimum time of flight over a triangle of 100 km can be deduced. So to obtain an average cross country speed of 100 km/h the average cruising speed must be 150 km/h and for an average of 133 km/h—200 km/h. This corresponds to a rate of sink of about 3 m/sec, when appropriate thermal conditions are prevailing.
The achievement of long cross country flights during the limited duration of good thermal or lee wave soaring conditions is facilitated if, without the performance of the sailplane for other flight conditions being reduced, their rates of sink at higher velocities are reduced. The advantages of these qualities are enhanced for soaring over continents where strong favorable thermal or lee wave conditions prevail.
Unfortunately, as can be seen from fig. 3, the maximum flight velocity in gusty weather and the maximum design velocity do not show, during the 1921—1968 period, such clear and large growth trends. This limits to a large extent the use of sailplanes for flights at higher velocities made available through their large aerodynamic improvements. Undoubtedly the relevant airworthiness requirements, at least formally, did not favour a proper relation between the performance and velocity to take full advantage of the above mentioned possible developments. A change of the French requirements presented by B. Schneider (3) at the X OSTIV Congress shows a possible direction of improvements.
From the technical point of view it seems that the main factors limiting further increases of flight speed are unfavorable and sometimes dangerous aeroelastic effects, such as flutter, appearing at these higher velocities.
The increasing use of plastic materials and man-made fibres requires additional care in structural design so as to avoid unfavorable effects connected with their stiffness properties. This can be noticed from table I, where their specific modulus of elasticity and specific strength are compared with other materials used. In addition their ratios of shear to tension moduli of elasticity is usually also less favorable than for other structural materials.
The mathematical methods and electronic computers developed lately for numerical calculations of loads, stability and control and aeroelastic effects can be used, treating the sailplane structure as a deformable system more closely related to its physical character. The existence of different numerical methods developed for aeroplanes (4) makes this task easier, but it is necessary not to forget that certain design features of sailplanes are different from those of aeroplanes and hence the simplifying assumptions must be carefully checked.
From the point of view of flutter the main distinguishing design properties of sailplanes are: their larger ratios of wing weight to total weight which is between $1/3$ and $1/2$, whereas for aeroplanes this figure is about $1/10$, and relatively much smaller longitudinal moments of inertia of sailplanes.
Hence the coupling between the dynamic deflections of different component parts of the sailplane is much more pronounced than on aeroplanes. These properties make it necessary to make flutter calculations considering the whole sailplane, i. e. wing + fuselage + tailplane ... as a deformable freely suspended system and not as is sometimes done for aeroplanes where the wing is treated as fixed to a rigid fuselage of very large mass.
Another distinguishing feature of sailplanes is that wings and stabilisers are of large aspect ratio and have cut-out free continuous structures, which leads to different effects due to changes of design.
A few examples will be quoted.
Whereas for aeroplanes the torsional and bending frequency of wings is such that their possible range of variation is covered by the segment AB of the flutter range curve, fig. 4; for sailplanes higher bending modes may become relevant and then the corresponding flutter stability segment is BC and hence a decrease of bending stiffness may lead to a decrease of flutter speed. For aeroplanes the effect is opposite and small.

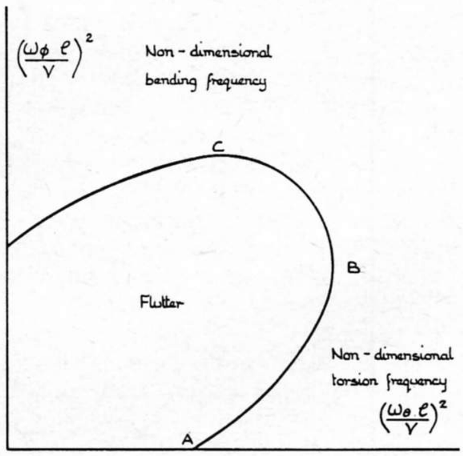


Fig. 4

As the moments of inertia of the control surfaces particularly ailerons are small, and as the effect on the flutter velocity of the degree of mass balance is of the form shown in fig. 5, it can be noticed that for sufficiently small values of these moments it is not necessary to fully mass balance the control surfaces.
Also as the control surfaces particularly ailerons are of large span and are relatively light and relatively very deformable, the selection of the dynamic model for flutter calculations must be made with great care. The variation of the flutter speed of a model in which the aileron is involved, depending on its mass balance and hypothetical deformations related to its deflection, is illustrated in fig. 6.
The selection of the position of attachment of mass balance weights on control surfaces, because of the above mentioned flexibility, must be made carefully to make sure that the rigidity of the attachments is sufficient and that the positions of the weights relative to the nodal lines of oscillation are properly chosen. Cases in which mass balance weights influenced the critical flutter speed unfavorably have been noted.

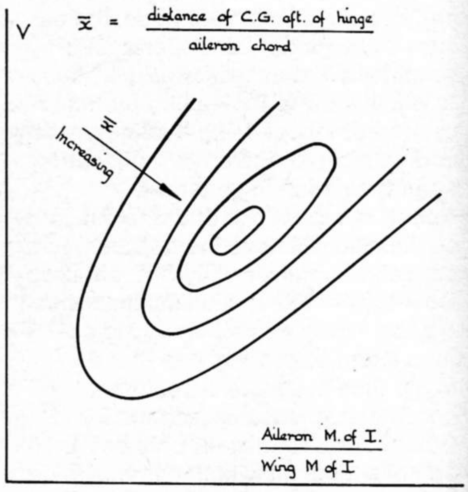


Fig. 5

While using «T» type tailplanes on gliders, as seems to be favored now, it should be noted that the necessary rigidity of the relevant structural elements increases the strong coupling of

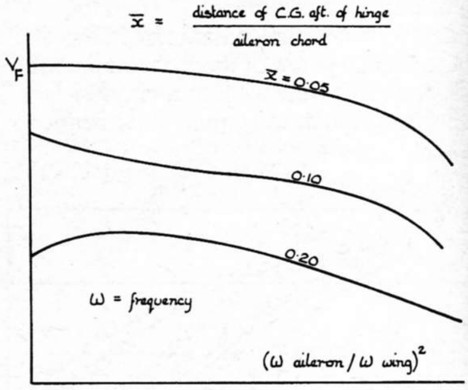


Fig. 6

the asymmetric vibration modes of this configuration and hence it is necessary to use more natural vibration modes for flutter calculations in this case.

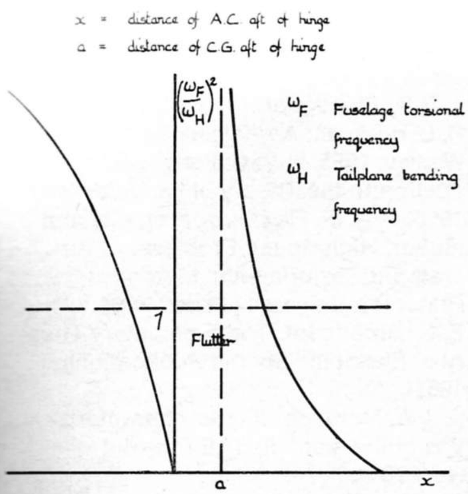


Fig. 7

Also while use is made of slab tailplanes some interesting couplings may appear as was shown by Mc Killop (5). The possibility of flutter, shown in fig. 7, when the hinge moments are reduced together with the distance between the aerodynamic center and the hinge exis, should be borne in mind.

The calculation of the load distribution on lifting surfaces of sailplanes must include aeroelastic deformation effects to avoid large errors. These effects are shown clearly on fig. 8 for the wing of a modern glider whose divergence speed is 660 km/h.

The influence of wing flexibility on loads due to gusts was discussed by Sandauer (6) at the VII OSTIV Congress. A more accurate calculation of loads on a flexible sailplane due to model or statistical gusts can be made numerically using data prepared for flutter calculations.

Also some irregularities in the stability and manoevrability noticed on sailplanes can be explained by effects of flexibility as will be shown in detail in Kacprzyk and Nowak's paper (7), during our present Congress, and I would like to show for illustration the dependence between the elevator angle and velocity they obtained for the rigid and flexible wing case.

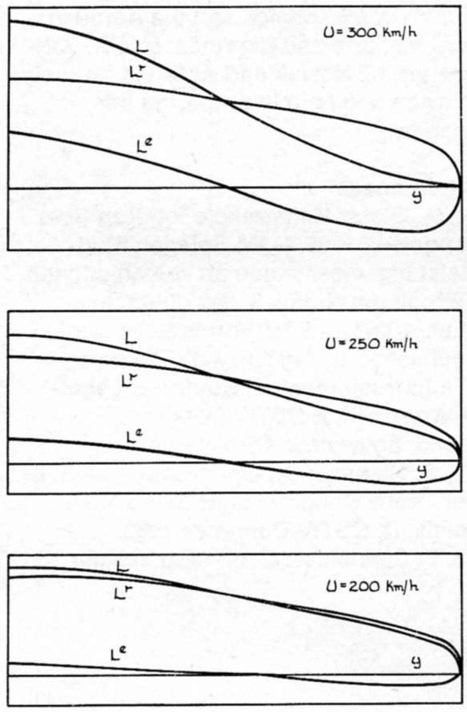


Fig. 8

L Load per unit span, elastic wing
L^r Rigid wing
L^e Elastic effect
Divergence velocity = 660 km/h.

Above at a certain velocity the slope of the curve is reversed when the wing twist is taken into account.

All the above mentioned effects and others appearing on sailplanes due to their relatively large flexibility were not intended, but simply resulted from designs made having in mind different purposes. A careful analysis of possible designs from the point of view of aeroelastic requirements could lead to possible optimization or compromises leading to overall benefits.

The unfavorable effects of structural flexibility should not stop us from research efforts on its use for the improvement of the quality of gliders. Research, leading to designs in which advantage is taken of the deformation of the wings to change the wing twist and possibly aerofoil shape depending on the velocity or angle of attack, so as to obtain optimum aerodynamic properties at more than one flight condition, will be useful. The best solution would be a self controlled one, but the ingenious solution of the designers of HKS1 (8) of about 15 years ago, where the aerofoil shape was controlled by the pilot, is worthy of further consideration.

It may be useful also to recall the original idea used in the design of the glider «Kashook» (9) with a wing

Table I **

Material	Tension strength $\sigma\beta$	Modulus of elasticity E	Specif. weight γ	$\frac{\sigma\beta}{\gamma}$	$\frac{E}{\gamma}$
	kg/mm²	kg/mm²	kg/dcm³	km	km
Duraluminium	40	1000	2,8	14	2500
Wood in grain direction	8–12	1100–1800	0,55	15–22	2000–3300
Glass fibre in direction of tension with epoxy filer	120–150	4500	2,3	50–110	1900
Glass fibre	350–490	7400	2,5	150–200	3000
Randomly distributed glass fibre with resine filer	30–80	1800–3000	1,7	18–50	1100–1800

** From: G. Fauner – Kunststoffe im Flugzeug- und Raketenbau, Luftfahrttechnik Raumfahrttechnik, *13*, 1967, Nr. 7, Juli.

hinged perpendicularly to its span at the fuselage joint, and which had in the fuselage an elastic suspension whose stiffness and damping could be adjusted to control the frequency and phase of the wing bending ascillations within certain limits. This arrangement was supposed to reduce drag due to oscillations excited by atmospheric turbulence in favorable circumstances. The results obtained on this very interesting experimental design are not known so far.

May I also call your attention to the fact that the outside surface of the sailplane components and also wings is usually rigid as on aeroplanes. It would be interesting to do some basic research with a view to clarifying under what conditions the flexibility of the surface is advantageous, as it undoubtedly is in the case of birds or dolphins, and to adjust the aeroelastic properties of the wing surface so as to increase further the quality and range of usefulness of sailplanes.

I hope that in this brief talk I have called your attention to, and indicated the importance and possible advantages of the aeroelastic effects, and have indicated the necessity to design sailplanes right from the beginning as flexible structures.

In conclusion I would like to thank the OSTIV Congress Committee for giving me an opportunity to express my views on an interesting subject before such a distinguished gathering of people interested in the further scientific and technical progress of sailplanes and soaring. May I also express my thanks to my numerous Colleagues of the Chair of Mechanics and the Aeronautical Institute and particularly to A. Sandauer, M. Nowak and A. Glass for their advice and help in preparing this paper.

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Zusammenfassung des Eröffnungsvortrages zum XI. OSTIV-Kongress

Zu Beginn des technisch wissenschaftlichen Teils des XI. OSTIV-Kongresses ist es angezeigt, sich die Ziele dieser internationalen Organisation in Erinnerung zu rufen. Vor nicht allzu langer Zeit wurden diese Aufgaben von Präsident L. A. de Lange formuliert:
1. Die Förderung und Koordinierung neuer wissenschaftlicher Erkenntnisse, die zur Verbesserung der Segelflugzeuge und der Technik des Segelfluges führen.
2. Die Förderung neuer Erkenntnisse zur Verbesserung von Trainingsmethoden, der Auslegung und des Betriebes von Segelflugzeugen und von Zubehörteilen unter der speziellen Beobachtung der Leistungsverbesserung, der Verbesserung von Flugeigenschaften, der Sicherheit und des Komforts zum Nutzen des Segelfluges und der allgemeinen Luftfahrt.
Während der Vorträge des technischen Teils würden wir die Gelegenheit haben, die verschiedenen Probleme, die mit diesen Aufgaben verbunden sind, kennenzulernen. Diese Erkenntnisse können auch kurz als «Fortschritte im Segelflug» bezeichnet werden.
In der kurzen ihm zur Verfügung stehenden Zeit, möchte er auf das Problem der Einwirkungen von Deformationen auf die Segelflugzeugstruktur hinweisen.
Die Teile des Segelflugzeuges, die aerolastischen Einwirkungen ausgesetzt sind, müssen bei den geforderten erhöhten Bahngeschwindigkeiten von Hochleistungs-Segelflugzeugen besonders beachtet werden.
Fig. 2 zeigt, dass die Bahngeschwindigkeit eines Segelflugzeuges, bei einer Sinkgeschwindigkeit von 3 m/s, sich in den letzten 2 Jahrzehnten verdreifacht hat.
Vom technischen Standpunkt aus gesehen wird die Grenze der Gleitfluggeschwindigkeiten in der Zukunft durch ungünstige und manchmal gefährliche aerolastische Erscheinungen wie z. B. Flattern gegeben sein.
Flattererscheinungen sind bei Segelflugzeugen eher zu erwarten als bei Motorflugzeugen, da bei Segelflugzeugen das Verhältnis des Flügelgewichtes zum Gesamtgewicht zwischen 1/3 und 1/2 wesentlich über dem Verhältnis von 1/10 bei Motorflugzeugen liegt. Daher sind die dynamischen Abweichungen der verschiedenen Teile an Segelflugzeugen viel stärker als an Motorflugzeugen.
Die Flatterberechnungen sollten daher für das ganze Segelflugzeug durchgeführt werden, nämlich für Flügel, Rumpf und Leitwerk als **ein** verformbares frei bewegliches System und nicht, wie das bei Motorflugzeugen getan wird, indem man sich den Flügel fest mit dem Rumpf als grosser Masse verbunden vorstellt. In der Folge gibt der Autor verschiedene ausgewählte Beispiele von Massnahmen zur Vermeidung von Flattererscheinungen an verschiedenen Flugzeugteilen.
Zum Schluss möchte er dem OSTIV-Kongresskomitee danken, dass ihm die Gelegenheit geboten worden ist, seinen Standpunkt zu diesem interessanten Problem vor einem Publikum zu erläutern, das am technisch-wissenschaftlichen Fortschritt im Segelflug interessiert ist. Er dankte ebenfalls seinen Kollegen vom Lehrstuhl für Mechanik und vom Luftfahrttechnischen Institut und speziell A. Sandauer, M. Nowak und A. Glass für ihren Rat und ihre Hilfe, um diesen Vortrag zusammenzustellen. Sulzer