Man Powered Flight in 1929

by

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Alexander Lippisch has spent more than 40 years in aviation and has left permanent marks on almost every aspect of it, but he has completely avoided ordinary aeroplanes.

He first came into prominence as the Technical Director of the Rhoen Rossiten Gesellschaft with his work on sailplane design at the Wasserkuppe from 1920 to the middle 1930's. He lectured to the Society (Vol. XXXV, July 1931) on "The Development, Design and Construction of Sailplanes" and produced a paper of outstanding value to all sailplane designers which was widely read and translated from the English. He designed, among other types of sailplane, the Professor, the Wien, the Falke and the Fafnir I and II. He then devoted himself to the development of the Delta wing, which he invented. In his 1931 lecture he illustrated his Δ-1 as a glider. His tail-less work culminated in the Me-163 tail-less rocket interceptor, the first aircraft to reach 1,000 km./h. (620 m.p.h.) in level flight, when flown by the late Heini Dittmar.

At the end of the War he was studying the problem of the heavily swept Δ and was spirited across to the U.S.A. where he has remained ever since. He is now Research Director for Collins Radio in Cedar Rapids, Iowa, where he has been working for some time on his Aerodyne, a tail-less and wingless deflected jet concept of great technical interest.

Alexander Lippisch also lectured to the Society on "Results from the DFS Smoke Tunnel" (Vol. XLIII, September 1939) in 1939 and showed remarkable slow-motion pictures of air flow, which must have been a revelation to designers.

His activities have embraced the problem of the flapping wing, kites and large-scale (12 ft. span) free-flying research models. He is an inspiring teacher, his teaching being pervaded with a sharp, unexpected gaiety. He has also written numerous papers, including a most useful method for span loading calculation, and has also worked on the problem of man powered flight. He has been most interested in following the efforts of the Man Powered Aircraft Group and is a corresponding member. He has just written the following note on some work he did 31 years ago, which is appropriate and useful even now in connection with our present efforts towards achieving man powered flight.—B.S.S.

THE REVIVAL of interest in flight by man's own muscle power brings back to me some early attempts to solve this problem some 30 years ago.

Needless to say I was—and still am—sold on this idea ever since reading Lilienthal's famous book as a youngster in school. Then came the Wright Brothers and the early years of flying and the years of the First Great War at the end of which I found myself as an Aerodynamicist, designing wing sections and calculating induced drag according to Prandtl's newly discovered wing theory.

The end of the war found us meditating about gliding and the possibility of soaring flight. And so came the Rhoen, and the "Sturm und Drang" of the years on the Wasserkuppe.

When the "Forschungsinstitut of the Rhoen-Rossitten-Gesellschaft" consolidated the efforts of research and scientific progress, there were again here and there people who tried to build man powered aircraft. We should probably not just say aircraft or gliders, since most of these "inventors" had figured out some kind of contraption which, seen from some distance, resembled more one of those prehistoric bird petrifacts. Quite often we were urged to give our expert opinion on such "Pteroptodons."

Usually there was not much to report on these inventions and one often thought how much waste of energy and time was invested in such fruitless endeavour. Would it not be better to give those people the opportunity to come to the Wasserkuppe during the contest and at least to see and learn something which would give them better understanding and opportunity to discuss their opinions. So we started the technical part of the contest and, although it was certainly not a great success, the meetings in the evenings were full of new initiatives.

Among the contestants for this technical event was a medical doctor, Dr. Brustmann, who brought a kind of ornithopter built around and above a bicycle. He did—for his own sake—not get into the air with this vehicle and his ground runs were one of the highlights of amusement, Ursinus running in front with a handkerchief to determine the wind direction and Brustmann high on the wheels flapping the wings like a newly hatched chicken. But Dr. Brustmann had something quite interesting to say.

As a sports physician who trained athletes for Olympic competitions, he had experimented on how to reach a man's highest power output. In the course of this activity he had measured the short-duration power which well trained sportsmen could produce. The figures he gave us regarding the possibility of a muscle-powered aircraft were most encouraging. Today, however, we know from other sources that Dr. Brustmann's figures were quite optimistic.

But the trend of the numbers which he gave me

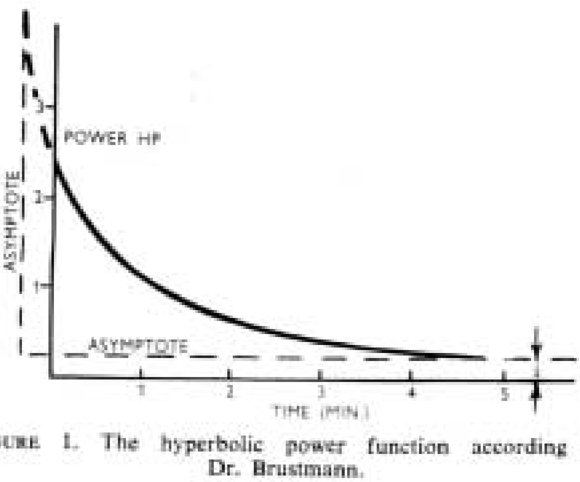

FIGURE 1. The hyperbolic power function according to Dr. Brustmann.

showed that the relation between the human power output and the duration of such effort was a kind of hyperbolic function (Fig. 1). The asymptote for an effort sustained over a long period was in the range of ¼ h.p. The other asymptote was to be placed at a negative time so that for zero duration a figure of 2-2·5 h.p. would result. This relation showed that the human body stored a certain amount of energy which could be expended over a short period, and high power output could be expected for a period of less than one minute. At least I knew that for a short time it seemed actually possible to fly by man's own power, since a lightly built glider plus man would not need more than one h.p. to be flown horizontally.

The discussion of this problem finally led to the plan to build a very light test aircraft to see what we could actually achieve. Since the ornithopter was still favoured in those days, we decided to build such an experimental vehicle as a flapping-wing, man powered aircraft. The reasoning was based primarily on the physiology of the function of muscles which are designed for intermittent use. Besides, it seemed to us that wing flapping would probably have better efficiency and would cause less additional structural weight for the necessary mechanism.

Today I am still inclined to think that wing-flapping actually gives better efficiency, but our knowledge of how to design a highly efficient flapping-wing is very limited and it is certainly easier to use a screw-propeller for propulsion, since we can base our layout on a large variety of experimental work.

It was quite obvious that minimum weight had to be achieved, since for any flying vehicle there is a basic relation between weight, power and lifting surface which states that:

$$\frac{W^3}{\rho \, . \, P^2 \, . \, S} = \text{dimensionless constant.}$$

where W = weight.
P = power.
S = surface area.
ρ = density of air.

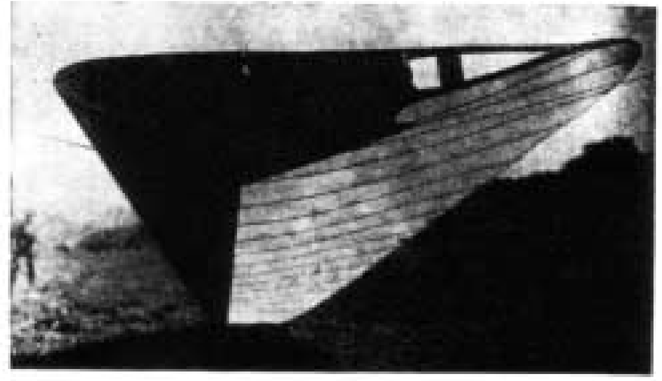

FIGURE 4. Centre view of a wing (inverted position).

Since the design has to strive for a minimum of this "performance number," the influence of saving weight is much more pronounced than that of good aerodynamics.

Most people who think about man powered aircraft today see only the aerodynamic problem. I want to remind these people that the aeroplanes which flew with the lowest power per weight, were the biplanes of the early days.

There is a basic difference between the design of a "minimum power" aircraft and an optimum performance sailplane.

So we decided to build a flapping-wing, man powered craft. I had to design the ship and Alex Schleicher in Poppenhausen was to build it. The main layout is illustrated in Fig. 2. It was a high-wing with open pilot seat and a covered fuselage behind it. The wings were moved by the action of the legs, quite similar to the rowing motion. Each wing had a triangular strut support underneath and on the end of this strut, cables moved the joint in a guide rail fastened to the fuselage. (Fig. 3.)

To compensate the normal lift force, which otherwise would have to be balanced by the force of the pilot's

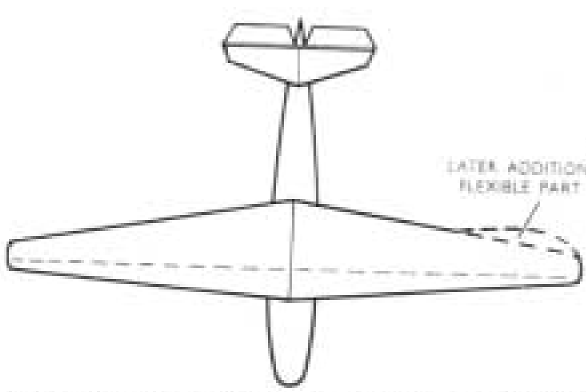

FIGURE 2. Sketch of the plan view of the "Schwinguin." The span was between 9-10 m.

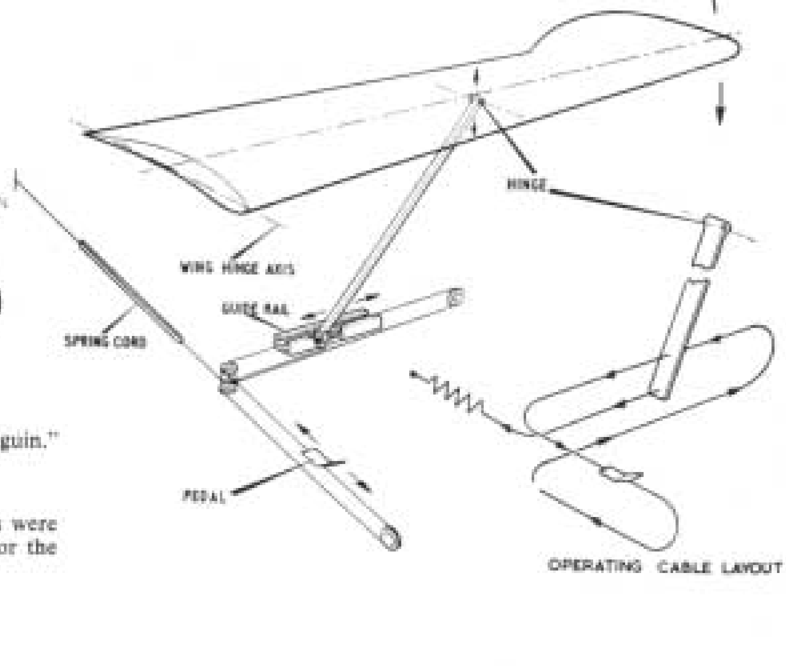

FIGURE 3 (*right*). The wing flapping system. The pullies were attached to a steel tube frame which served as a guide for the movement of the strut joint.

FIGURE 5. Hans Werner Krause after take-off. The height over the ground is obtained from the shock-cord energy.

NB. In both flight pictures the rear extension of the outer wing cannot be seen because this part is flexed upwards.

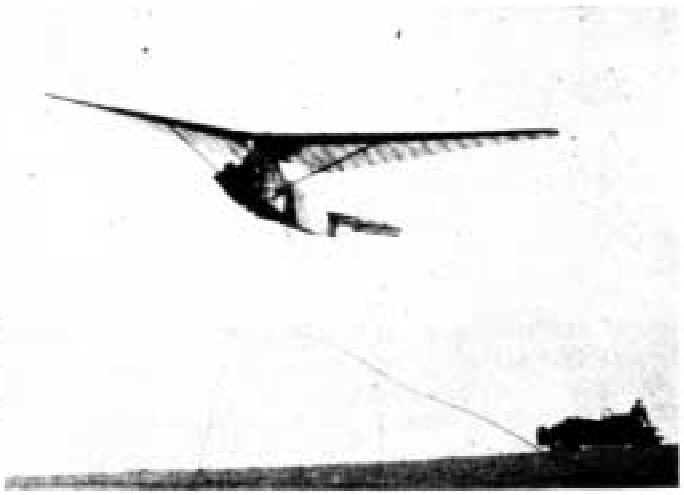

FIGURE 6. The take-off for the "vacation" flight. It is obvious that the crew tried to give Hans Werner as much acceleration as possible. The cable hanging from the rear of the ornithopter was the retainer fastened to the centre frame, since the rear fuselage was not strong enough.

legs, springs (from shock-cord rubber) were located in the rear fuselage. These springs had to be adjusted in such a way that, without any leg force being exerted by the flyer, the aircraft wing would be in a slightly dihedral position in normal gliding flight. The wing structure consisted of a single spar and a very light plywood cover for the nose part and fabric for the rear. The root section was highly cambered and the tip an almost symmetrical section (Fig. 4). The empty weight of this little ship was around 50 kg. This was actually heavier than originally planned since the wing-flapping mechanism with the steel tubing, struts, guide, cables and pulleys took more weight than estimated. Each wing, without the struts attached to it, weighed 4·5 kg. (=10 lb.)

I had further estimated that the thin plywood covering of the nose part of the wings would allow the wing to twist in a downstroke. On the other hand we thought we could expect good propulsive efficiency even without any twisting, due to the Katzmayr effect as measured in a wind tunnel.

As test pilot for this little ornithopter Dr. Brustmann had selected a young pilot, Hans Werner Krause, who was also a good athlete. It must have been spring of 1929 when we began the first test flights.

The control was a stick for elevator and rudder. Sideways movements of the stick gave rudder deflection. There were no wing ailerons because I thought that flapping one wing more than the other would give some lateral control.

The aircraft was launched with a shock cord, which was the usual procedure with gliders. After testing the ship a few times in gliding, Hans Werner tried the first flapping-wing flights. The result was quite disappointing, since we could not see any improvement of the glide angle. At least the effect was so small that the measured Katzmayr effect did not show up, and the twisting of the wings, even with this light construction, did not occur. At first we did not know what to do next.

To find out how to improve things I made some tests with a model wing, and I clearly observed that a stiff wing in flapping motion did not produce any forward thrust. Even turning the wing in its incidence was not sufficient. I then remembered that some of the stories from early years told about a flexible trailing edge. I therefore enlarged the outer portion of the wing by the addition of a flexible (single bamboo sticks) Zanonia-like rear surface as shown in the sketch. This piece was not very large but what a difference in propulsive action was caused by this change!

We tried it first with some flights from the old Weltensegler barracks towards the Pelzner Hang (north-east direction). After a few tests Krause flew all the way to the road, flapping continuously, making eleven flappings for this distance which was in the range of 600 ft. (Fig. 5). An attempt to fly from higher elevation over a larger distance ended in a crash since the lateral control with wings in the lower position was ineffective. We repaired and adjusted more dihedral in the neutral position of the wings.

The main trouble was that Hans Werner did not see any real reason for working hard while flying, since a little engine could have done these things so much better. Such arguments are quite difficult to refute. But there came a rare oportunity in Hans Werner's demand for a vacation to Berlin to see his sweetheart. Well, I said, you can have your vacation if you fly the ship over a horizontal course and a pre-determined distance, which we will lay out. After some arguments about muscle power and too much work we entered a gentleman's agreement on these terms.

The place of action was the little airfield on top of the Pelzner Hang and the distance and the goal were marked by a small puddle which had to be crossed at the end of the flight. (The distance was between 250 and 300 m.).

This flight was accomplished on the first attempt. The crew which stretched the shock cord for the take-off gave all the encouraging "Ho-ruck" cheers and to our amazement and amusement Hans Werner Krause crossed the "lake" still in flapping flight (Fig. 6). I think he was on his way to Gersfeld and the railroad station ten minutes later.

Unfortunately the machine was afterwards shipped to Berlin for a show and for the unreasonable reason of a better take-off, a steel tube welded undercarriage was added to the aircraft. It was obvious that such "improvement" made this machine a truly earthbound vehicle, since the increase in weight prohibited any further possibility of man powered flight. (Hans Werner Krause died in an accident with a sports aircraft soon afterwards.)

Since the original test flights were not brought to the final achievement of the initial task, the results which, seen in the light of later experience were quite remarkable, were never published.

From this experience gathered from these early man powered test flights I can conclude that an improved version of such an aircraft would give very interesting results.

Now, what should be improved?

First of all the empty weight of such aircraft must be smaller than the weight we achieved by our first attempt. I know now that this can certainly be done.

In recent years we have tried Balsa wood as material for different parts of aircraft construction. The use of this material has brought remarkable results in weight saving. At first sight it seems that Balsa wood is much too low in strength. But if you consider the fact that such material makes it possible to use larger cross sections for the same strength, you begin to realise that you obtain higher local stiffness and quite often you can replace an actually too-heavy member with a properly dimensioned piece from Balsa wood.

The ornithopter described did move the whole wings up and down. From later experiments with flapping wing models I have learned that a design which has a fixed centre part of the wing mainly for lift and which uses the flapping part only in the outer regions, is more efficient. The propulsive efficiency improves if the mean loading of the flapping wings is decreased. A rotational flapping motion similar to the wing movement of most insects and birds is better than a simple up and down stroke.

The flying ornithopter models have further shown that, due to the intermittent break-away of the tip vortex, performance in gliding is improved by flapping. The non-stationary flow also has the advantage of a reduced boundary layer which does not have time to develop to its full grown strength.

The mechanical efficiency of the power transmission from the legs or the arms of the operator to the wings can be considerably improved. The system with cable and pulleys, as we used it, was not satisfactory. A stiff linkage is probably the answer. The counterbalancing by a spring system to hold the wings in a mean position is advisable. The natural frequency of the wing-spring system should be close to the wing beat required in horizontal flight (around ½ per second). From the evaluation of bird flight measurements*, I found that weight, span and wing flapping frequency per second were related by

$$\sqrt{\left[\frac{W}{(\rho/2)\,b^2}\right]} = n_s\,.\,b.$$

where W = weight.
b = span.
n_s = strokes per second.
ρ = density.

There are some other important characteristics to be taken care of. (Flexible trailing edges in the outer wing or torsional flexibility but stiff in bending!) But I must say again that weight is a dominant factor for the success of such a task.

During the Rhoen years I saw several gliders which had an empty weight of 50 kg. and below. The lightest man-carrying glider was Pelzner's Hangglider of 1922 with a weight of 9 kg. And at that time we did not have the light-weight materials which are available today.

And now I wish much success to my old friends and those younger ones of whom I have heard. Good Luck and "Hals- und Beinbruch"!

*See *Der Biologe IX*, Jahrjang 1940, Heft 5, Die Gesetzmässigkeiten des Vogelfluges. A. M. Lippisch.