Flapper Facts

Newsletter of the Ornithopter Modelers' Society

Winter 1998

Editor/Publisher: Nathan Chronister, PO Box 376
Arkville, NY 12406 USA

Membership dues, payable to the editor:
New members: $14 for one year ($21 outside USA)
Renewal: $9 per year ($14 outside USA)

Special Issue: Manned Ornithopters in Russia

Flapping Flight Today and Tomorrow by Valentin Kiselev

For more than 20 years, a research group of Moscow Aviation Institute has been studying different aspects of flapping flight. Flapping flight is very difficult because a flapping wing is the source of lift and thrust at the same time. Man created the aeroplane by dividing the wing functions, leaving lift for a wing and thrust for a propulsion system. It is well known. Are there any losses here? An aircraft needs high speed to be able to fly. Thus, long runways are needed.

Watch the birds. For example, a duck that has a great weight to wing ratio: Among birds, it is the closest one to a flapping wing aircraft prototype. Let's have a look at its way of mak-

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Vladimir Evgrafovich Tatlin (1885-1953) by Reuben Hoggett

Probably most remembered for his Monument to the Third International, Tatlin's enthusiasm ranged from folk music, for which he made his own many-stringed instruments, to sailing, to poetry, to art. He designed for the stage, for films, for books, and even for ornithopters. His non-art activities included his involvement with aeronautical design and sailing ships.

For the Russian "Constructivists", and for Tatlin in particular, an important precedent

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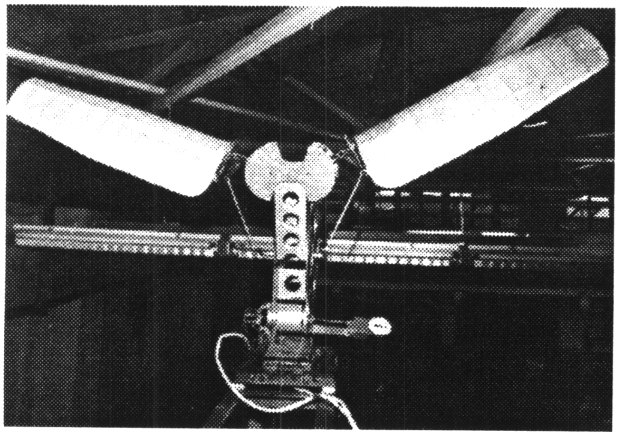


Fig. 1. Flapping wing testing at the strain-guage stand.

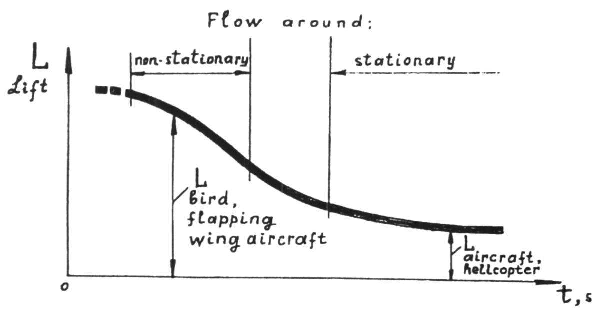


Fig. 2. Change of aerodynamic force over time with wing sharply entering the air flow. The speed of the air flow and the wing angle of attack are constant.

ing a landing. First it glides with its motionless wings. When the speed decreases, it begins to flap its wings to lower the speed down to zero and makes a vertical landing. Conclusion: a flapping wing will allow an aircraft to make vertical takeoffs and landings. This is the main future advantage of a flapping wing aircraft in comparison with the aeroplane.

However, first calculations were not optimistic: too great frequencies of flapping were required for creating the necessary aerodynamic forces, and inertial loads were too great. But these pessimistic results simply did not agree with the facts that stimulated us – bird flight observations.

Different test stands to measure aerodynamic forces created by a flapping wing have been constructed. And when the wings, driven by an electric engine, began to flap at the strain-guage stand (Fig. 1), we were surprised to see the engine could not bring the frequency of flaps to the necessary values and speeds, but in spite of this the aerodynamic forces created by this slow wing were not lower but even higher than the design values. To study this paradox in a more "pure" form, a special installation for an experiment in the wind tunnel was made, allowing the wing to enter the airflow sharply. The result was supported: At first, aerodynamic forces sharply increased, and then (as shown in Fig. 2) decreased up to the point of stationary flow-around. The explanation should be in non-stationary flow processes, when due to considerable positive accelerations of the flow it would involve large joined air masses. In popular literature it is often said that a cockchafer "cannot fly according to the laws of aerodynamics." Here the following should be more definitive: "...according to the laws of stationary aerodynamics". It is quite evident that a flapping wing allows us to apply the effect of non-stationarity to improve takeoff and landing characteristics up to acheiving a vertical takeoff and landing.

The second important conclusion from the discovered phenomenon is that once, due to non-stationarity, the necessary speeds of a flap decrease, inertial loads of a wing structure decrease accordingly. Aerodynamic and inertial forces loading a flapping wing are not added, as they appear at different times and at different wing positions. Inertial forces are maximum in its extreme positions, and aerodynamic ones peak near the average positions when the speed of the wing is at a maximum. Hence, we get to the most important conclusion: aerodynamic loads, as a rule, are greater than inertial ones. The former are useful, and it is they, not the inertial loads, that determine the wing strength. As a result, fears of inevitable destruction of a flapping wing because of huge inertial loads disappear. Of course, this does not belittle the problem of providing fatigue strength in such aircraft. But at the same time, the importance of the described effect allows one to speak optimistically about future development of flapping wing aircraft.

To research flapping wing aircraft with the presence of forward speed, a rotative stand was designed that rotated on account of the thrust of a flapping wing mounted on it (Fig. 3). With the increase of forward speed the flapping wing flow-over becomes more stationary, which decreases its load-bearing characteristics. But it does not affect the lift: it can be saved and increased on account of the increase of dynamic air head.

At vertical takeoff and landing, under the mode of aircraft hovering, the position of the wing flap plane should be close to horizontal. In straight-and-level flight, the plane sets in a vertical position. The speed of the flight at that point considerably exceeds the speed of the flapping wing proper about the times that the lift of the wing is more than the its drag. It is especially noticeable with the birds of a high lift-to-drag ratio wing, for example seagulls and cranes. Measured slow flaps of the wings and a fast straight-and-level flight. And on the contrary, under a horizontal or nearly horizontal flap plane position, a straight-and-level flight is practically impossible due to absence of a thrust component of aerodynamic forces. At small inclinations of this plane, the flight speed can be increased only on account of its multiple excess by the speed of wing flapping (as, for example, high speeds of helicopter blade motion). But high speeds result in great aerodynamic drag (first of all, a profile one), small lift-to-drag ratio, flight distance and speed decrease, necessary power and weight increase.

These are all disadvantages of a helicopter in comparison with the future flapping wing aircraft in a straight-and-level flight. To receive higher speeds a flapping wing can be easily stopped; the thrust can be received on account of jet engines. Here a flapping wing will be used only to provide a vertical takeoff and landing. For example, we have developed a project of a business aircraft weighing 5600 kg carrying 10 passengers over 1000 km or 5 passengers over 1800 km with a cruise speed of about 800 km per hour (Fig. 4). It can make a vertical takeoff and landing with the ratio of takeoff engine thrust to takeoff weight of 0.48 on account of using a flapping wing moved by a hydrodriver consuming the whole power of the engines under takeoff and landing regimes.

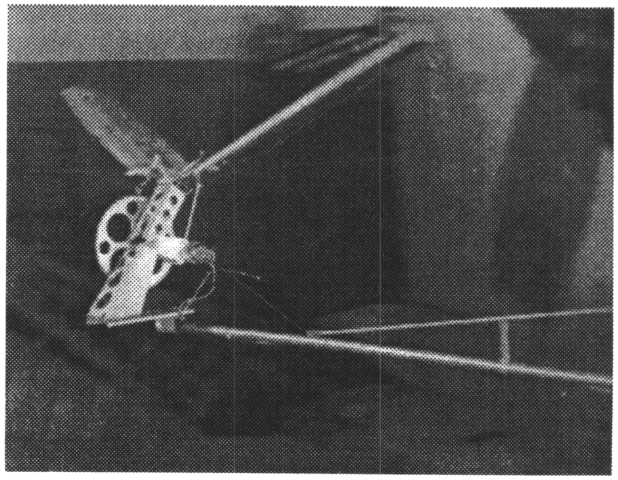
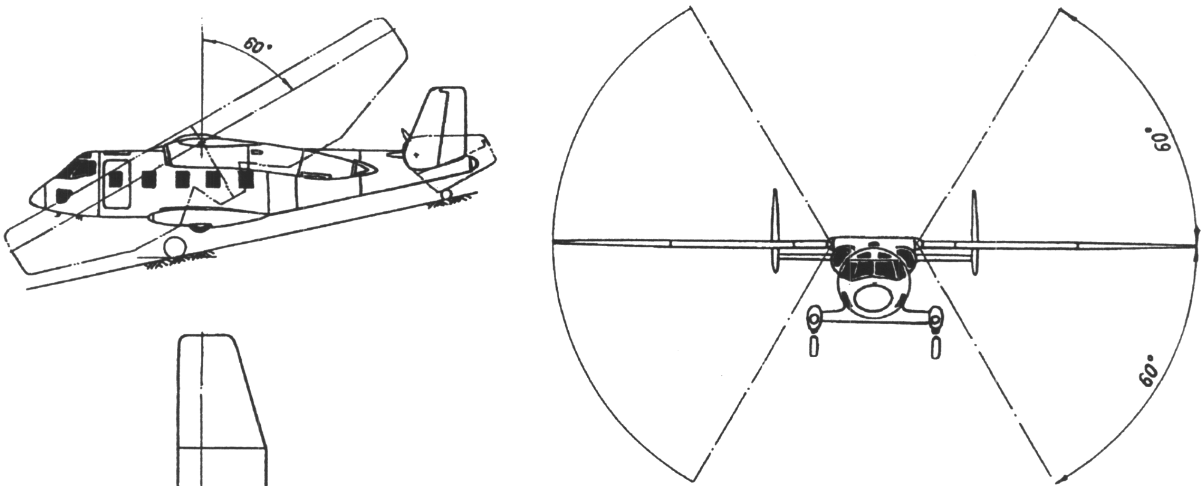


Fig. 3. Flapping wing testing at the rotative stand.

Comparing flapping wing aircraft with vertical takeoff-and-landing aircraft receiving vertical thrust on account of special lift engines or on account of thrust vector deflection of the main engines, you can easily see that flapping wing aircraft are more effective at takeoff and landing. This is because the less the speed and the greater the mass of the air pushed downward, the less power is necessary for vertical takeoff. Flapping wing aircraft as well as helicopters have the greatest wing or blade swept area and can push downward the maximum air mass with the least necessary speed. A cold air flow pushed downward with small speeds will not destroy the surface of the ground at takeoff or landing, which supports non-airfield basing of the aircraft. A flapping wing is an integral lift system used in both takeoff and landing and straight-and-level flight regimes, which



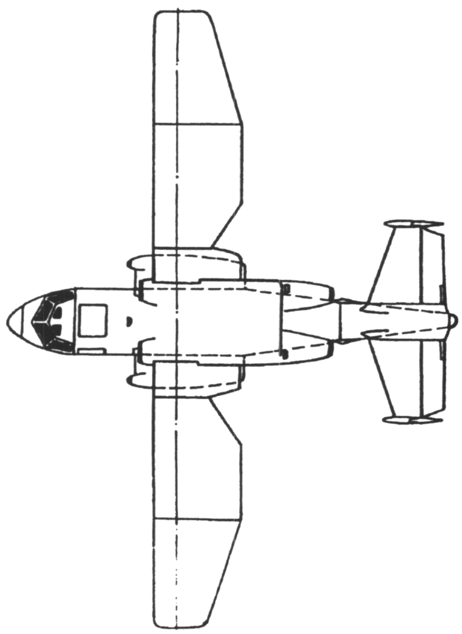
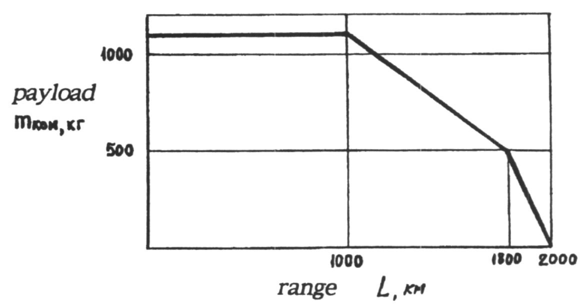


Fig. 4. Business aircraft with flapping wings (project).



reduces dry weight of the aircraft compared to vertical takeoff-and-landing aircraft that do not use a wing at vertical takeoff and landing. Thus, a flapping-wing aircraft combines the advantages both of a helicopter at takeoff and landing regimes and an aeroplane in a straight-and-level flight and it is better than other vertical takeoff aircraft by many factors.

Most fears, as a rule, are said about an impossibility to increase the dimensions of flapping wing aircraft. We did not find principal barriers on the part of flapping wing aerodynamics that could be an obstacle for increasing dimensions. Theoretical dependencies on the basis of Struhal similarity criterion show that under the regime of aircraft hovering, the change in lift is directly proportional to the fourth degree of a flapping wing size change with geometrical similarity and frequency of flapping held constant. This means that the lift increases faster than the weight of an aircraft (weight is proportional to the cube of sizes). Conducting stand tests of wings differing by five times in size supported the theory.

The necessary power in the said conditions is proportional to the fifth degree of size change. However, to increase the lift in a greater degree than the aircraft weight increase is not necessary at all. They can be changed proportionally to each other, that is the cube of the size change. In this case under the aircraft hovering regime, the necessary frequency of flaps with the increase of size will even decrease (reversely proportional to a square root of a wing span change); the necessary power will be proportional to wing span only in the degree of 3.5,

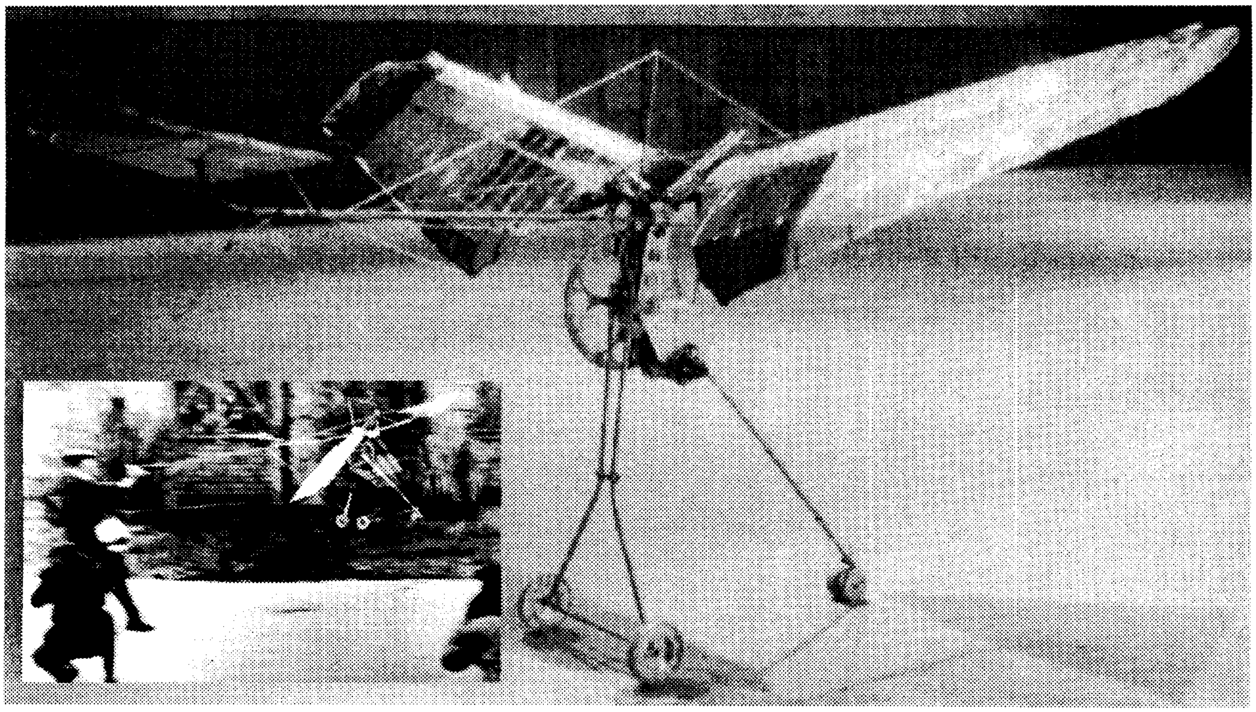


Fig. 5. Control line flapping wing model.

i.e., it will a little exceed the intensity weight change. Even though with increasing size, the thrust-to-weight ratio of a flapping wing aircraft should increase, that can be supported by application of gas tubine engines for heavier flapping wing aircraft.

After stand testing, a flying control-line model of a flapping wing aircraft with an electric driver and power supply by control lines was constructed. This model allowed us to demonstrate flapping flight, takeoff, and landing without application of radio control system. The flights were made using pads of limited sizes and in the halls as well. Shown in Fig. 5, a control line flapping wing aircraft weighed G=7 kg; wing area S=1.3 m^2; span l=3.3 m; a wing had two consoles flapping symmetrically; engine power N=0.33 horsepower. With a frequency of flapping, n, of about 1.5 oscillations per second, the flight speed was 40 or 50 km/hr. The first flight was on July 9, 1981.

Since 1984, the experiments were conducted with free-flying radio-controlled flapping wing aircraft. Fig. 6 shows one of these aircraft in flight, called a "Dragonfly" as it has two tandem wings (altogether 4 consoles) flapping in anti-phase. Similar aircraft do not have body oscillations in flight, as at any moment a couple of descending wing consoles produces lift. The necessary power value also decreases due to the decreasing peak loads. At the same time it should be noted that we can get a straight-and-level flight, with a vertical overload equal to a unit, that is practically without oscillations of the aircraft body, with the wing of two consoles as well.

When we speak about flapping flight, similar flights of wound-toy birds or other light-weight models are often referred to. There is an easy way of thinking about flapping flight based on glider flight: to cause its wing to have flapping movements, its flight should not be worse or should even get a propulsive force. But this is not a solution of the flapping flight problem, it is only a way round this solution. To get a propulsive force from a flapping wing is not difficult, but at the same time to receive greater values of the lift is a much more difficult prob-

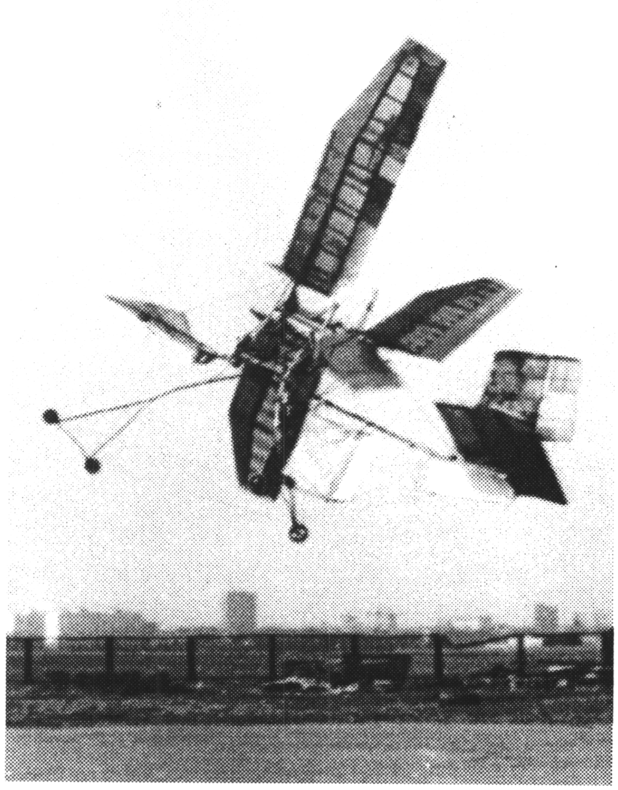


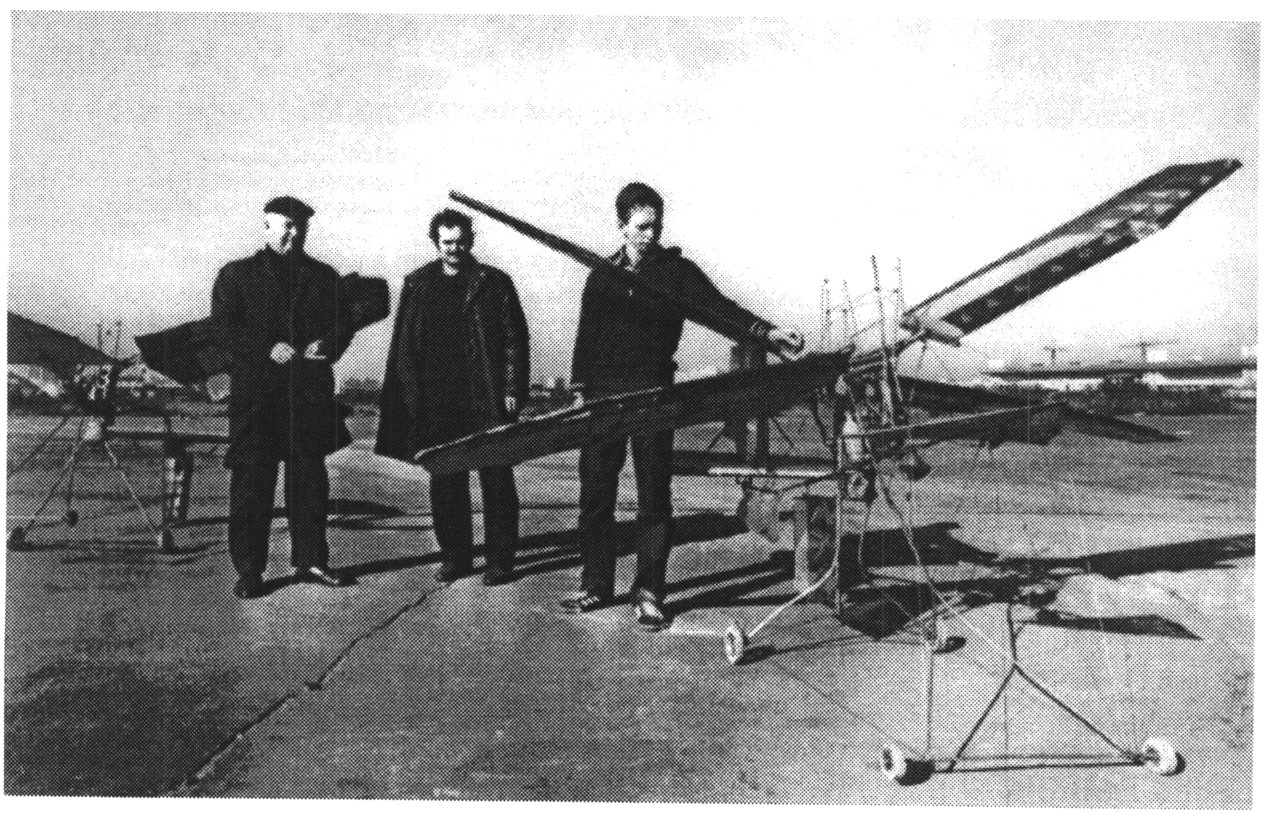
Fig. 6. Radio remote-controlled flapping wing aircraft "Dragonfly" in flight.

lem. However, only the solution of the latter in a flying flapping wing relates to the feasibility of flapping flight. The indicator of its solution is the level of acheived load-bearing wing characteristics, determined by an acheived specific wing load G/S (weight per wing area) that must not be lower than the minimum one.

$$W/S \geq (W/S)_{min} = 0.022\, n^2\, (l^4/S),$$

where W = the aircraft weight in kg; S = wing area in m^2 including its motionless part if it is present; l = the greatest dimensional span of the whole wing in m; n = number of full flaps per second.

This minimum level corresponds to a lower limit of load-bearing features of bird wings. A specific loading of many birds is several times greater than the minimum level. The criterion can be shown as correlations of flight weights, if both parts of the equation are multiplied by wing area:



$G \geq G_{min} = 0.022\ n^2\ l^4.$

These dependencies have been received for aircraft with two wing consoles; for a scheme with four consoles (two tandem wings) the received results must be doubled. So, for our "Dragonfly", (Fig. 6) having a span of 2.89 meters and a weight of about 10 kg, the necessary minimum weight by a formula with frequencies of 1.5 to 2 oscillations per seond is 6.9 to 12.2 kg; that is, its real weight is within the necessary range. This condition of realizing a flapping flight should be added by another condition – independent aircraft takeoff from the ground rather than its forced takeoff with the help of a hoist, catapult, from hands, from a height, etc.

The acheived level of flapping wing characteristics is not limited, there are reserves not used yet, there are fields for future research. At present we have founded the design fundamentals of a flapping wing aircraft flight; a mathematical model of a flapping wing aircraft has been created not only to calculate its flight performance but also to simulate the process of the flight proper in real time (which in a number of cases gives a possibility to replace a flight experiment itself).

In 1986 an experimental piloted flapping wing aircraft was designed, an engine was selected, strength calculated, the structure developed, and a wing hydrodriver produced. Its model is shown in Fig. 7. However, due to specific conditions of our work such an aircraft has not been built up to now, though the past years only supported the true basic solutions. Its construction and testing is a good field of possible cooperation. Besides scientific and engineering results, a flapping wing aircraft can be used for demonstration flights, as it is a new type of aircraft causing a general interest, for advertisement aims, for crossing the English Channel. The construction and testing of a piloted flapping wing aircraft would be the base for getting orders for mass production of flapping wing aircraft of different purpose. Their application may be very wide; for example, they promise to oust helicopters as a transport means leaving them only the role of an air crane where long-term hovering is needed.

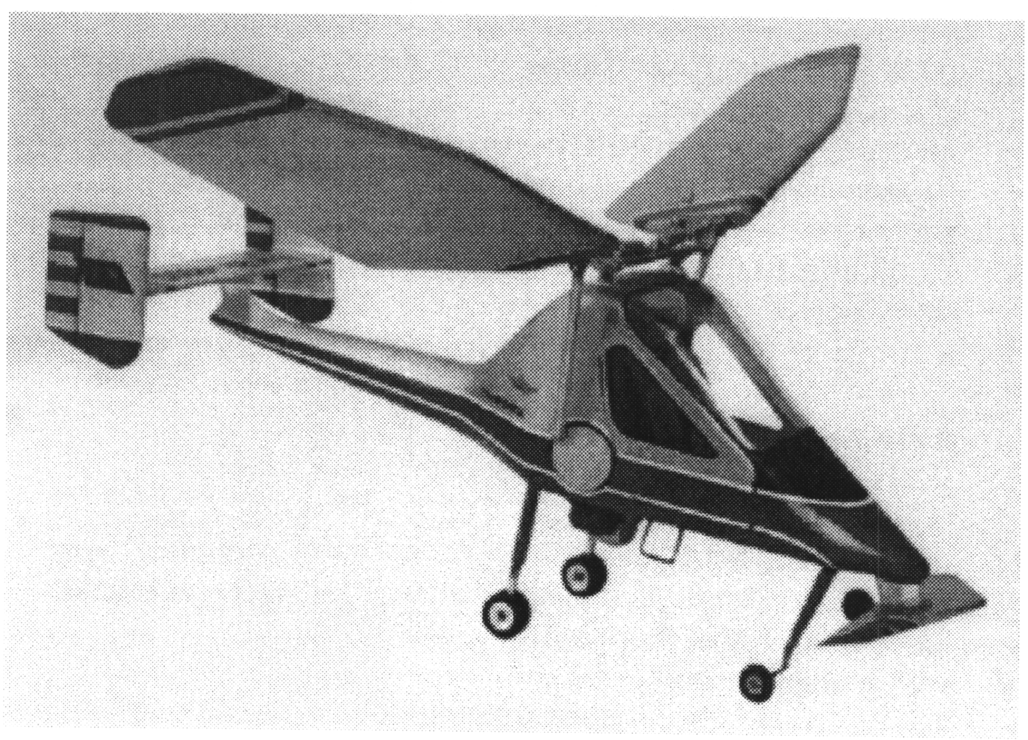
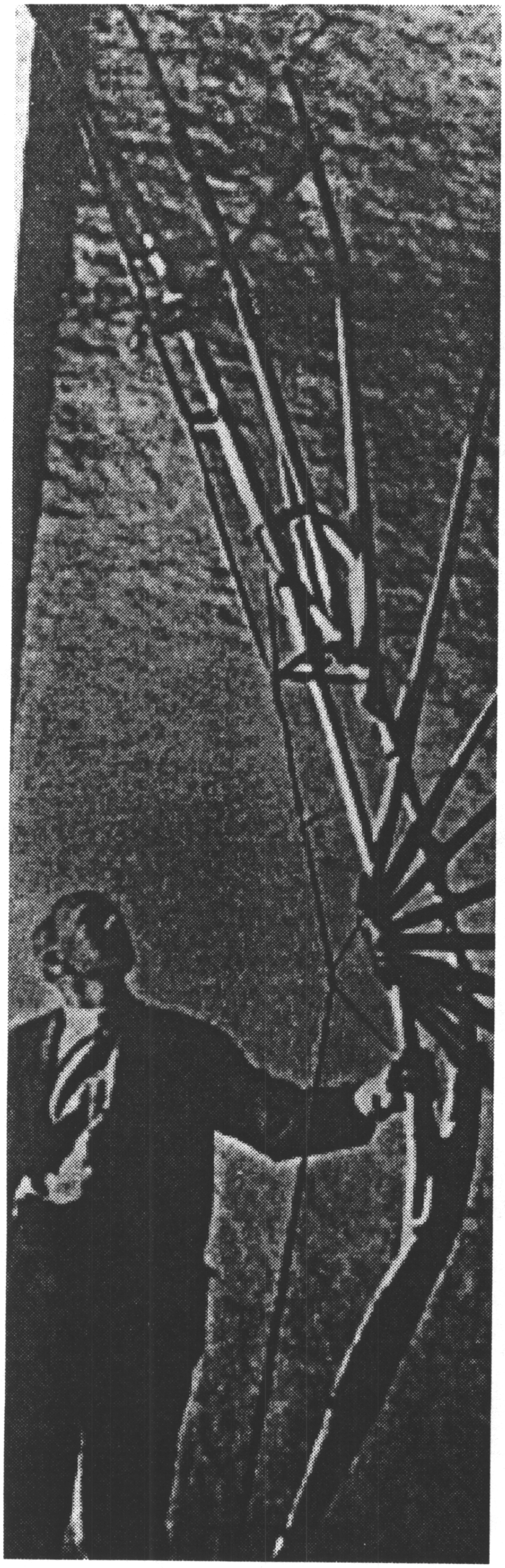


Fig. 1. Experimental piloted flapping wing aircraft model.



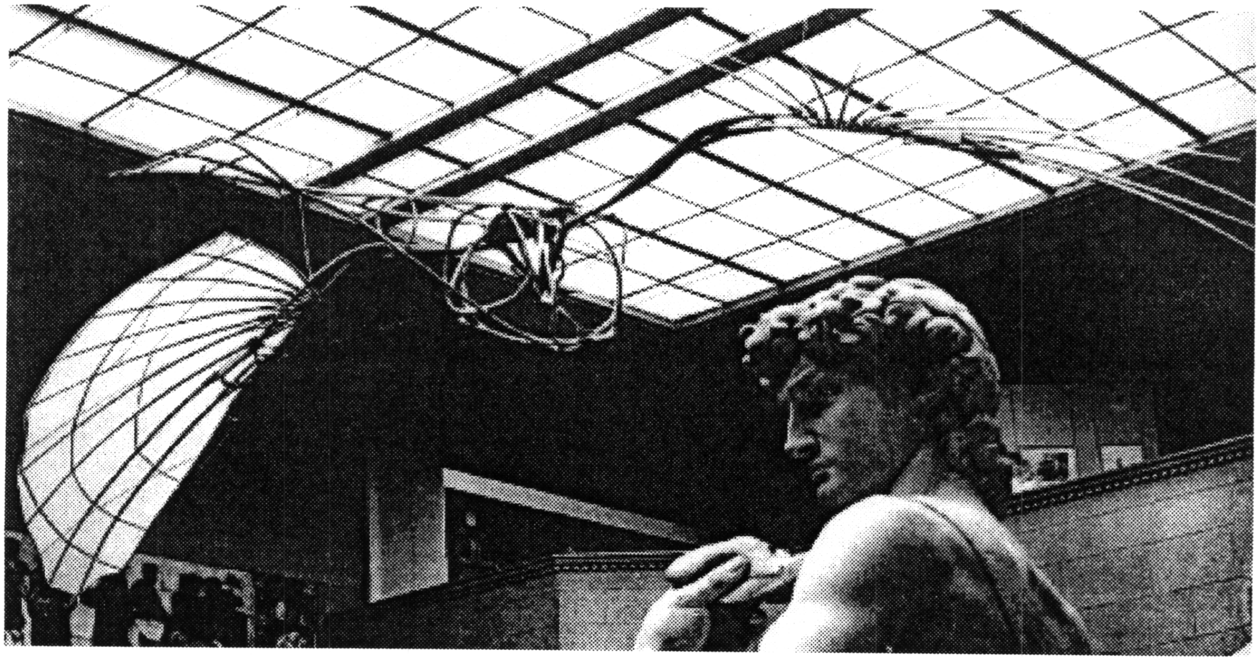
Tatlin, continued from page 1

existed in the work of Leonardo da Vinci, as much inventor and constructor as painter, for whom there was no contradiction in the simultaneous study of painting and the design of machinery. Tatlin's project for a flying machine (see picture), between 1929 and 1932, recalls both Leonardo's example and Khlebnikov's (note 1) preoccupation with birds. Tatlin the sailor had watched tireless gulls follow his ship for days scarcely moving their wings. Letatlin, his ornithopter, was a response to that memory. The verbal pruning of its name recalls the neologisms of Khlebnikov: letat, to fly, plus Tatlin gives Letatlin.

Tatlin, teaching the culture of materials of bentwood, evolved Letatlin as head of a small group of researchers at the Experimental Scientific Research Laboratory in the Novodevichy Monastery in Moscow. They studied the handling of materials according to principles of organic construction. "My machine," observed Tatlin, "is built on the principle of life, of organic forms. Through the observation of these forms I concluded that the most aesthetic forms are the most economical. Creative work is giving form to material." In particular Tatlin and his group studied insect flight and the flight of birds reared at the laboratory in the monastery.

Letatlin was a flying machine in the tradition of experiments by Leonardo da Vinci and, recently, by Lilienthal. By 1932 mechanised air travel did not rely upon human effort or gliding. Tatlin's "glider" was a machine independent of the geometric forms of modern engines. His approach was not the engineer's disposition of materials into a predetermined form, but the exploration of material qualities and their articulation with minimal interference. His aim, as a constructor, was neither to depict bird-flight in the manner of the artist nor to build aeroplanes in the manner of the engineer. Working with a surgeon and a pilot he evolved an equivalent for the flying mechanism of the bird. His construction included the mechanical structure of the human being. Tatlin extended the figure, adjusting the levers and rhythms of the body to the movements of flight.

Tatlin's construction mediates between the natural



forces of wind and living organisms. "I want to give back to man the feeling of flight," wrote Tatlin, "We have been robbed of this by the mechanical flight of the aeroplane. We cannot feel the movement of our body in the air".

Tatlin intended to make his "aerial bicycles" a consumer article: "I chose the flying machine as an object for artistic construction because it is the most complicated dynamic material form which can enter into the daily lives of the Soviet masses as an object of widespread use".

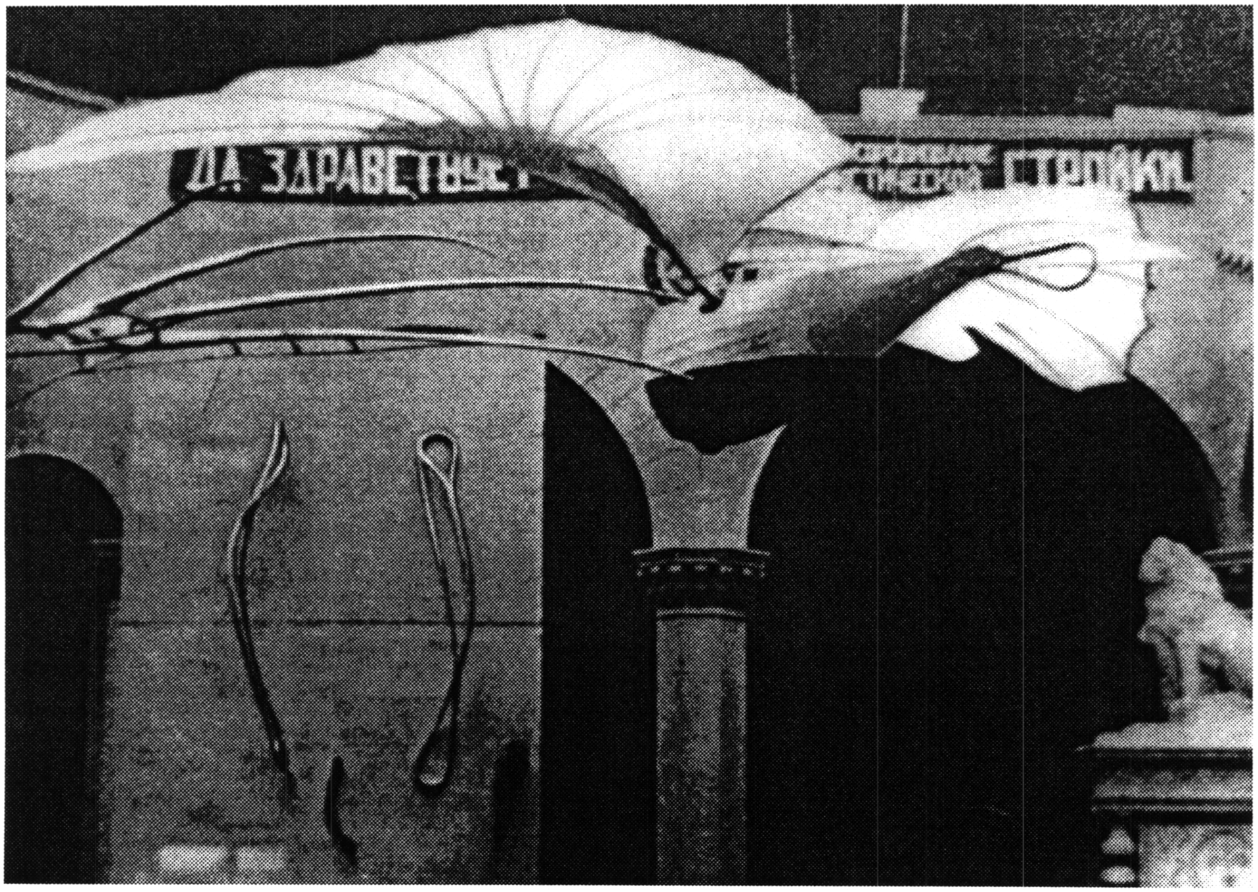
Letatlin was intended to be a prototype. The total weight of the construction was 32 kg, the wing surface 12 m^2; with 8 kg load factor per one square metre.

In the work on Letatlin, he used a multitude of materials: ash, lime, vine, cork, silk cord, Duralumin, steel cable, whalebone, hide rope. Their selection and combination were based on their inherent properties and adaptable functions within the construction.

The flapping wing construction was based on reproducing as accurately as possible the dynamic mechanics of the flight of birds. The proportion of the total weight of the apparatus and the weight of the wings was one to six; this ratio characterises most birds.

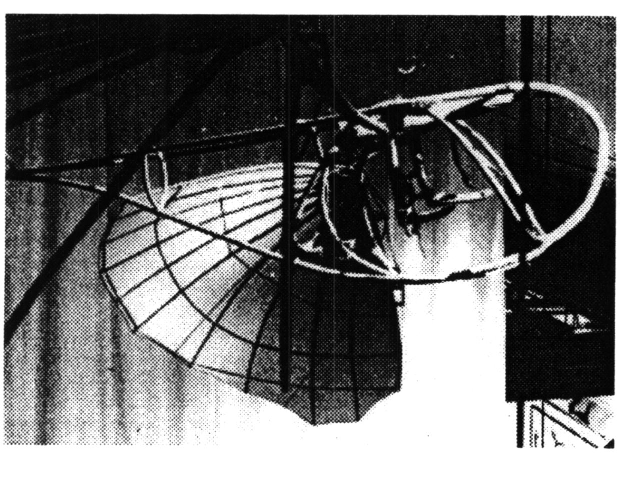
Tatlin studied birds for a long time and not for the sole purpose of reproducing the mechanism of their flying. The source of his flying apparatus was a detailed analysis of the wings of living birds which can change their form flexibly during flight, and of their chest and wishbones which function as brakes during their fall. In the structure of Letatlin he reproduced the form of birds' wings with artistic perfection as "an organic natural phenomenon".

The technical execution of such grandiose



construction never saw the light of day; it never got off the ground. In the professional literature the design for Letatlin has often been considered a "groundless Utopia".

Towards the end of his life, during 1951-53, his work on gliders received increasing recognition and Tatlin worked at the Moscow Centre for Research into Gliders (Dosaaf), giving lectures and reporting on his pre-war experiments. He died on 31 May 1953. An urn with his ashes was taken into the cemetery of the monastery where he had studied the flight of cranes.



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2. Milner, John. Vladimir Tatlin and the Russian Avant-Garde. Yale University, second printing, 1984.

Notes:

1: Khlebnikov – Influential Russian poet of the time.

Experimental Flapping Wing Aircraft (EFWA): Main Principles and Features of Design by Boris M. Doukarevitch

No flapping wing aircraft exists today. It will be a manned vehicle whose flight closely resembles that of a bird. The wings will be set in motion with a motor and, like those of a bird, will combine the support and propulsion of an aircraft.

History

FWA models, wing span up to 2 to 4 meters, are widely known. For more than 100 years, they have been designed now and again. However, this cannot be considered a significant achievement: flight of all these models is unpredictable and casual due to absent or insufficient control over wings. The distance from such a model to a real manned FWA is even more than that from a paper "dove" to a real manned plane.

Repeated attempts were also made to create full-size manned motor FWA, to say nothing of man-powered ones. As far as I know, none of these vehicles flew successfully. Therefore it is really a potential first-in-the-world project, which is not often the case nowadays.

Main principles

1. Reasonable limiting. Flapping flight of flying beings is an extremely multiform and complicated natural phenomenon. It comprises vertical takeoff and landing, maneuvers with change of wing area and setting wings forward and backward, hovering, and so on. Flapping flight surely cannot be mastered at once. So, to begin with, I will consider only the simplest and energetically easiest case: fast, uniform, straight, horizontal flapping flight. "Fast" means that the horizontal speed is large enough for normal fixed-wing gliding of the same aircraft at maximum Q, which is the usual gliding ratio. The term "flapping flight" will denote further exactly this case, unless otherwise stated. Other, more difficult, forms of flapping flight will be mastered later, as soon as practical experience has been accumulated.

2. Relation to existing aircraft. There are vast observations of flying beings in nature; let us note big-size, perfectly flying birds such as an albatross or seagull. The observations clearly show that these birds master both flapping flight and usual fixed-wing gliding to an equal, perfect degree; there is no definite boundary between the two forms. They alternate both forms many times with no visible changes of wing or "fuselage" appearance; the same wing construction is used with the same success. It is obvious that for these live "aircraft" usual

gliding flight is only a simple, particular case of flapping flight, when the motor is turned off and wings set motionless. It is obvious too that flapping flight of a bird is easy and effortless only if this bird is able to glide well. I offer to reformulate this into the important principle for the design: First of all, EFWA must perfectly fly with motionless fixed wings, preserving all performance of a good glider. Therefore, a usual modern high-Q glider must be used as the base for future EFWA. In order to preserve unchanged MTOW, geometry, and performance of the basic glider, it is expedient to use 2-seat (tandem) glider for the alteration into 1-seat EFWA: The powerplant will be placed in the cabin of the second pilot. Such approach largely facilitates the whole design, reduces expense, and ensures safety in an emergency, e.g., motor failure. On the whole, future EFWA have the direct and immediate relation to existing aircraft, especially to (motor)gliders; creating the EFWA will be a further development of the glider manufacturing branch of aviation.

3. Structure of a flapping wing. The said observations also show that the movements of birds wings are binary: flapping up and down with simultaneous change of end parts incidence. Such movements are not new for existing fixed wings: Long, flexible glider wings intensively deviate up and down due to overloads and air pockets, while the change of end parts incidence is widely used for roll control. The construction of wings to ensure reliable operation under these conditions is far advanced. Therefore, an existing glider wing can be taken as a base, but further alteration of wing and centerplane is obligatory.

Wing flapping is the new and very important parameter, which affects all others. For a wing span of about 10 to 15 meters, the frequency is expected to lie within the range of 0 to 1 Hz, even lower than the wing's own resonance frequency. Since flapping frequency is low, it is harmless for the construction.

4. Power supply. The simplest calculation shows that for horizontal flight it is necessary to produce and transfer to the flapping wings a power volume up to 10 to 15 HP. Extra power is required for takeoff. It is not a problem: Any combustion engine (30 to 50 HP) will ensure the necessary power. Since the motor will drive only a hydraulic pump, which is part of the hydraulic system, no mechanical transmission is required.

5. Control over flapping wings. This is the main problem, even more important than that of flapping wing construction. This is confirmed by the same observations of nature. The fact is that the wing structures of flying beings are often disadvantageous and imperfect from the point of view of aerodynamics – as we humans understand it. Thus, the wing of a bat is a simple elastic web on a frame of several bones. Nevertheless, some bats fly perfectly, not worse than birds. Probably the key is in extremely perfect control over these imperfect wings.

It is optimum choice and further maintenance of the order of wing movements which ensures stable propelling effect without loss of lift force, stability, and control over attitude. There are seven parameters of the flapping movement, which relate to a definite cross section of a wing:

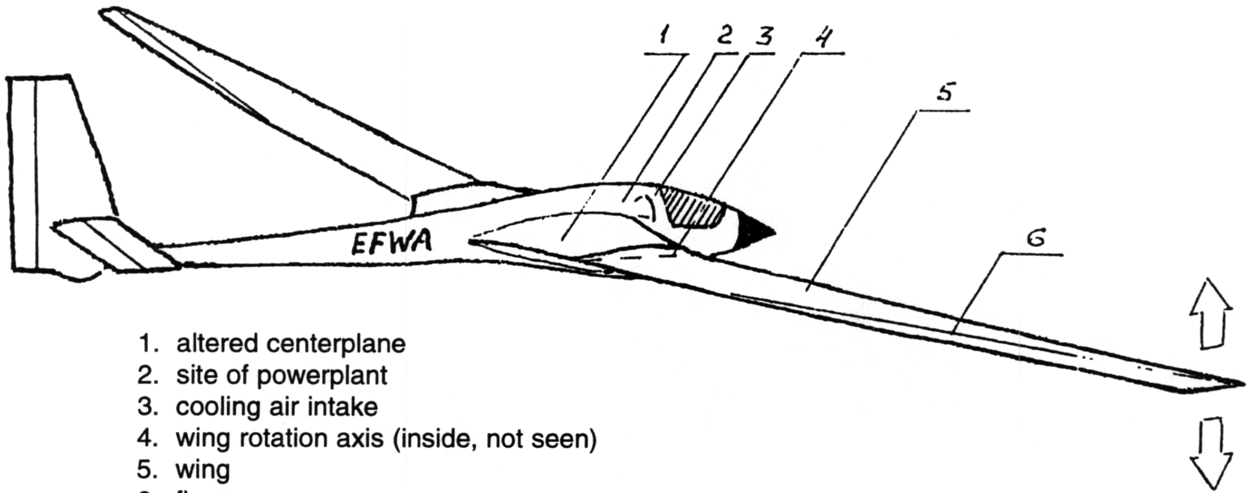
- Frequency, amplitude, form, and phase of the flapping motion.

- Frequency (the same as that of the flapping), amplitude, form, and phase of the incidence change process.

All these parameters (except the frequency) are variable in respect to wing span due to flexibility, twisting, and mechanical losses of the wing. Propelling and lift effects depend on all these parameters in an unknown way; speed, weight, and geometry of an aircraft affect them too.

The observations show that live beings carry out an optimum control over wings; their movements are highly variable and expedient. How to carry out such a control over wings of man-made aircraft? The conventional, generally accepted way is to describe all processes mathematically, to determine the algorithm of control and, at last, to create the corresponding control device. Unfortunately, this method does not fit here, since mathematical theory of flapping wing operation does not exist now: only fixed wings have been used in aviation, so existing fixed wing aerodynamics can be considered as a simplest particular case – at zero

Concept Experimental Flapping Wing Aircraft (EFWA)



1. altered centerplane
2. site of powerplant
3. cooling air intake
4. wing rotation axis (inside, not seen)
5. wing
6. flaperon

frequency – of future free wing theory.

Scale modeling, so widely used in various fields of technology, would not work here either. The reasons are:

- It cannot be used to prove efficiency and feasibility of flapping flight, since it goes without saying as a result of above-mentioned observations.

- Not supported by theory, any modeling produces results of doubtful value. What causes failures: bad construction or bad control over it? It is always difficult to divide and understand.

- Criteria of similarity of flapping wing models are much more complicated and less investigated than those of fixed wing models. The smaller the model, the higher the flapping frequency – the main parameter which determines all the other ones.

The only way to solve the problem of control is to remember that there is on board a man-pilot, who, at least, does not yield to any flying animal: a man has the perfect nervous-muscular system, as well as the ability to master new, complicated successions of movements. It is necessary to note that flapping flight is a rather easy job for many living beings, from insects to mammals. It would not be difficult to prove that it is a quite feasible occupation for men as well. Considering all this, the way of controlling becomes clear: A pilot must directly by hand control each movement of the flapping wings, at the same time with the usual conventional control over attitude.

Naturally, such a control must be within the pilot's powers and abilities, so certain arrangements must be applied. The main ones are:

- Using devices (i.e., hydraulic boosters) which reduce pilot's efforts on the joy-sticks to acceptable values.

- Proper feedback, preserving small residual exertion on the joy-sticks, etc. Due to the feedback, a pilot will be able to dose his efforts, to evaluate movement efficiency, and as a whole, to "feel" the wings, as well as he now "feels" rudder and elevator. Speaking figuratively, the flapping wing will become the continuation of the pilot's arm.

- Full value, safe training, since any habit (dynamic stereotype of movements) takes time to develop.

As mentioned above, flapping frequency of a full-size EFWA is expected to be within the range of 0 to 1 Hz, which is quite acceptable for the direct control over flapping wings.

I must note that the brothers Wright had run against the analogous problem during the creation of the first-in-the-world plane: how to control its flight, i.e., attitude. Nobody could guarantee that a man would be able to control flight, since no man had flown before. The Wrights rejected "control device" and entrusted the pilot with direct by-hand control. It was a very natural, right, and bold solution; autopilots and even the general theory of fixed wing flight came into being much later. I have to follow this way too.

The nearest analog: US patent 3,498,574 (author A. Ernst, March 3, 1970). The main idea is partly the same; the construction differs completely.

EFWA construction

The appearance of EFWA (enclosed) in the motionless state very much resembles that of the basic glider, for example the German DG-505 or similar: tandem one is preferable. The alteration (transformation) from a glider into the EFWA comprises rewinging, installation of the powerplant (in the space of the second cabin instead of a pilot's seat) and the new control system. The hinges are provided in construction of the altered centerplane, which enables wings to rotate up and down (flap) simultaneously. At the end parts of the wings there are devices for incidence change, e.g., flaperons. Wings and flaperons are connected with the pilot's cabin; these mechanical connections go through the hydraulic boosters. Hydraulic pump driven with a motor supplies energy for the boosters (for wings and for flight as a whole), while the control depends exclusively on the pilot.

Control of attitude is conventional. The devices for independent takeoff and taxiing are provided.

After the alteration of general appearance, MTOW and gliding performance must remain unchanged, the same as those of the basic, original glider. Since the basic glider can be of various type and construction, the concrete construction of the EFWA can vary too, but the exemplary construction remains the same. The latter is worked out up to details, but this is not the right place to describe and disclose it.

The merits of future FWA

1. Very low noise – only weak muffled exhaust of relatively low-powered motor. Noiselessness is the unique property, now inaccessible for any existing motor aircraft.

2. Highest efficiency, minimum fuel consumption. Flapping wings have a larger (relative) area and lower speed of movement than aircrews or jets. Hence the wings throw off the maximum amount of air at minimum speed, which, after the great scientist N. E. Zukovsky, determines efficiency.

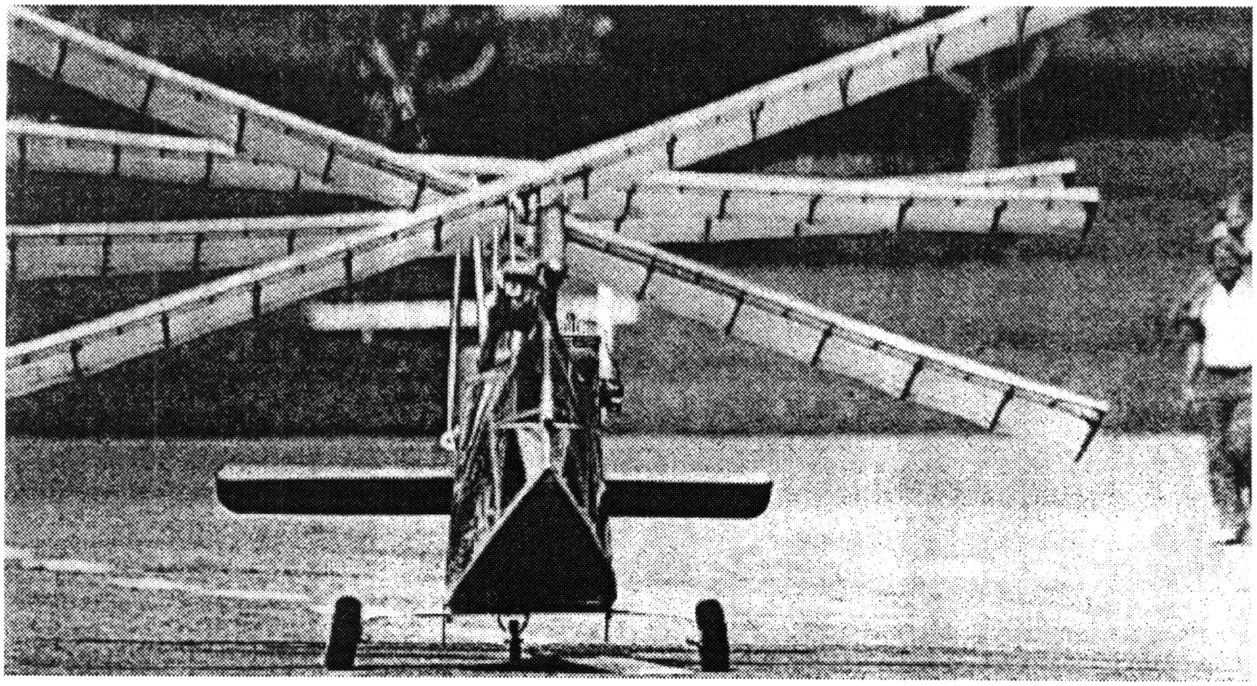
3. Better performance and maneuverability, especially during takeoff and landing.

4. New discoveries and sensations of the previously unknown flight which the pilot will obtain flying like a bird with obedient wings. As a whole, the prospect is great: Since humans like to fly by planes and gliders, they will surely adopt and like FWA.

Possible fields of application

1. A kind of movable "test bench" for scientific investigation of flapping wing work.

Continued on Page 16



Toporov Ornithopter #1

The photo above is from the magazine Soviet Life (February 1988), in which it appeared as part of an article on homebuilt aircraft. The article is about manned aircraft, but it doesn't really say whether this ornithopter, built by Victor Toporov, was manned:

"Let's look next at what seems to be a boat with two sets of oars. On takeoff the oars wave to lift the craft into the air. It rises only a few meters, but spectators gave this aircraft top marks for courage and imaginative design. The cynics noted the talent it took to accumulate the necessary materials."

"Victor Toporov built the plane from parts he made himself or took from a dump and old automobiles."

Toporov, I have recently learned, also built another (much different) manned ornithopter. The apparently more advanced design will be described in a future issue of Flapper Facts, once I get the article translated from Russian.

It's amazing how one can fill an entire 16-page newsletter on what must be the most obscure topic in the world, and still have a ton of info left over that didn't fit.

The next article is reprinted in whole from the (London) Observer, 17 April 1960. Kiselev thinks it may be invention of facts: "Otherwise, everybody would know about it," he said. He may be right, but there have been plenty of real ornithopters nobody knew about. I keep finding new ones to report in this newsletter.

Flapping Wing Plane

"The first successful flight of an 'ornithopter', an aircraft with flapping wings, was claimed by Russia yesterday. A Tass announcement said that the ornithopter, apparently powered by a motor-cycle engine was flown 'for several yards' in Moscow."

Coming Soon:

Florida Blown Away!

Kinkade's 10-minute, fully controlled flights

Unusual Actuators

Wham-O Bird Discovered

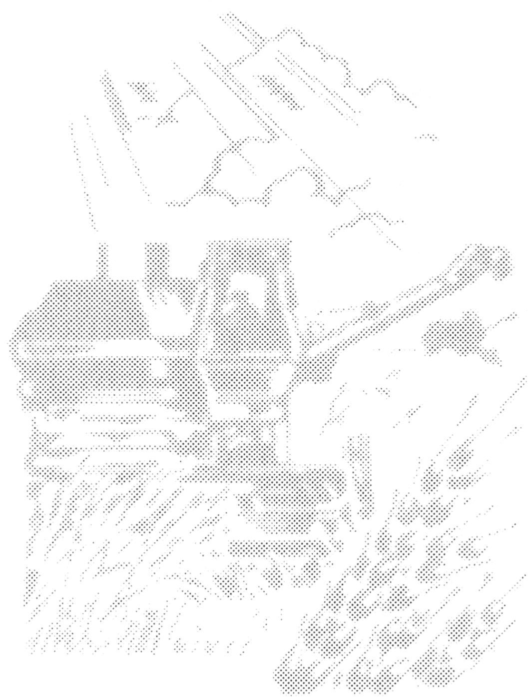
EFWA, continued from page 14

Obtained data will serve as a practical base for the future non-fixed wing aerodynamics and be useful for conventional plane design as well.

2. A demonstration exhibit for airshows, etc., for acquiring prizes and patents, and for establishing the new trend in aviation.

3. An aircraft for sport and amateur flying.

4. Light, ecologically friendly, economical, noiseless stealth aircraft for patrolling, reconnaissance, etc.



In the future, measures can be made in order to automate the control over wings and so to liberate the pilot from constant, routine work. A computer will be used to memorize and reproduce movements of the pilot, or to control some (or all) parameters without the pilot's aid. I can easily imagine a hybrid aircraft which will have both airscrew (for long, uniform fixed wing flight) and flapping wings (for maneuvers, reducing of noise, etc.).

It is necessary to state that in the future there will be no competition between FWA – from the one side – and planes and copters – from the other, because they have different fields of application.

Financial and other considerations

The creation of the first EFWA will be approximately 70% an assembly of usual and ready parts: non-finished basic glider, suitable motor of any destination, hydraulic system from fighter or bomber and so on. Manufacturing only one or two samples would be quite enough for this concept project. The dimensions and weight of the future EFWA will not be great. Considering all this, I suppose that the manufacturing will be rather cheap, by aviation measures: up to 80,000 to 100,000 US dollars, two times more than usual motorglider costs. Since the first sample of the EFWA will be a mere concept, experimental aircraft, technical requirements in relation to service life, paint finishing, etc. are relatively easy to meet. Nevertheless, the creation requires rather high technology and so can be fulfilled only at a factory experienced in manufacturing modern high-Q (motor)gliders.

[Editor's note: Doukarevitch says he already has the necessary information (description of principles, the detailed exemplary construction, methods and stages of tests, pilot training, etc.) to complete the EFWA project outlined above. The volume of this information, he says, is quite enough to begin the design and manufacturing immediately. He is seeking a manufacturer for the aircraft and is willing to negotiate terms. All rights and patents will belong to the manufacturer of the first flying sample, which sounds like a pretty good deal for the manufacturer willing to invest in this potential world's first. The inventor can be reached by mail at "To be called for", B. M. Doukarevitch, Main Post Office, Moscow Center, 101000 Russia.]