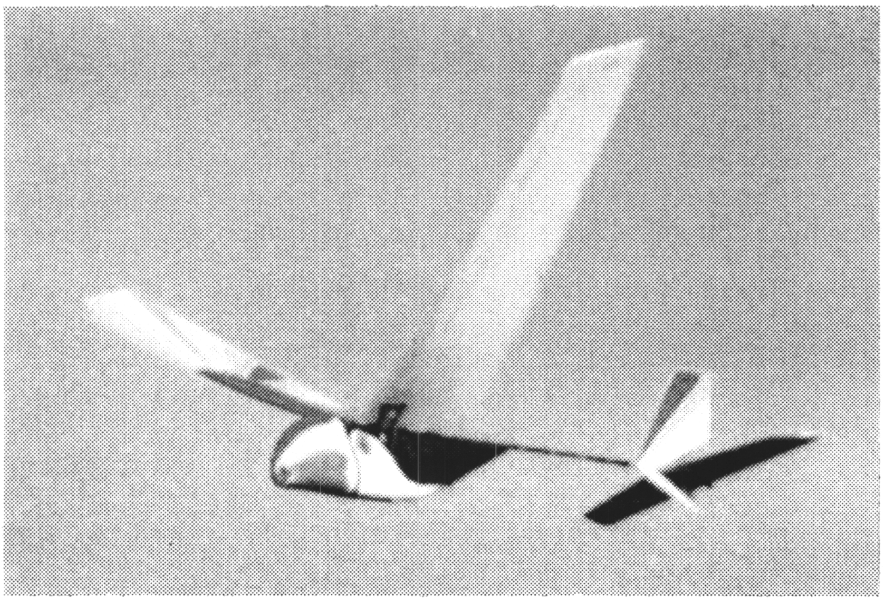
SPRING 1999

Flapping Wings

THE ORNITHOPTER SOCIETY NEWSLETTER



Albert Kempf's TrueFly electric RC ornithopter.

Il Vole en Battant

by Xavier Rémond

After ten years of reflection and observation, the young inventor Albert Kempf reproduces the magic of birds in flight using a glider that spans 1.66 m. A fantastic and unique first! Moreover the very simple mechanism enables one to imagine new possibilities. We are to meet on the edge of the highway, a stone's throw from Vaulx-en-Velin. Albert Kempf, a quiet man, quickly takes out his bird which is in the back of the car. "Here he is", he proudly says like a father showing off his first born.

The bird has a sparkly plumage, like something out of a childhood dream, but seems to unhappy with its wings hanging loosely down. His master holds the neck in one hand while adjusting some connections. "There, he's ready to fly!" This rural area is surrounded by woods and there is no breeze. The neighboring city of Lyon gives off a pale halo in the autumn sky and emits a low humming sound. I step away, afraid to see the creature suffer, and I wait.

Three steps, arm stretched toward the sky, and the toucan leaves the hand of the bird keeper in an upward curve, smoothly yet laboriously sweeping the air with multicolored wings. One holds his breath at the sight. The bird dips gently to fly over the place where it left from. Its body is straight like an arrow; its wings make a squawking noise, like a bird

RC Ornithoper Plans Available

Now, for the first time ever, plans are available for a successful, engine-powered RC ornithopter. Almost 40 years after it was flown, PH Spencer's Orniplane, the first RC ornithopter, is now the first RC ornithopter for which plans are available. Jack Stephenson, whose expertise in radio control and sail design helped make the Orniplane a success, is selling the actual size plans, which take up three, 36x48" pages. The cost is $40 including postage. For $8, he has a detailed article he wrote on the Orniplane, Spencer's test report, and suggestions for improving the design. Contact Jack Stephenson at 22 Hook Road, Gilford NH 03246. Allow several weeks for delivery.

Ornithopter Society Membership Info

To join the Ornithopter Society or renew your membership: Dues in the USA are $9 per year. Dues outside the USA are $14 US per year. Checks are payable to:

Industrial Evolution
PO Box 376
Arkville NY 12406 USA

Newsletter: Nathan Chronister, editor of *Flapping Wings*, invites you to submit material for the newsletter. Send items to Nathan Chronister at the address above, or E mail your articles to evolution@catskill.net.

OS on the web:
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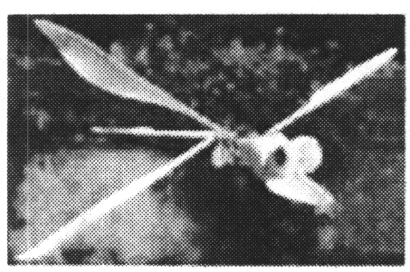
in heat. Only the cross-shaped appendage in place of its tail reveals its man-made origins. From time to time, he abruptly changes direction in a hazardous "wing-over" motion, then resumes his unrestrained race. At the third pass, he perks up again, rises up higher and flies towards the edge of the woods. Two nearby crows are enraged by the intruder encroaching on their territory. For a second, it's unsure whether the toucan will escape unscathed by his newfound friends. However, Albert calls the bird back to him. The bird obediently sweeps down to the ground. The beat of his wing slows. Afraid that the bird's batteries would give out without warning, the keeper directs him to climb one last time.

The approach for landing must be very smooth, as nature did not see fit to give him landing gear. The descent is uncertain, as he flaps intermittently, since this first prototype doesn't know how to glide. One would have to be able to block the wings in a slight upward angle, and that's planned for the next model. On three previous occasions, the wings became stuck in a slight downward angle, causing a series of tumbles, like a pheasant full of lead. But the bird is tough; his polystyrene fuselage takes the blows without complaint. On landing, his wings of depron scrape against the ground. Nothing serious, though. After a 2 minute 35 second flight that seemed to last an eternity, TrueFly (that's his name) is lying on the ground, ready to fly again.

We return to the workshop. We're in an house from the 1960s, in the suburbs of Lyon. The bike hangar serves as a laboratory. Our bionic bird hangs lifeless from a hook, like a Christmas turkey who's been cleaned out. His insides reveal a fragile mechanism, shaped and soldered like wrought iron. I was expecting high technology and sophisticated circuitry. It's almost too simple. The rods that move the wings are pushed by a double crank offset by a sliding part. Albert Kempf chuckles as he unveils his unique motor. It costs less than 50F ($8) retail and has an efficiency of only 64%. I'm speechless. Leonardo could have almost made this mechanism in the 16th century. But then why has no one else come up with this design? "Established thought. People get stuck in theories! I wanted to make it simple, with the minimum amount of parts."

While the bird's nicad batteries recharge, the professor takes me to his living room. The prototypes of the bird hang from his ceiling, illustrating the countless hours of thought that have gone into the finished product. Albert Kempf can't help himself from building and tinkering each time he gets into a new field. He was even awarded a silver medal at the 1992 inventors convention in Geneva for a system of waterproof bags.



This mania probably comes from his childhood in Africa. He was born in Bangui in the Central African republic, then lived in the Congo until the age of 17. Over there one learns to do a lot with very little. At age 11, he built his first glider, and at 14 he did circular flights. In 1989, he contemplates motorizing his hang glider, but since the concept is unconventional, he decides to try it out on a reduced model. It's then that he finds the book by Jean Ponca, *Manifeste en Faveur du Vol Humain,* and he builds the first little model with flapping wings in 1990. The mechanism employs a rubber band (like the toy pigeons), but gives mixed results. "I tried everything, but it didn't really work." In 1997, he finds himself out of a job (like everyone) and takes advantage of it to further his studies on the flight of birds. "Birds control at every moment the angle of their wings, which necessitated a certain amount of rigidity in the turning. I started to have good results when I combined the upward motion of the wings with a positive twisting motion."

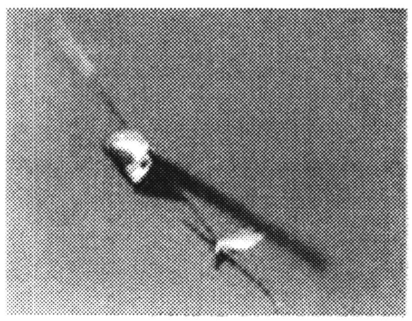
TrueFly makes its first test flights in April of 1998 and accomplishes its first successful controlled flight on May 3rd: more than a minute long with altitude. It's made 15 to 20 more flights of more than two minutes in length and 600 mA of energy. Without optimization, the output is as good as with a propeller. Since he could not find a reducer adapted to his needs, Albert cut the gears himself. For the time being it works well, despite a few problems during the landing. Kempf has presented his machine in several model conventions, each time getting rave reviews. The producers he's shown his creation to are mesmerized, yet perplexed by this inclassable object.

Meanwhile, Albert plans to create a new mechanism that's even more efficient and comes closer to the ideal movement. He's already working on the next model: very simple and lightweight, made completely of polystyrene foam, having reinforced rods, enhanced control, and a tail that more closely resembles a bird's. At the end of our conversation, Albert Kempf admits almost timidly that he imagines the possibility of making a wing propelled by a pilot, assisted or not by an electric motor. Albert Kempf doesn't believe that scale penalizes performance. "On the contrary! One observes that a reduced model doesn't fly as well as the original." The debate remains open, and will likely continue to fuel many discussions. Another encouraging element is the behavior of TrueFly in turbulence, as he absorbs the shaking by adapting the wing twist continuously.

Albert Kempf should be credited for the tangible results he has brought. He holds a commercially viable product that has what it takes to seduce any enterprising company. This process is likely to meet much skepticism, as with all great technological breakthroughs. The problem is to know whether France will know how to harness this discovery.

To better understand the principle that allowed Albert Kempf to arrive at a tangible result, let's follow his reasoning through some key observations. To analyze the flapping flight of birds, one has to consider one phase of stabilized flight. The majority of nice photos of birds in flight are taken during takeoff or landing, which are both transitory phases, difficult to analyze. Bats, insects, and pterodactyls fly just as easily as birds with feathers, independent of their weight. Therefore one must not look for the secret of flapping flight in feathers or their so-called rotational effect.

When the bird flies, its body follows a smooth trajectory, without jerking upward when its wings go down, or plunging when they go back up. One can assume that the lift remains constant regardless of the position of the wings. The energy expended by the bird to make its wings go down is transformed into propulsion, which give the animal its speed. This energy creates an aerodynamic flow like any glider, regardless of whether its wings move. During the period in which the wings are raised, the bird continues forward. To compensate for the lower pressure, he increases the angle of the wings. This in turn increases the air friction; raising the wings tends to slow the bird down.



In flight, the speed due to forward motion is the same along the whole span of the wings. However, the vertical speed due to flapping is null near the base and increases progressively toward the tip. These two speeds combine, creating a varying angle of attack, depending on which portion of the wing is being studied: horizontal at the base, and more and more vertical going out toward the tip. But a wing profile does not tolerate more than a minimal variation of its angle of incidence. Consequently, the bird adapts its wing twisting motion to keep the angle of incidence pretty much constant. That translates into a negative twisting motion of the wings as they descend and a positive twisting motion as they ascend. The pressure, having a perpendicular direction as compared to the wing, will pull the wing forward during the descent, in the same way that a helicopter rotor tilts forward and propels the helicopter forward. It is indeed the flapping associated with a judicious twisting motion that propels the bird and permits it to fly.

A bird generally doesn't use its tail during the straight portion of its flight; it is folded most of the time. One has seen that in one flapping cycle, birds create an acceleration (downstroke) and a deceleration (upstroke). Following the concept that these forces are exerted above and below the middle line, they create an alternating pitching up and pitching down motion of the plane. The bird compensates by constantly shifting its center of pressure compared to its center of balance, meaning by shifting its wings forward and then backward. The vertical and horizontal movements come together to form a figure 8 movement.

TrueFly stats: Span, 1.66 m. Weight, 1.325 kg. Wing loading, 40 g/dm². Frequency: 2.7 to 3 flaps/sec, 60°. Albert Kempf: truefly.kempf @wanadoo.fr. [Translated from *Aérial* (#8) by Roland Gauthier.]

Watercraft

Reuben Hoggett writes: " In tracing back my first interests in ornithopters, it was probably due to the movie *Gizmo* which features many early ornithopters and the particular watercraft Roy Clough described in the last issue. *Gizmo* is basically a collection of early newsreels. I have a taped copy which is starting to degrade and has 15 minutes missing due to a recording error (trying to edit out ads!). However, you may be able to find it locally. It is from High Wire Productions, produced and directed by Howard Smith."

"Some other useful references:
1. *Wasn't the Future Wonderful* by Tim Onosko contains reprint articles from science mags, has an article on page 140 about a model whale-sub.
2. Ettiene-Jules Marey's book, *Animal Mechanism,* contains articles on marine motion."

Jet Ornithopter and Combustion Actuator

by Scott Leatham

I'd like to build a jet-powered dragonfly-style ornithopter (wing span about 4 feet) with a computer-controlled trim and flight system (using a BASIC programable robotics chip). This model would fly with its wings, not with propulsion from the jet directly. The jet turbine will weigh 4 pounds and produce 14 lbs of thrust (enough to push a 12 pound plane about 100 kph). Exhaust from the engine would be used to power the actuators. Another possibility is gasoline-powered actuators — ever see a gasoline powered pogo-stick? I'd like to make it look like a huge prehistoric insect that actually flies. I'm hoping I can make it sustain flight, and fly forward as well as backward.

There's a good chance I may have to write a self-learning genetic program (not AI or neural) to produce the optimal BASIC flight program for the model. In my humble opinion, genetically derived programs are better for emulation of natural processes than AI or computer neuron systems which learn on-the-fly (pun intended). It's really simple; a program created using genetic techniques is really just a formula that's derived from a database of simple primitive functions: AND, OR, GETDATA, DECIDE, PUTDATA, SIN, COS, etc. A rule is applied to each generation (randomly selected combinations) of primitives. The formulas that perform the best are applied to the next generation of randomly selected functions and so on. Eventually you get a formula that does the task that you want it to do. You can convert the final formula into a BASIC program for the robotic controller chip or even use the BASIC commands as the functions themselves in the genetic process — it's very strange, but fun!

The gas actuator is kind of like a 2-cycle motor. It's a cylinder with a spring-loaded piston and shaft. The resting position for the piston is in the up position. Premixed fuel is pushed through a tube to a one-way (check) valve, then an electro-valve is opened to let the fuel mixture into the combustion chamber just above the piston. Fuel is ignited via an electrode; the piston is pushed by expanding gases until an exhaust port is uncovered, which releases the remaining gas. As the piston moves, the actuator shaft is extended. Once the gas is released, the spring recoils the piston back to top-dead-center. Recoiling is often slow, so sometimes a pressure relief electro-valve is used. This also eliminates the need for the exhaust valve at the bottom of the cylinder. Valve timing controls thrust, stroke, attack, and decay. A locking device at the bottom of the cylinder can hold the actuator in the locked open position if desired. These devices are very lightweight and very powerful, but tricky to work with. The up-side is amazing however.

The simple pogo stick type could enable an adult person to jump as far as 21 feet during a competition years ago. The smallest one I built was a little over 1/4 inch in diameter and 2.5 inches long with a stroke of a little under 1 inch. Larger ones (for walking devices) measure 1.5 to 3 inches in diameter and about 10 inches long. Valve timing was all manual using microswitch triggers on a control panel. My goal was to build a gasoline-powered horse.

Fuel can be fed in the same way as a traditional model airplane engine (via carb or venturi). The first one I made could idle at 15 SPM (strokes per minute) using human manual timing with a hand-held trigger switch. It could speed up to well over 3000 SPM with mechanical timing and varying the fuel. Mechanical-timed idle with the throttle nearly closed was about 100 SPM; after that there wasn't enough vac to draw in fuel. Manual timing works at 15 SPM because the throttle is all the way open; essentially the engine is restarting every 4 seconds. Duration could be longer if I can reduce pressure loss while the engine is stopped.

After about 3000 SPM, the PRS (piston return spring) would "float" due to harmonics. However with progressive spring coils (multiple levels of harmonics) I think that 5000 to 6000 SPMs could be sustained. One other big issue is heat. If the PRS or PSS (piston shock spring at the top of the piston) gets too hot, then the spring fails, which can lead to cylinder breaking. At one point I had to replace the PRS (my early design had no PSS) every time I used the ICA (internal combustion actuator). Adding heat sinks slowed this process down. Note: The stroke of the ICA varies with throttle position. So by timing and throttle and using a computer you could get many different bird-like dynamics, such as long, powerful take-off strokes, or short, fast strokes for minor ATMs (altitude translation maneuvers). Short, slow strokes for sustained flight and soaring (I don't have an acronym for this) are possible as well. All this without having to hassle with gear reduction of crank-shaft based motors.

One item about springs, it's possible to use an "air spring" instead of a steel spring. This would eliminate the heating issues and could actually be used for control. The air spring is a small cylinder and piston connected to the crank-strut of the ICA. One big problem is how to start the system running. In an early design, the plane would just flap it wings — you toss it and it flies. If I use air springs, then perhaps I could start the engine with compressed air from an external source!

Manned Ornithopter

Tony Baker writes: "I am drafting a realistic plan to build a manned, 20 HP Ornithopter — a foot-launched machine. I would like to recruit a team of interested people from within OS who have the talent and motivation to help me fulfill this plan. It should be profitable for all involved. I am not ready to reveal my plans publicly yet, but I'm interested in talking to members from OS about the feasibility of such a project." Contact Tony Baker, 2646 E 5 Place, Tulsa, OK 74104.

Freebird 2 Record

The popular, easy-to-build Freebird 2 ornithopter was never intended for duration. Akihiro Danjo, however, had an interesting experience with his: "I have built two and both flew very well. When I flew one on a windy day, it was nearly out of sight without thermals. It did over 1 minute. I built an indoor ornithopter, too. At 1.5 grams, it flew 6 minutes in a Cat. 1 site.

Modified Servos

Servos are a wonderfully convenient, ready-made motor, gearbox, and crank — but we've found that they simply don't have enough power for flapping a pair of wings. Or do they? We could save a lot of weight by dispensing with the rest of the radio. A servo can be modified to run continuously when hooked up to a small nicad pack. The all-up weight of only 30 grams or so would result in a much better power-to-weight ratio. In about an hour, I modified a standard servo to operate as a mini ornithopter gear box. Unfortunately, it ran at about 1 flap per second, and that's much too slow. Tower Hobbies sells a $23 "TS-35 Power Mini Servo" that has more torque (55oz-in @ 4.8V), faster action (60°/0.14s), and less weight (0.95oz) than the one I converted. If it can be modified for continuous running (not all servos can), it just might work. I hope someone will give this a try.

University Contest

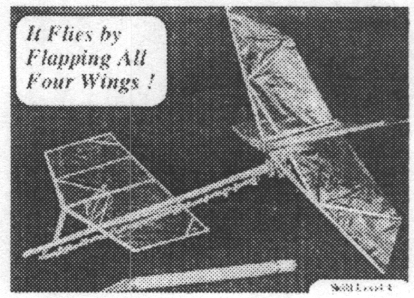
Reuben Hoggett sent pictures from an ornithopter contest for students at Royal Melbourne Institute of Technology. It took place in 1976, so it's old news, right? Maybe, but I think it's interesting to see the ideas people come up with. Like the Australian-style paperclip that accompanied Hoggett's letter, independent solutions to the problem of flapping flight turn up clever approaches, and sometimes they even work. Some of the ornithopters made it to the target 30 meters away. An ornithopter with vertical wing folding and stretched rubber is shown. The photocopies I got are difficult to interpret, but they show a biplane and another monoplane, both with unusual mechanisms.

Useful Materials

Bamboo ballon sticks, 24x3/16", item #20/21 from Oriental Trading Company, tapered with razor plane, make good wing spars. $6 for 144. Call (800) 228-2269. Stealth helical planetary gearhead PS-40, $800 from Bayside Motion, (516) 484-5353, is perfect for 05-class motors. Giant condoms, 8.5 cm diameter, 10 grams, are wing covering for torsionally flexible airfoils. Sold in novelty stores.

New Kit Makes Debut

Recently I received a small envelope from Karl Brown, whose company, Frontroom Flyables, sells the new Flutterby ornithopter kit. Brown's design is nothing like Indoor Model Supply's Flapping Flyer. The new kit is a tiny canard biplane whose 28 cm span allows it to be flown in your living room! The weight is under 3 grams.



The kit includes a pre-bent and very accurate wire crankshaft. You will have to cut your own aluminum and sheet balsa parts, but both materials are accurately printed. The plans are detailed and thoroughly explained. Thanks to its canard biplane design and light weight, this ornithopter should put in really good flight times (once it gets beyond my frontroom). The model is less temperamental than the tailheavy Flapping Flyer. I like the flight performance despite the non-birlike appearance. Says Brown, "I do not view the Flutterby as a device which imitates a bird, but rather just a novel flying machine", which it is.

Brown says "The kit is for experienced builders only. It requires about 10 hours to build, a fine eye for small parts, and (here is where most strong men pale) the ability to read and follow instructions." If you're up to the challenge, you can order the new kit for $15, plus $3 for shipping, in US dollars, from Frontroom Flyables, 861 E 20 Ave, Vancouver BC, V5V 1N4 Canada.

A Man-Dragonfly

by Jury Egorov

In 1987 there was a local aviation show in Moscow. Vladimir Toporov demonstrated a full-size flapping wing aircraft named Istina (the truth) which had a motorcycle engine. The vehicle ran along the Tushino airfield runway, raised its nose, but did not fly. The designer promised to show an improved model that would fly.

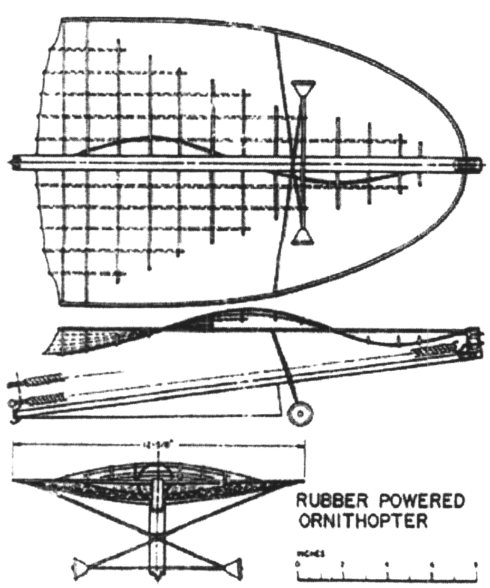
Two years later, at Riga ultralight aircraft show, Toporov demonstrated a good-looking FWA model with a model airplane engine that weighed 7 kg. The hand-launched model climbed up to 50 m and fluttered until running out of gas. We do not understand why the Toporov model at Riga did not became a world-wide sensation. The model largely exceeded other models the Western press told about. An almost 5 minute long flight was registered . This tandem model had close-placed wings and a classic empennage. The MKD-0.25 motor was strong enough to fly the 3 m span model at 32 km/hr. The power loading was 24 kg/hp — fantastic! The model had devices for auto-twisting of wingtips due to aerodynamic forces.

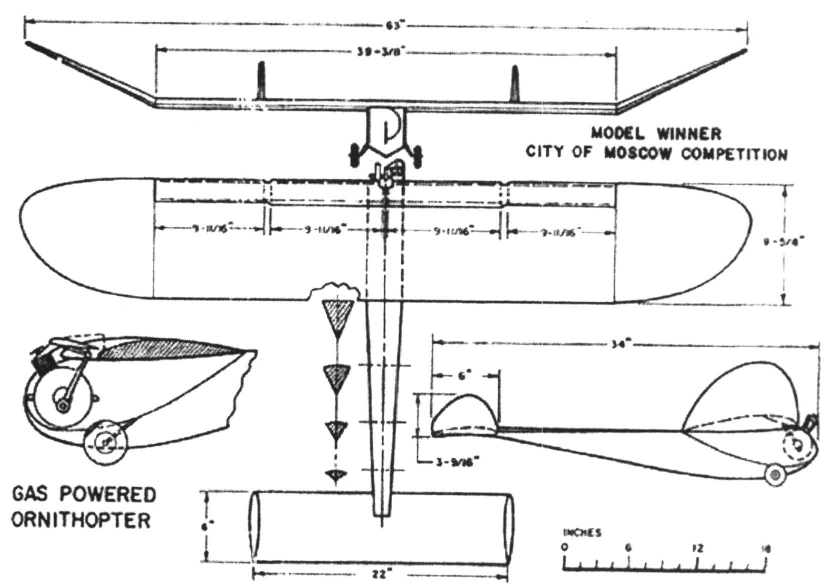
Not long ago there was a call: Toporov from the town of Votkinsk here. The aircraft is ready and fight tested. Two days later I admired the beautiful tiny town with a sapphire lake in the middle. It is the birthplace of Pyotr Chaikovsky. Marvelous landscapes gave inspiration to the great composer. But nowadays there is a factory that produces up-to-date medium-range missiles, the subject of envy of foreign engineers. The club Scarlet Sails, which Toporov is chief of, was under patronage of the factory, and Toporov worked as a designer there. In summertime the club moved to the country, where Toporov and his 12 assistants built a camp. The life combined the pleasant and the useful, but testing the FWA was the main occupation. Taxiing along the runway (unused highway), improvements, runs again and again. I spent 4 days here with the boys. They were from 11 to 16, and each was the Jack of all trades. Flights were festivals for them.

On a sunny, calm morning, we transported the aircraft from the hangar to the nearby field. The pilot was Toporov himself. All the rest ensured a takeoff run using a winch. The pilot operates the wings. The speed increases and after a short run the aircraft flies up. Toporov does his best, vigorously flapping the wings. For some time the aircraft climbs, but his powers are limited. After 100-200 meters of flight, there is a smooth landing on the edge of the field. It is a victory! But Toporov seems not very pleased. These low half-flights, he says, are the very beginning: "I feel with my backbone that we can get rid of the tow winch, and I know how. My team is very good." Before my departure, Vladimir changed the tail structure from box-like to classical rudder and elevator and made a certain twisting of wings ends to make them work as ailerons. Wish you luck, chief designer! I will wait for your call.

The construction reminds one of a usual plane. Gross weight is 60 kg. Longerons and bars were made of very thin aluminum tubes, stringers and ribs of bamboo. Very thin fabric and films were used. There is an original device for auto change of wingtip incidence. Toporov's ornithopter was built by mere inspiration, without any calculations, finished by trial and error, in a small club with zero financing. [From *Tecknika Molodejy,* translated by Boris Doukarevitch.]

Samples from a Russian book, Models With Swinging Wings, courtesy of David Dodge.





Rotopter

by Vladimir Savov

In 1996 I was reading lectures on aerodynamics to helicopter pilot students. Trying to explain the phenomenon of autorotation, I used one of my daughter's toys: a windmill made of a paper square, pinned to a stick. Under certain conditions, moving the stick up and down, it is possible to make the windmill to rotate in one direction only. This is not a trivial result and perfectly well illustrates the essence of autorotation. And then it struck me that the very same effect could be achieved not by reciprocal motion of the whole propeller, but through flapping movement of the rotor blades. A laboratory model was made in order to test the idea (see photo), and immediately the name of this conception was forged. The choice was obvious: rotopter, from "rotor" and "ornithopter").

So, the initial idea of the Rotopter was simple: to replace the progressive motion of a flapping wing with rotation around the vertical axis. As known from the flapping wing aerodynamics, thrust comes mainly from the downstroke. Designing a link mechanism that drives the wing (blade) in flapping movement and enables free rotation around the vertical axis was not difficult. Much more challenging was creating a device that allows variation of the wing incidence angle. Two designs were tried. The first, a kinematic chain similar to the wobble plate of the helicopter rotor, did not work properly due to the existence of a dead point. The second one is more simple; the blade turns around an axial hinge under the influence of inertial, elastic, and aerodynamic moments. This method gave more promising results.

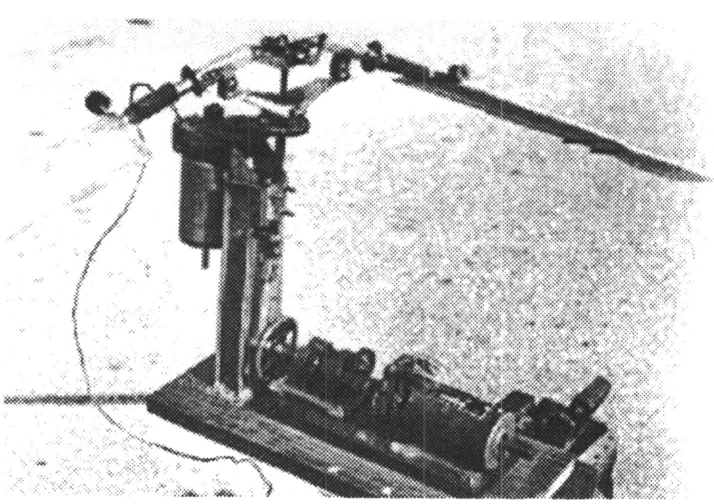
The rotopter may have some advantages over a helicopter rotor and an ornithopter wing: Unlike the helicopter, there is no torque reaction. Velocity triangles in different cross sections along the rotopter blade are geometrically similar, hence there is no need to twist the blade, like the wing of an ornithopter. This simplifies the problem of finding the best incidence angle. Induced power losses may be lower compared to the helicopter due to the unsteady flow.

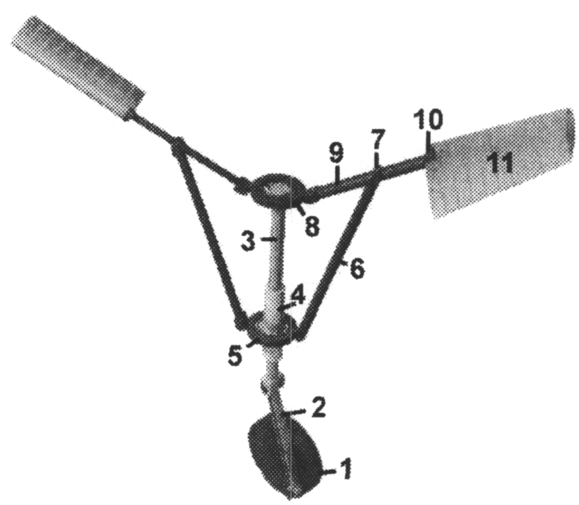
Experiments with the laboratory model demonstrated that the concept of the rotopter works — the blades rotate and create lift force. It was also ascertained that the efficiency of the rotopter is sensitive to the blade angle of incidence. At the current stage, achieved coefficient of efficiency of the rotopter is half the usual for a conventional helicopter rotor. If a numerical model of the flow around the rotopter blade is developed and the motion of the blade is optimised, the efficiency of the rotopter will improve.

At this stage of developing the rotopter, the core problem is controlling the incidence angle. Problems at later stages will include increased magnitude of the Coriolis force in comparison with the helicopter blade, unfavorable load distribution along the blade unlike the helicopter blade, the aerodynamics of the rotopter outside hovering or vertical flight, and the method of controlling the lift force magnitude and direction.

As far as I know, the rotopter concept is new. All my aerodynamic intuition tells me that there is some potential in the idea. On the other hand, there are a lot of obstacles, and any one of them could prevent the development of a full-size rotopter. I intend to find out which exactly.

Rotopter: 1, crank. 2, connecting rod. 3, slider. 4, bushing. 5, bilateral thrust rolling bearing enables free rotation of blades around vertical axis. 6, link, together with 9 converts slider motion to flapping. 7, horizontal hinge. 8, bearing enables free rotation of blades around vertical axis. 9, link, together with 6 converts slider motion to flapping. 10, axial hinge allows incidence to vary. 11, blade.





Member Directory Survey

If you wish to be included in the OS Member Directory, please complete this survey and mail it to Tony Baker, 2646 East 5 Place, Tulsa OK 74104 USA, or complete the survey online at www.catskill.net/evolution/flight/osform.html.

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Accomplishments:

Current interests or projects:

Publications. Please list books or articles you have written, or that have been written about your work, with page numbers and issue dates.

Plans and info. Please describe any plans, data, photos, etc. that you are willing to give or sell to other members.

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