# Flapper Facts

Newsletter of the Ornithopter Modelers' Society

Issue #12 — Fall 1995

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**How to Join OMS:** If you are reading someone else's copy of Flapper Facts and want your own membership, you can join now by sending $9 ($14 outside the US) to the address above. Payment should be made to "Nathan Chronister."

## Survey Results

Nathan Chronister

I would like to thank everyone who sent me their survey cards from Issue #10. Your suggestions were very helpful.

Concerning newsletter content, the opinions were equally divided between those who would like to see other unconventional model types in the newsletter, and those who think *Flapper Facts* should be for ornithopters only. Among those who favored the inclusion of other models, there was an even split between those favoring unconventional rotary models and those favoring surface craft with oscillatory propulsion. About half the people sided with one or the other of these categories; the other half wanted to include both.

Due to the ambiguous results of this survey question, I will include some material on non-ornithopter topics, but will do so only on a very limited basis. Most of what I do include will pertain to flapping fin water craft, because that is what I have the most material on, and because this topic is in keeping with the title, *Flapper Facts*. However, I welcome any reproducible material on other unusual models.

### OMS Member Survey

**Number of votes in parentheses. Number of replies = 40**

**What should be included in *Flapper Facts*?**

| | |
|---|---|
| **Walking machines (12)** | **Autogyros (13)** |
| **Flapping-fin water craft (14)** | **Indoor helicopters (13)** |
| ***Only* ornithopters (20)** | **Other (7)** |

**Ornithopters plus anything else (20)**

**AMA ornithopter event should allow only:**

A. Models which derive most of their lift from flapping wings. (16)
B. Any model propelled by flapping wings or fins, *even if* most of the lift is provided by a fixed wing. (4)
C. Any model propelled by flapping wings or fins, *even if* most of the lift is provided by a fixed wing, as long as the area of the fixed wing is relatively small. This option includes the current rules. If you chose option "C," do you prefer: (8)
  Keeping the current rules. (2)
  Adopting a simplified version with fewer restrictions. (4)
D. Other. (9)

The AMA rules vote was fortunately more decisive. Most of the members favor the proposal in which most of the ornithopter's lift must be provided by the flapping wings. Half as many preferred the limited area rule. Several replies suggested possibilities other than the above, nearly all of which involved two separate categories, one similar to A and one similar to C.

Now that we know what kind of rule is desired, all we have to do is make sure our proposal is practical and effective before submitting it to the AMA. We want to make sure this is done right, so discussion of the proposal will be encouraged at every step. The latest draft along with some points of lingering debate is found in this issue. Please read it and give some feedback. Let us know of any problems with the rule and improvements that would fix those problems.

## Contest Winners

The only documented flight of a folding wing ornithopter was submitted by Robert Eskridge, who constructed a modified version of the Flapping Flyer kit (from Indoor Model Supply) with a jointed wing spar. The longest reported flight time for this model is 25 seconds, and it folded its wings on the upstroke to about 70% of their downstroke span.

The first place winner in the design category, chosen by your votes, was Georges Chaulet. His entries used a transverse crank to drive circular flapping of the wings. The second place winner in this category was T. R. Quermann.

His several entries showed a variety of approaches to span variation.

Thank you for your participation, both in the contest itself, and in helping to choose the winners. All of the designs were excellent, and some of the cards I received said that everyone should win! The list of contestants follows:

| | |
|---|---|
| A | Barry Evans (2 votes) |
| B | Georges Chaulet (6) |
| C | Georges Chaulet (5) |
| D | Lee Onishuk (0) |
| E | Dan Garfinkel (4) |
| F | Sid Davidson (3) |
| G | T. R. Quermann (0) |
| H | T. R. Quermann (3) |
| I | T. R. Quermann (4) |
| J | T. R. Quermann (3) |
| K | John White (3) |
| L | James DeLaurier (1) |

## AMA Rules Proposal

Here is the latest draft of the ornithopter rules proposal some of us have been working on. Please consider issues such as practicality and effectiveness of the rule: Is it reasonable to expect a contest director to interpret and enforce the rule, and will it in fact exclude the models it is intended to exclude without excluding others as well? If you see any problems, please give us your constructive suggestions for how the rule might be improved.

"An ornithopter model derives its chief support and sole propulsion from flapping wings. All wings shall be substantially identical in degree and rate of flapping motion. The model may have a maximum of one fixed horizontal surface or V-tail (the stabilizer), which shall be placed at the extreme front or rear of the model. When measured parallel to the flight path with each wing in its mid-downstroke position, no points on the wing and stabilizer may be longitudinally coincident, and the center of gravity shall be located less than 1/3 (2/5 for canards) the distance from the point on the wing(s) farthest from the stabilizer, to the point on the stabilizer nearest the wing(s). Takeoff gear is not required. Twenty seconds will define an official flight."

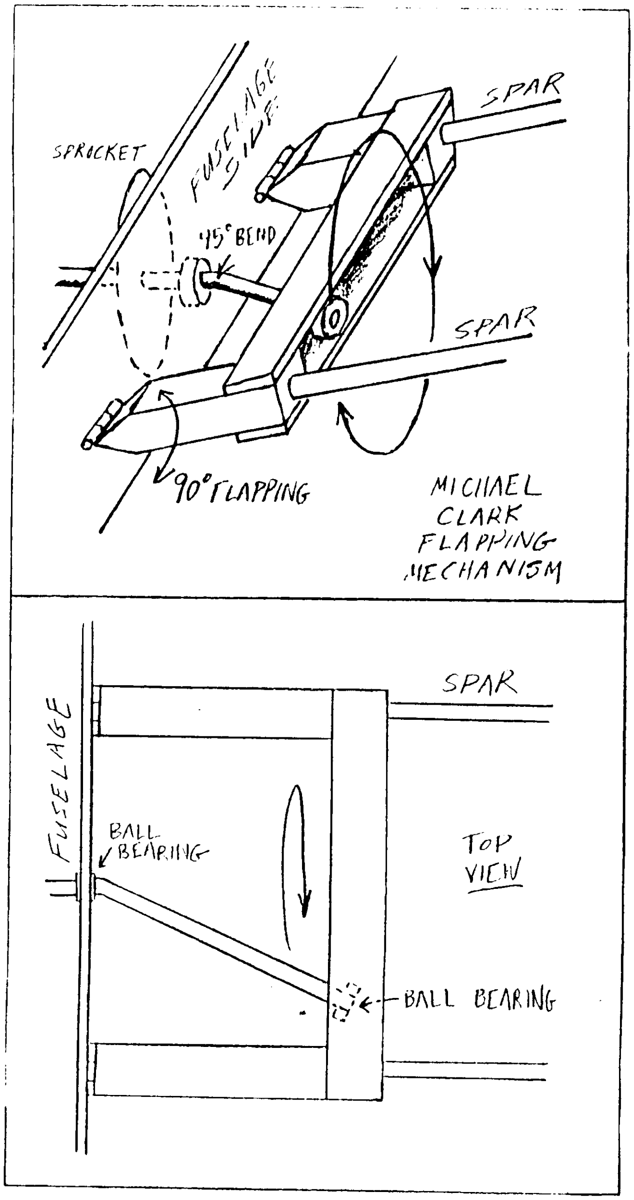
T. R Quermann believes that a small, fixed lifting area should be allowed in addition to the stabilizer. This could be located near the center of gravity (for example, in the center section) and would be limited to 10% of the wing area. Since, according to Quermann's own estimate, flapping wings produce only a third as much lift as fixed wings, this 10% area would contribute 25% of the total wing lift and, if the tail contributes 1/3 of the model's lift, 7/16 of the total model lift will come from fixed supporting surfaces. For these reasons, I would prefer not to allow a fixed center section.

Quermann wants to allow fixed center sections in order to permit the use of some traditional designs, but it is very simple to convert these designs to the new rules simply by not covering the center section. He also suggested that the rule as stated above might prevent the use of cowlings to reduce drag.

## Scotch Yoke Michael Clark

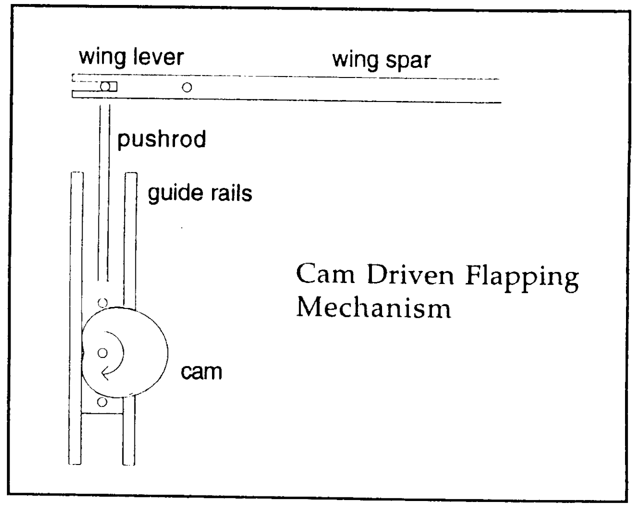
Here is a rough sketch of the drive system I used in my electric thopter. For clarity I show only the right side. It is a form of scotch yoke. It handled well over 35 pound feet of torque and was very reliable, surviving many tests and severe crashes. The motor was in the 50 to 100 watt range, using 7 to 12 volts. It drove a three stage planetary gear box that I salvaged from an old copier. The final stage was a 1/4 inch pitch chain drive. The large sprocket was 4 inches in diameter and is shown in the drawing. Construction is mainly pine with fiberglass reinforcing the joints. The drive shaft is 1/4 inch steel, the ball bearings are set in 1/8 inch aluminum. Spars are 1/2 inch fiberglass. The action was very powerful and smooth with none of the sudden jerk that occurs with other systems when the crank goes "over the top". [ed. That may be because it's an electric system.]

I want to stick with single surface wings for the sake of simplicity. Thick airfoils have the leading edge suction advantage; however, any such airfoil will pay the price of higher drag. I want to try borrowing from the owl's barbed feather vortex generator to get the same advantage [high lift over a wider range of angles of attack] with a thin airfoil. [Clark says his electric ornithopter is too heavy to fly. He has also built a much lighter pneumatically powered ornithopter using a 2 liter pop bottle and landing gear retracts. It nearly sustains flight.]




# Cam Driven Flapping

Bill Saunders sent in a working mockup of a new flapping mechanism he designed. Although he hasn't had any great results from this mechanism in flying models, I think its potential benefits make it worthy of mention. The use of a cam to drive the flapping allows the flapping motion of electric powered ornithopter to be tailored to any need one might have, for example the flapping may be sinusoidal or sawtoothed depending on the wishes of the builder. For rubber powered models, the cam mechanism allows energy to be allocated differently to different parts of the flapping cycle. For example, rather than wasting a lot of energy when the wing direction is reversing between strokes, when a crank would be snapping past the dead center position, the cam can be shaped so that less unwinding of the motor can occur during the wing turnaround. Saunders used a heart shaped cam for this purpose. You could use a different shape to concentrate energy in the downstroke.




Cam Driven Flapping Mechanism

# Reduction Without Gears

For gas powered ornithopters, Larry Burks has proposed a system which would eliminate the need for gears. This would make it much easier to build a gas powered ornithopter, if the system works. Preliminary testing has been successful, but the device has not yet been used in an ornithopter.

Burks suggests using the engine to drive a bolt and using the rotation of this bolt to drive a nut. The nut would be driven at a slow speed with sufficient force to drive the wing flapping, and no gears or crank would be needed. The traveling nut could be securely embedded in a plywood plate, which would be linked directly to the wings.

For the return stroke, Burks plans to reverse the direction of the engine. In his experience with Cox reed valve engines, he has often had them stop and run backwards when interrupted by an object in the path of the

# Engine Reversing Mechanisms for Cox Reed Valve Engines

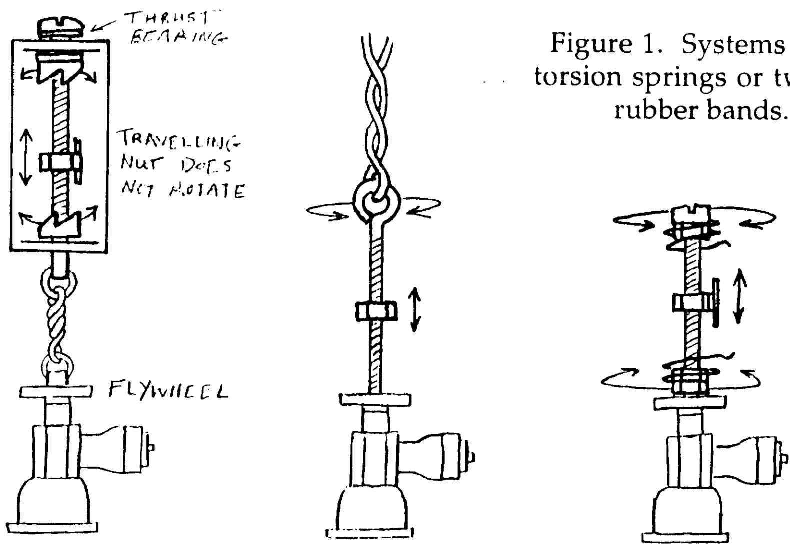



Figure 1. Systems with torsion springs or twisted rubber bands.

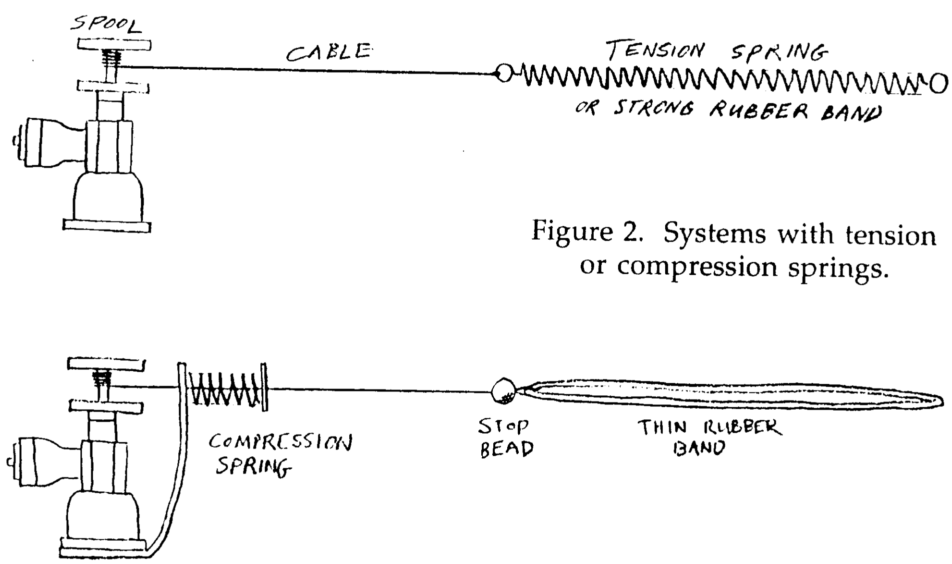



Figure 2. Systems with tension or compression springs.

propeller (hopefully not his finger), and the ability of these engines to run backward without modification is widely known. The question is, will this happen reliably, several times a second, when the engine has little time to run before being reversed again?

Figure 1A shows the design as originally proposed, in which the engine direction is reversed by stops at either end of the nut's travel. Notice that the stops operate without allowing the nut to tighten against them. A short rubber band interposed between the engine and the bolt then restarts the engine, and after this is accomplished, the nut begins moving in the other direction.

A second alternative is my own version of Larry's idea. In this version, energy is stored by a long rubber band throughout the last half of each stroke, and is then released at the end of the stroke, helping to restart the engine and contributing power during the first half of the subsequent stroke. One advantage is that the wings reverse their direction as soon as the engine does. However, Larry pointed out that the more gradual reversal of engine direction in this design might be disadvantageous.

He then suggested a third variant, in which the bolt is attached directly to the engine, but the reversal is accomplished suddenly by springs at the end of the nut's travel. Experimentation will tell whether the quick reversal or slow reversal is more effective.

Burks tested the ability of the engine to reverse directions when attached to a rubber band as in figure 1B. Instead of a bolt and nut, the load was provided by an ordinary propeller. A flywheel was used, and seven #64 rubber bands were attached to the propeller. The engine reversed successfully, and according to Burks it seemed to be running in its normal power and speed range. After about 20 cycles, however, the rubber bands were cut through by rubbing on the propeller, and when they broke, the engine stopped reversing. Another problem was that the rubber band swung outward due to centrifugal force. Burks did not indicate the operating frequency of the system he tested, but presumably this could be adjusted by changing the length and thickness of the rubber band.

Fortunately, both of the above problems could be solved by using a steel spring instead of rubber, or by using a linear arrangement, in which the rubber band or spring does not rotate. Figure 2 depicts two such devices. The first of these uses a stretched rubber band or spring, attached to a spool so that it can exert a rotational force on the engine output shaft. As the motor runs, the cable is would onto the spool. This stretches the rubber band until the engine stops, at which point the rubber band restarts the engine in the opposite direction.

In a system such as this, the effective gear ratio is determined by the number of turns of the bolt per engine cycle, and the cable length and spool diameter should take this into account. For a reduction of 60:1, the bolt will turn 30 times per stroke. Since the cable is totally unwound (unless you are trying to balance the force of lift on the wings) about half way through the stroke, the cable length will be 15 times the spool circumference.

The QN replica created by Paul MacCready and Aerovironment used a similar system with electric motors. Two 1000 watt model airplane motors (Astro Cobalt 60s or something similar) were controlled electronically so that power to the motors was reversed at the end of each stroke. Momentum of the rotating parts, especially great in an electric system, was stored in a stretched rubber band. The rubber band was attached to a cable, which was wound around a spool to exert torque on the rotating system. The rubber band also balanced the force of lift on the wings. QN had a low-friction ball screw to convert the rotation to linear motion for flapping the wings. The QN model was very heavy and did not sustain altitude, but it was quite able to flap its huge, 5.5 meter wingspan.

The second design in figure 2 is intended to provide a more rapid reversal of engine speed. Thus, the rubber band serves mainly to take up the slack in the cable, while a compression spring reverses the engine when the cable is wound in to a certain point.

The bolt and nut arrangement will have a lot of friction, but this system will be much lighter than gears. The early tests show promise, and this idea is bound to tempt anyone who has taken on the frustrating task of building an ornithopter gearbox.

# Letter from Horst Handler
Translated by Dora Czike

14 February 1995

Dear Mr. Chronister,

As an enthusiastic and long-time subscriber to your magazine, I would like to send you some pictures of the model airplane I have assembled up to this point.

You may use the pictures at your own discretion.

It is only a small part of my over 30 years' work in this field.

Despite my age (71) I still occupy myself with this problem, and have already had a few successes with the models.

I now use mainly electric power. The bigger models are all equipped with it.

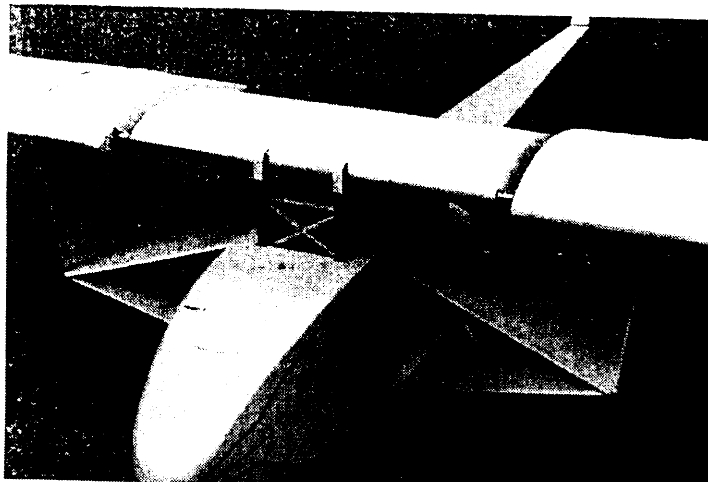
Two years ago I also built a reproduction of Professor DeLaurier's model. The power is a cobalt-Somarium electric engine. The smaller models are reproductions by Prof. v. Holst from the 1940's. The power consists of a very cleverly devised rubber engine energy storehouse.

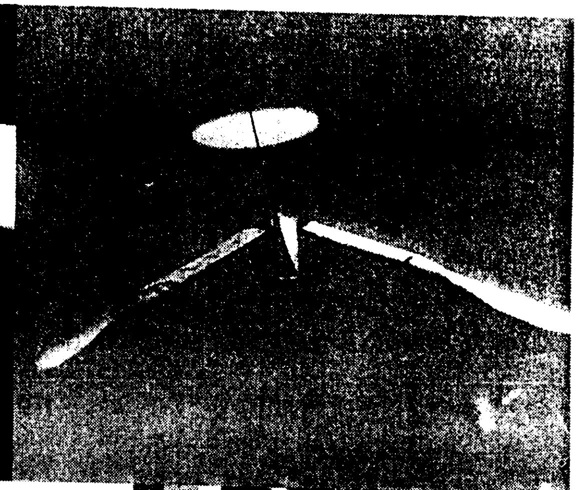
You will surely be able to understand by looking at the pictures. If not, I could give you more detailed information if needed.

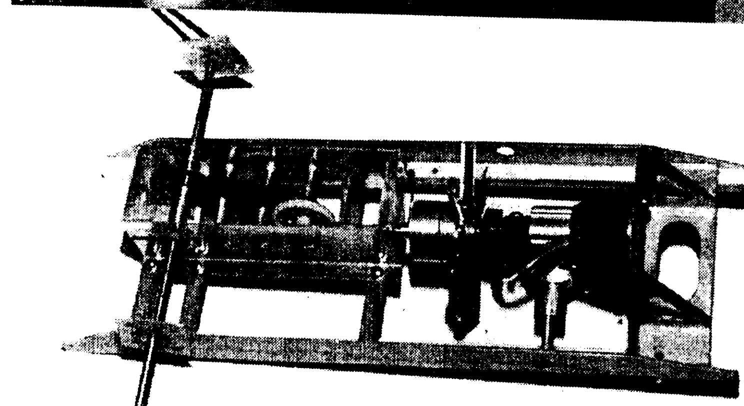
Incidentally, I have been friends with Mr. Räbiger for a long time and we have worked together.

Unfortunately my English is so poor that I couldn't expect you to be able to read it. I am sure you will find someone who will translate my lines for you.

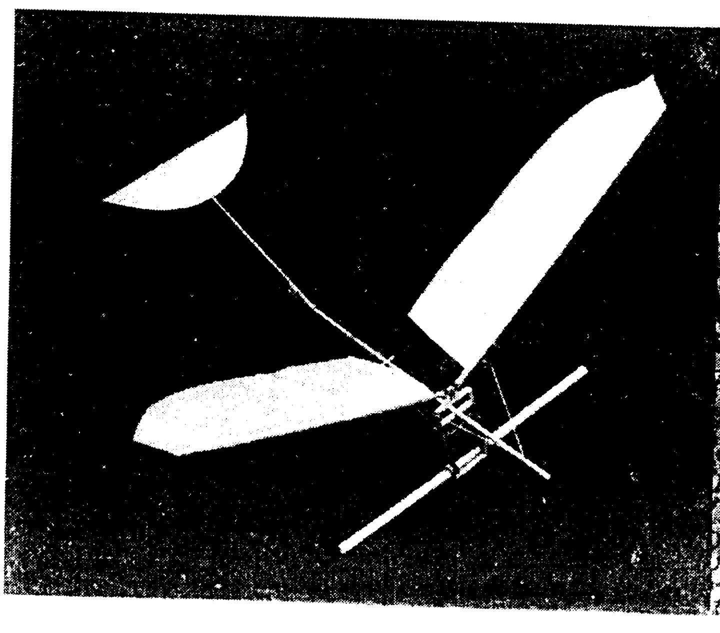
I hope you have fun looking at the pictures. You are welcome to publish this in Flapper Fact.

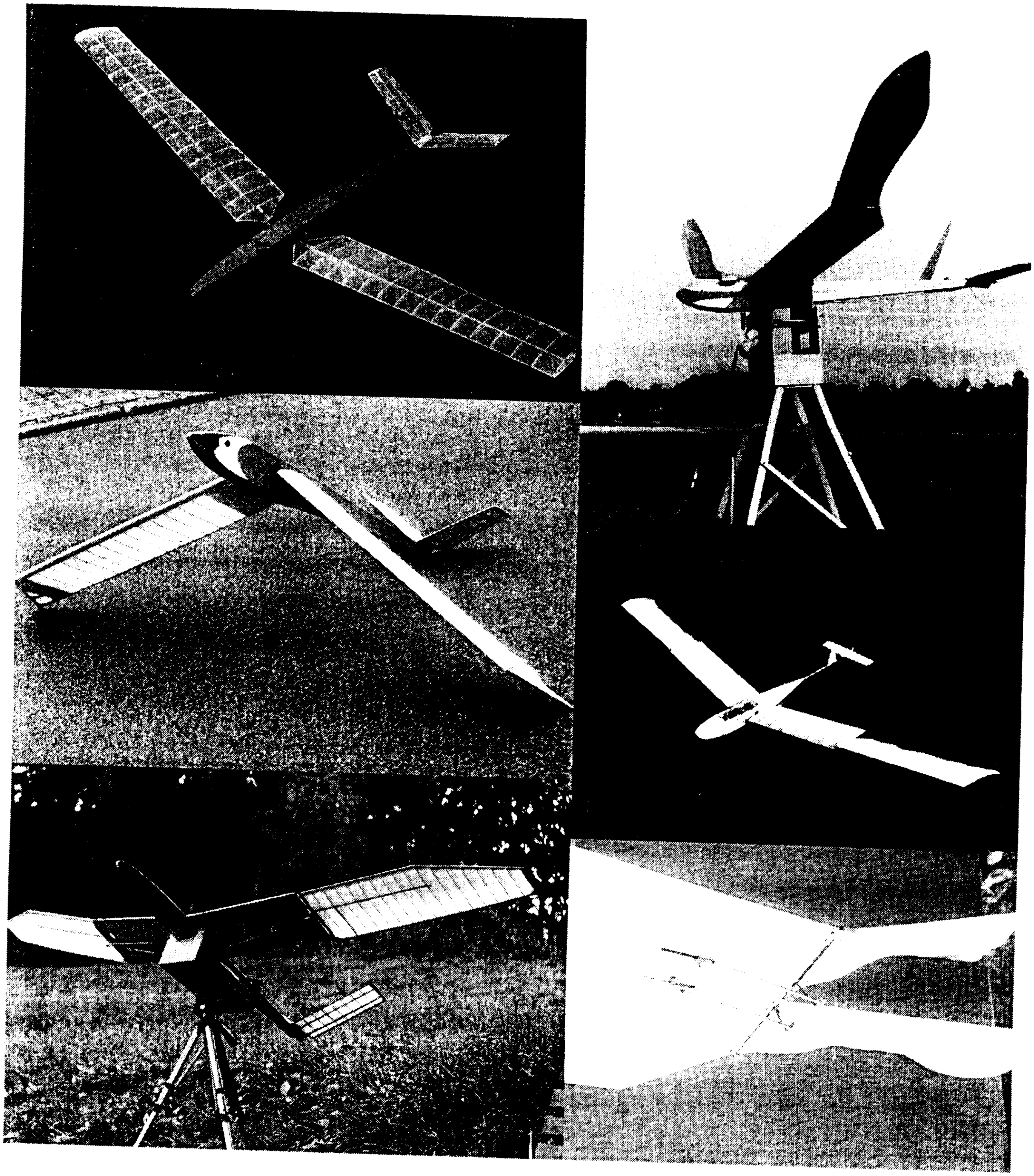






Gear system: March/April 78
ratio = 1:306
Motor: Cox Tee Dee .020
.052 PS, 19500 RPM
Centrifugal clutch
Total weight = 97 g





30 Jun 11

Dear Nathan

Thank you for your recent letters and for taking the time to describe your thoughts on flexible wing design. I don't know yet which method I will use. It was a relief to learn that latex-covered wings do not necessarily need such a large quantity of ribs as was used on Paul MacCready's pterosaur. The trouble with a solid trailing edge, however, is that it is inextensible, so the wing perimeter at the trailing edge is prevented from increasing in length as the wing twists, and the wing twist axis is therefore moved back from the leading edge. I know you can't have everything but I would like to use wing warping as a means of lateral control, by having the leading edge spar of each wing able to rotate within a sleeve at the wing root. An inextensible trailing edge might make this ineffective.

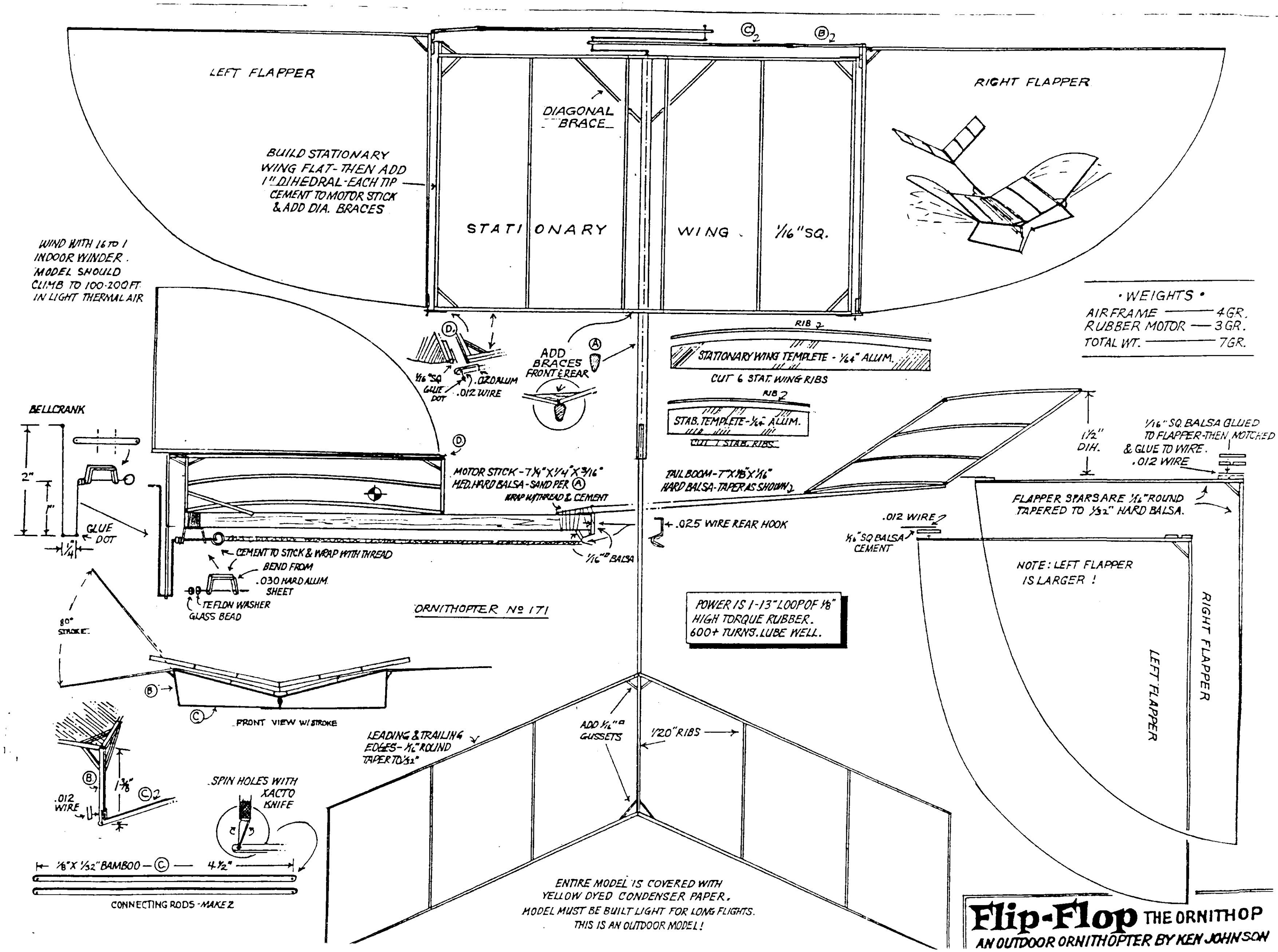
I might opt for the Lycra woven fabric since this should be able to stretch along the weft (which would be run in the spanwise direction) without any tendency to contract along the warp (chordwise direction), so a trailing edge member would not be necessary and also it would be easier to cover the wings with a material that only needs to be stretched in one direction (in this fabric only the weft yarns are elasticated).

I don't know how well this would work in practice, and I shall continue to consider all the options while I proceed with the construction of the rest of the model.

Torsion Springs

I do not believe there is much energy loss when a torsion spring turns a crank past dead centre. The only way energy can be "lost" within the spring itself is if the energy is dissipated as heat. A certain proportion of the energy may be lost in this way within a rubber spring, as rubber has a damping property; but this is not the case with a spring made from spring steel as this is a very low hysteresis material, and therefore virtually all the stored energy is released to do work. A steel spring is in fact extremely close to being 100% efficient.

Most of the energy is transferred to the crank and connecting rods which accelerate and gain kinetic energy (as does the spring itself).


LEFT FLAPPER
DIAGONAL BRACE
RIGHT FLAPPER
BUILD STATIONARY WING FLAT-THEN ADD 1" DIHEDRAL-EACH TIP CEMENT TO MOTOR STICK & ADD DIA. BRACES
STATIONARY WING 1/16"SQ.
WIND WITH 16 TO 1 INDOOR WINDER. MODEL SHOULD CLIMB TO 100-200FT. IN LIGHT THERMAL AIR
•WEIGHTS•
AIRFRAME — 4GR.
RUBBER MOTOR — 3GR.
TOTAL WT. — 7GR.
RIB 2
STATIONARY WING TEMPLETE - 1/64" ALUM.
CUT 6 STAT. WING RIBS
ADD BRACES FRONT & REAR
1/16"SQ
GLUE DOT
.020 ALUM
.012 WIRE
STAB. TEMPLETE-1/64" ALUM.
CUT 7 STAB. RIBS
BELLCRANK
2"
1"
1/4"
GLUE DOT
MOTOR STICK-7 1/4"X1/4"X3/16" MED. HARD BALSA-SAND PER (A)
WRAP W/THREAD & CEMENT
TAIL BOOM-7"X1/8"X1/16" HARD BALSA-TAPER AS SHOWN
1 1/2" DIH.
1/16" SQ. BALSA GLUED TO FLAPPER-THEN NOTCHED & GLUE TO WIRE. .012 WIRE
FLAPPER SPARS ARE 1/16" ROUND TAPERED TO 1/32" HARD BALSA.
.025 WIRE REAR HOOK
.012 WIRE
1/16"SQ BALSA CEMENT
1/16" BALSA
CEMENT TO STICK & WRAP WITH THREAD
BEND FROM .030 HARD ALUM. SHEET
TEFLON WASHER
GLASS BEAD
NOTE: LEFT FLAPPER IS LARGER !
ORNITHOPTER № 171
POWER IS 1-13" LOOP OF 1/8" HIGH TORQUE RUBBER. 600+ TURNS. LUBE WELL.
80° STROKE
FRONT VIEW W/ STROKE
LEADING & TRAILING EDGES-1/16" ROUND TAPER TO 1/32"
ADD 1/16" GUSSETS
1/20" RIBS
.012 WIRE
1 7/8"
SPIN HOLES WITH XACTO KNIFE
1/8"X1/32" BAMBOO — (C) — 4 1/2"
CONNECTING RODS-MAKE 2
ENTIRE MODEL IS COVERED WITH YELLOW DYED CONDENSER PAPER. MODEL MUST BE BUILT LIGHT FOR LONG FLIGHTS. THIS IS AN OUTDOOR MODEL!
Flip-Flop THE ORNITHOP
AN OUTDOOR ORNITHOPTER BY KEN JOHNSON

But in order for momentum to be conserved (as per the laws of physics) the changing momentum of the spring, crank and con. rods must be balanced by an equal & opposite change by the rest of the aircraft. Hence there is an unwanted recoil action.

Fortunately the mass of the rest of the aircraft is likely to be many times greater than the mass of the flapping mechanism. Therefore it will experience an acceleration many times smaller than that of the mechanism. It follows that the kinetic energy transferred to the rest of the aircraft will be very small indeed compared with the transfer to the mechanism (because kinetic energy is proportional to the square of the speed). The situation is similar to the recoil of a gun: it is the less massive projectile, rather than the more massive gun, which receives the bigger share of the energy liberated from the exploding charge.

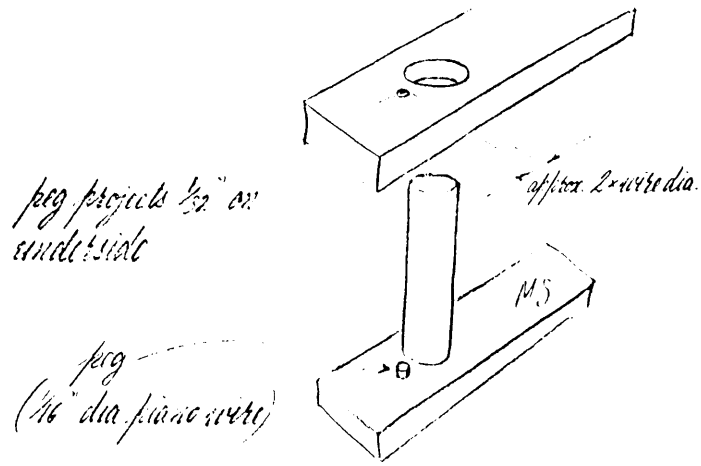
You asked if the sudden release of energy makes it easier for the motor to flap the wings, by relieving spring torsion. It shouldn't; unless the spring is too short (stiff). It is a purpose of the spring to provide a uniform load for the motor (because we don't want the motor's speed to fluctuate); and the longer the spring is, the closer we come to achieving this ideal. The spring only unwinds through a small fraction of a turn at dead centre so, if the spring is already wound up several full turns, its torque will remain nearly constant.

In summary, the only ways I can see in which energy can be wasted are through hysteresis (negligible), friction (negligible) and recoil action (quite small).

In case it is any help in judging the size of spring you will need, I can tell you the size I have been using recently on the O2 model. I make the springs myself now, and the current one (which seems to be satisfactory) is larger than the one originally fitted.

It is made from 1/32" wire wound twenty turns around a 3/8" dia. mandrel. This expands to about 1/2" i.d. × 15 turns on release from the mandrel.

## Winding Tool



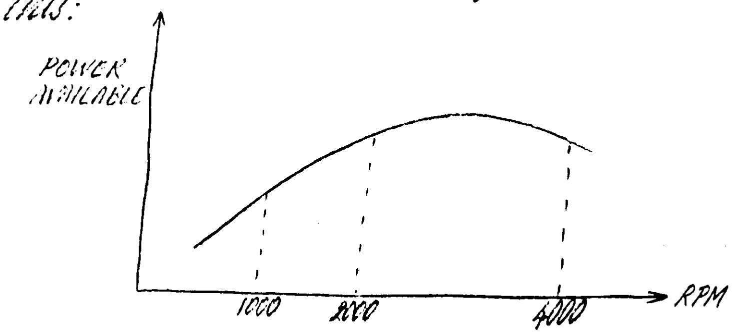

Hammer the pegs to produce burrs to prevent wire slipping off.

The spring is now enclosed within an aluminium can (5/8" i.d., made from a section of Multicore solder container – a cigar tube would do just as well – and drilled with lightening holes) This prevents the spring from deflecting to such an extent where it would suffer permanent deformation (otherwise the spring sometimes tends to bunch up like a rubber motor, and then it is scrap!). It is still capable of winding up two full turns.

A more ideal spring would be a spiral clock-type spring. I will be using one in the new model; it is a motor cycle kickstarter pedal return spring. I have however continued using a helical spring in the $CO_2$ model for simplicity.

## $CO_2$ Motor Power Characteristics

Unfortunately I don't know the answer to this one. I have never seen any figures, graphs etc. published. Common sense says the maximum power output and the gas consumption should both be proportional to speed. However, these motors are always fitted with really enormous airscrews, regardless of model type, and run at very low speed, which suggests that efficiency decreases severely as r.p.m. rises. Running speed is typically between 1000 r.p.m & 2000 r.p.m. The lower end of the speed range is used for very light weight aerodynamically clean "floaters" to give very long motor runs, whereas the higher speed of around 2000 r.p.m seems to be used at the expense of gas consumption efficiency where more power is needed. For my model, I was aiming for a gear ratio that would give a motor speed of about 2000 r.p.m, since it seemed a good bet that I was going to need all the power I could get. As it turned out, I underestimated the flapping frequency and had the motor running at 3500-4000 r.p.m. Changing the gear ratio from 17½:1 to 9:1 had no noticeable effect on the flapping frequency, so the power output couldn't have changed much despite the motor speed being nearly halved. My guess is that the power curve looks like this:




This is of course all speculation, and I am sorry that I can't give you any definite facts.

$CO_2$ model - latest news

My flight attempts at the recent Model Engineering Exhibition were a dismal failure. This was due to a problem with the motor; apparently some obscure fault had developed with the valve or gas sealing arrangement in one of the cylinder heads. I was fortunate enough to meet the motor's designer, Stefan Gasparin, at the exhibition, and he very kindly offered to take the motor back to Czechoslovakia with him for repair and then post it back to me. Needless to say, I think this is first rate service, and he wouldn't even accept any payment for it. I also got to see his latest $CO_2$ motors, which he had brought with him and included a V-8 and an eighteen cylinder radial. He even makes rotary engines, which should be excellent for ornithopters because these motors are their own fly-wheels.

I did get a few half-hearted flights with the motor stopping & starting & changing direction, and the fact that it flew at all is probably a good sign for when I get the repaired motor back.

The language barrier was a problem, but I think Mr Gasparin may himself be an ornithopter enthusiast. He explained that he has drawings of Lilienthal's $CO_2$ ornithopter and also mentioned that it

should be possible to develop a linear $CO_2$ motor to actuate flapping wings.
I should be getting my motor back any day now, and I will try flying the model outdoors this summer.

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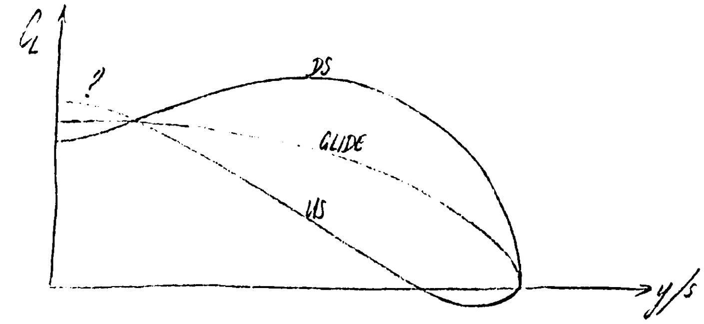
Having just read the new Flapper Facts, I wonder if you have the answer to something I found puzzling. I didn't fully understand the $C_L \sim y/s$ graph. Why do the three curves not meet at $y/s = 0$, or even cross over since the fuselage is likely to be rising during the downstroke (reducing the angle of attack at the wing roots) and conversely on the upstroke?




I had attempted to allow for this on my $CO_2$ model by arranging for the wings to start twisting at some distance out (½" actually) from the wing hinge lines, but now I am wondering if this was misconceived.
Mr Rabiger's models are clearly very elegant & impressive designs, & I hope you'll get more details to print.
I enclose some more articles. I don't remember whether I already sent "Biological & Aerodynamical Problems of Animal Flight". If not, let me know and I'll put a copy in with my next letter.

Best Wishes
Joss

(I replied to Joss Levy that Rabiger's figure seemed to be based on a mathematical model which might not have accounted for rise and fall of the fuselage. Other possibilities include spanwise airflow and a large phase difference between flapping and fuselage motion. Maybe someone can tell us if this is right or not. -NC)

**REYNOLDS ENGINEERING COMPANY**
3802 - 127th Avenue N.E.
Bellevue, WA 98005-1346
(206) 885-2647

July 1, 1995

I enclose a spreadsheet study relating to my ornithopter-model wing design. This is one of forty-some such sheets, which vary all the variables one at a time in an attempt to optimize the design. There will doubtless be still more of before the wing design is cast in balsa-wood and epoxy-graphite. You will see on this sample sheet some of the things you discussed in your "New Twist" article.

Because it was written only for my own use, you probably won't be able to understand everything which I have done on it, but it will give you a feel for the approaches I am taking. Unfortunately, the spreadsheet printouts don't show the formulas from which the computer calculated all the values. I have found computer spreadsheets a wonderful time-saving tool for making ornithopter design trade studies. I assume you have used spreadsheets in other work-- I highly recommend them for ornithopter design if you are not already using them there. I have make very useful flapping-wing studies on spreadsheets which I never would have gotten enough ambition to study by old manual methods.

My "RCSeagull" ornithopter model is coming along. I now have the wing twisting mechanisms built and integrated with the flapping mechanisms. These are currently installed in an "Iron Bird" test rig. It had demonstrated, under the power of the small electric wing-leveling motor, combined flapping and pitching of the wing spars and radio control of the maximum pitching angle and of differential pitching for roll control. As far as I know, mine will be the first ornithopter with controls on all three axes. It will also have pitching (twisting) amplitude control and throttle.

I made a presentation on my ornithopter work to the Northwest Section of the American Institute of Aeronautics and Astronautics in May, '95 (I am an Associate Fellow of that organization). It is likely that they will recognize my efforts as an official AIAA Flight Research Project and grant me a modest sum for parts and materials.

With regard to your item on the Kiselev Russian rocking-tandem ornithopter model work: I have a copy of a 1988 article in Russian (I got a crude translation from the local Russian Tea Room) on the SLA-87 powered mancarrying rocking-tandem ornithopter, which was designed by Valadimir Toparov, director of a research organization. It would taxi "up to 50 kmh, but did not fly." The photos of it are interesting in that they show not two, but four pairs of wings. It is a "double tandem" with two forward wings rocking out of phase with each other, and two aft wings also rocking out of phase with each other. This would, of course, cancel out the yawing and rolling moments which are generated in the basic tandem rocker configuration when it flaps; but at great cost in complexity.

Toparov is said to have experimented with ornithopter models for a long time first, but no mention was made of Kiselev. Another "expert", Zhukovoski, was mentioned.

G13.tpl   3/28/95   40.00 fps   1.50 cps   28.50deg flap

Identical to G10 & G11.tpl except for upstroke alphas, change by 0.7° steps

Cessna wing with 4 ft panels and 14 in. main chord. 9.0ft span. Tapered from Sta.7, 10in. tip C. AR=7.98, S=1464 sq in.=10.17 sq ft.
Airfoil Selig S4233 Midstroke (max) values shown. Increm. areas=.467 sq ft

DOWNSTROKE

| Sta | Vv fps | Feather | Resul V | Twist | Alpha | L coef | Resul F | Lift | Thrust |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.00 | 0.00 | 40.00 | 0.00 | 4.00 | 0.55 | 0.24 | 0.24 | 0.00 |
| 0.1 | -1.88 | -2.68 | 40.04 | -2.68 | 4.00 | 0.55 | 0.49 | 0.49 | 0.02 |
| 0.2 | -3.75 | -5.36 | 40.18 | -5.36 | 4.00 | 0.55 | 0.49 | 0.49 | 0.05 |
| 0.3 | -5.63 | -8.01 | 40.39 | -8.01 | 4.00 | 0.55 | 0.50 | 0.49 | 0.07 |
| 0.4 | -7.50 | -10.62 | 40.70 | -10.62 | 4.00 | 0.55 | 0.50 | 0.50 | 0.09 |
| 0.5 | -9.38 | -13.19 | 41.08 | -13.19 | 4.00 | 0.55 | 0.51 | 0.50 | 0.12 |
| 0.6 | -11.25 | -15.71 | 41.55 | -15.71 | 4.00 | 0.55 | 0.53 | 0.51 | 0.14 |
| 0.7 | -13.13 | -18.17 | 42.10 | -18.17 | 4.00 | 0.55 | 0.54 | 0.51 | 0.17 |
| 0.8 | -15.00 | -20.56 | 42.72 | -18.17 | 6.39 | 0.76 | 0.71 | 0.66 | 0.25 |
| 0.9 | -16.88 | -22.88 | 43.41 | -18.17 | 8.71 | 0.96 | 0.82 | 0.76 | 0.32 |
| 1.0 | -18.75 | -25.12 | 44.18 | -18.17 | 10.95 | 1.25 | 0.35 | 0.32 | 0.15 |
| G13.tpl | | | | | Totals per panel | | | 5.47 | 1.38 |
| | | | Total per bird at mid DOWNstroke, pounds | | | | | 10.94 | 2.76 |

UPSTROKE

| Sta | Vv fps | Feather | Resul V | Twist | Alpha | L coef | Resul F | Lift | Thrust |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.00 | 0.00 | 40.00 | 0.00 | 4.00 | 0.55 | 0.24 | 0.24 | 0.00 |
| 0.1 | 1.88 | 2.68 | 40.04 | 1.98 | 3.30 | 0.49 | 0.43 | 0.43 | -0.02 |
| 0.2 | 3.75 | 5.36 | 40.18 | 3.96 | 2.60 | 0.43 | 0.38 | 0.38 | -0.04 |
| 0.3 | 5.63 | 8.01 | 40.39 | 5.91 | 1.90 | 0.37 | 0.33 | 0.33 | -0.05 |
| 0.4 | 7.50 | 10.62 | 40.70 | 7.82 | 1.20 | 0.30 | 0.28 | 0.28 | -0.05 |
| 0.5 | 9.38 | 13.19 | 41.08 | 9.69 | 0.50 | 0.24 | 0.23 | 0.22 | -0.05 |
| 0.6 | 11.25 | 15.71 | 41.55 | 11.51 | -0.20 | 0.18 | 0.18 | 0.17 | -0.05 |
| 0.7 | 13.13 | 18.17 | 42.10 | 13.27 | -0.90 | 0.12 | 0.12 | 0.11 | -0.04 |
| 0.8 | 15.00 | 20.56 | 42.72 | 13.27 | -3.29 | -0.09 | -0.08 | -0.08 | 0.03 |
| 0.9 | 16.88 | 22.88 | 43.41 | 13.27 | -5.61 | -0.29 | -0.25 | -0.23 | 0.10 |
| 1.0 | 18.75 | 25.12 | 44.18 | 13.27 | -7.85 | -0.48 | -0.13 | -0.12 | 0.06 |
| | | | | | Totals per panel | | | | -0.11 |
| G13.tpl | | | Total per bird at midUPstroke, pounds | | | | | | -0.22 |

G11 shows very high negative lift on upstroke due to constant alpha in order to keep upstroke and downstroke twist the same.

G12, with .6deg/sta. reduction in alpha on upstroke shows modest neg. thrust on upstroke. This G13 attempts to eliminate neg. thrust on upstroke.

It still has a little neg thrust on upstroke. See G14.tpl

Francis Reynolds