Everyman's guide to... Ornithopters

John White takes us through some of the design considerations to achieve the oldest form of flight.

John White explains some principles behind his successful Ornithopters

Winged flight

Before M. Penaud invented the propeller in the 1870's (fig. 1) climbing flight had been achieved only by means of beating wings. Many species of living creatures were successful. It is thought that among the first were the dragonflies. Fossilised remains have been found that show they existed three hundred million years ago. With wingspans of up to thirty inches they were much larger than present day species.

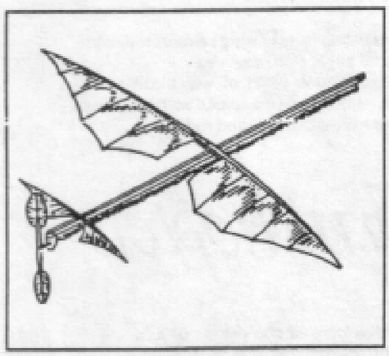


Fig. 1. The 'Aeroplane' by M. Penard. Note the use of feathers for propeller and stabiliser.

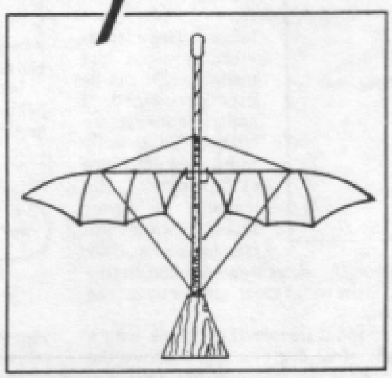


Fig. 3. Mr. Tatin's ornithopter the 'Bird'.

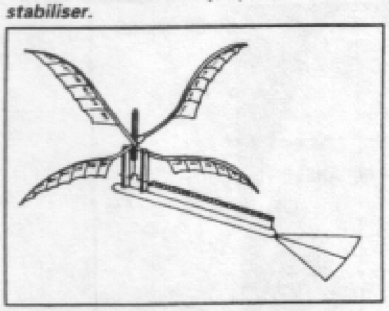


Fig. 2. The artificial dragonfly built by M. Jobert.

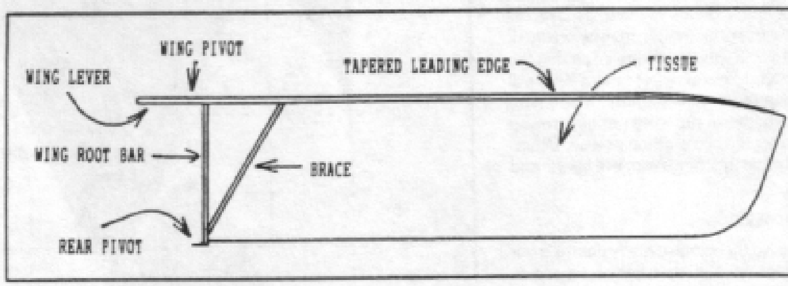


Fig. 4. A typical ornithopter wing.

Ornithopters [from the Greek ornith (bird) + pteron (wing)]

Ornithopters are machines that fly by beating their wings. In the early 1870's a Frenchman, Jobert, built an artificial dragonfly (fig. 2). In the 1880's several models were built - notably the 'Bird' by Mr. Tatin (fig. 3).

On December 17th 1903 came the historic flight of the Wright Brothers at Kitty Hawk. Research and development was then directed towards fixed-wing aircraft. However, many enthusiasts continued to experiment with ornithopters. Among them were Dr. Lippisch who designed 'Schwingin' in 1937/8 and Dr. Eric von Holst who designed 'Buzzard' in 1939. Parnell Schoenky designed 'Flap Happy' in 1949.

Leonardo de Vinci thought the bird a machine that operated according to mathematical law, but the analysis of bird flight is very complex. Ron Waring in an article published in 1953 suggested that if we wanted a successful model ornithopter we would have to start by forgetting about bird flight.

The dragonfly is a very efficient flying insect and according to some estimates it is capable of speeds of up to 60 m.p.h. As its wing motion is relatively simple, I chose to experiment with ornithopters based on the flight of the dragonfly. In 1954 I developed the phased bi-plane that enabled model ornithopters to achieve climbing flight. Almost 40 years later there is still much more to be learned about the design of ornithopters. The following are my own views, formed by study and practical experience.

Ornithopter wings

The wings of an ornithopter are pivoted at their root to a fixed structure called a cabane. Wings are the model's propellers, providing thrust. A suitable power source must be available, which when linked to the wings, causes them to beat up and down.

Fig.4 shows the construction of a typical wing. Note that the only rigid parts are the root bar and brace. The leading edge must be light but strong enough to resist undue flexing in both vertical and horizontal planes. The choice of material depends on the size of the model and whether it is designed as an outdoor or indoor model. I have found that tapered cane is best for outdoor models. The tissue may be strengthened with a flexible non-shrinking dope. The grain of the tissue is best across the chord.

Ornithopter wings usually copy the dragonfly wing in depending on air pressure to form the tissue to a shape similar to that of a propeller blade. The tension and the plan form of the tissue plays an important part in the shaping of the wing under power. It is best viewed in stroboscopic light. One wing of an ornithopter is not counterbalanced by the weight of the opposite wing, as are the blades of a propeller. For this reason the wings should be made as light as possible. Lift is obtained by giving the wings a high angle of attack. Fig. 5 shows a tail plane with a large angle of elevation enabling the wings to provide lift.

Linkage systems

An important part of any ornithopter design is the linkage that connects the power source to the wings. Wings are normally operated by rods connected to a continuously rotating crank shaft. The linkage may take many forms, some of which are shown in fig. 6.

In designing a linkage system try to arrange for the wings to beat sinusoidally. This means

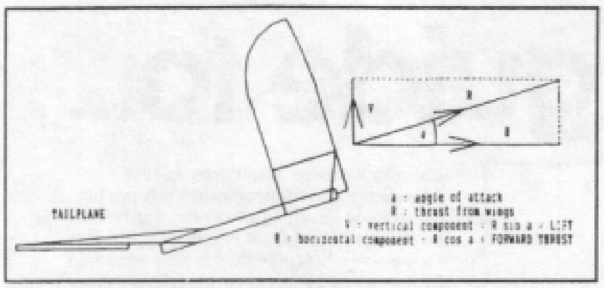


Fig. 5. Shows the attitude of a model to obtain lift.

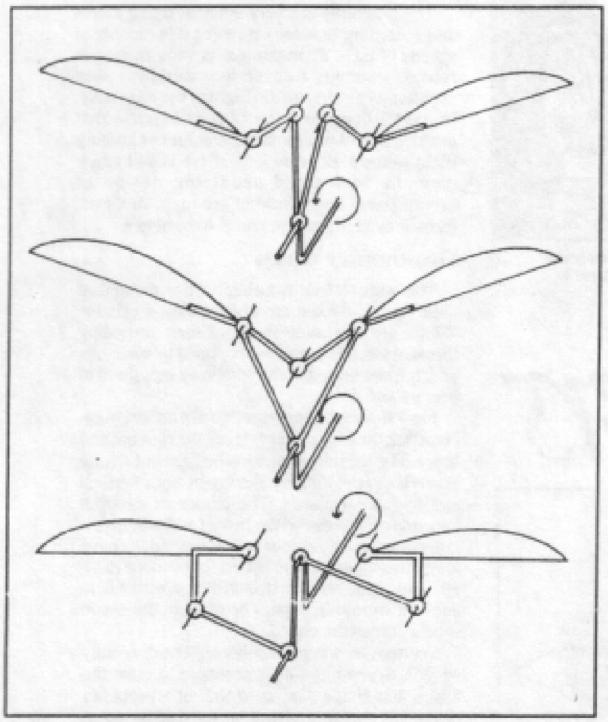


Fig. 6. shows three linkage systems.

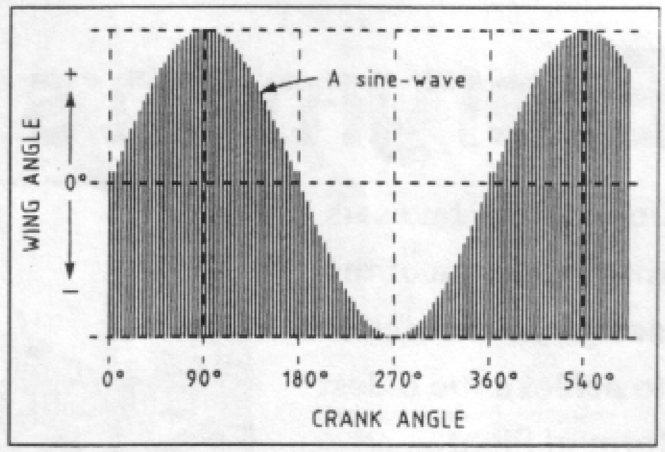


Fig. 7. The Graph of Wing Angle versus Crank Angle.

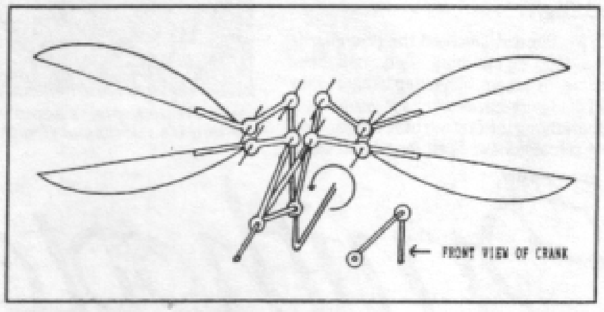


Fig. 8. A double-throw crank.

that if the wing angle is plotted against crank angle the resulting curve is a sine-wave (fig. 7).

This wave-form is difficult to achieve. I have found that if the length of the conrod is made equal to the vertical height of the wing pivots above the crank centre, and the ratio of this height to the crank radius is made as large as practical, a close approximation may be reached. A wing offset angle should be chosen so that the mean sweep angle of the wing is at a dihedral angle sufficient to provide stability. Make sure that the angle between the wing radius arm and the conrod is not too acute or too obtuse. Otherwise it is likely that the radius arm will toggle and lock up.

Motive power

Power to drive the wings usually comes from a rubber motor as a high level of torque is required. Electric motors and I.C. engines need large reduction gears which reduces their power/weight ratio. An ornithopter with a single pair of wings does not utilise the power of the motor efficiently. Approximately half the energy is wasted. The resulting vibration requires the model to be built robustly. This increases its weight and so reduces its efficiency.

Bi-plane ornithopters

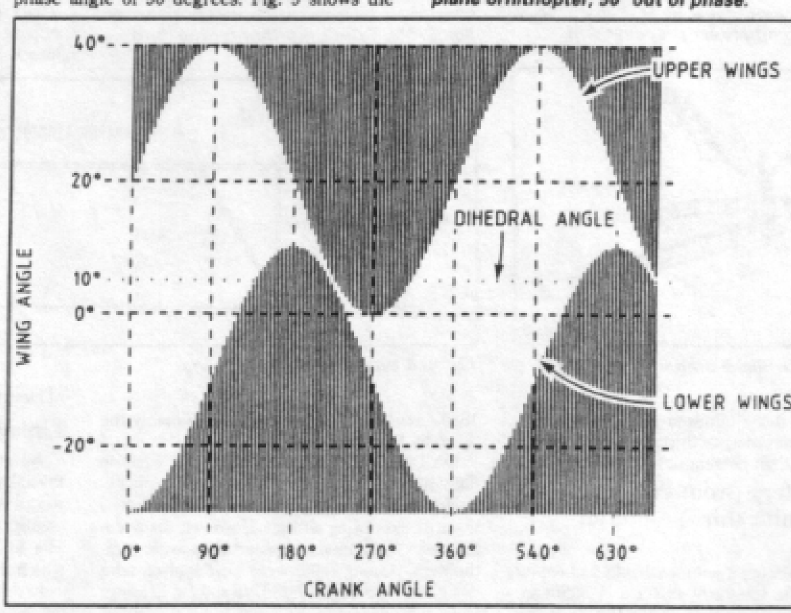
By adding a second pair of wings out of phase with the first pair almost all the power may be utilised. There is less vibration and the model weight can be greatly reduced. If both pairs of wings are beating sinusoidally with a phase difference of 90 degrees, the transfer of power should be at a uniform rate. In addition, if the offset angles of the wings are adjusted so that the upper and lower wings meet, greater thrust can be generated.

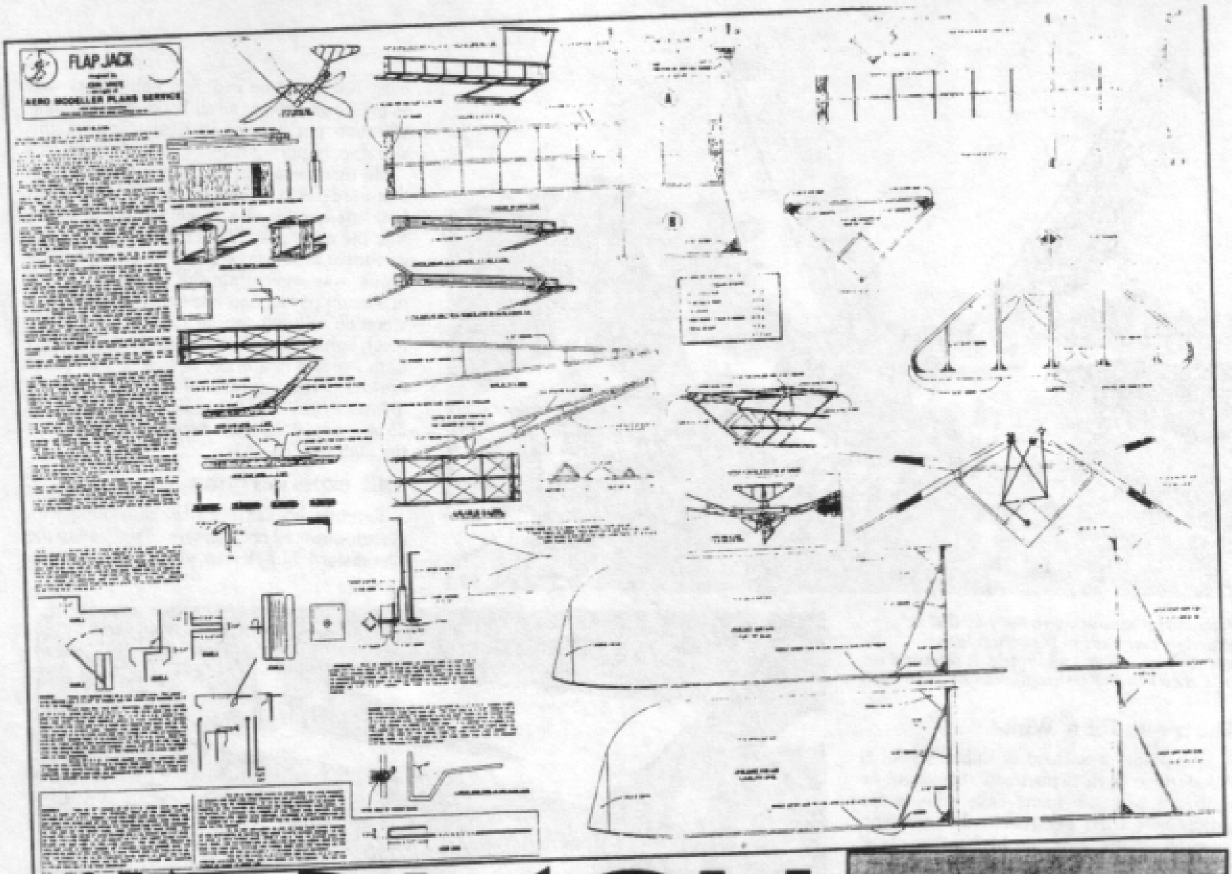
Fig. 8 shows a double-throw crank with a phase angle of 90 degrees. Fig. 9 shows the waveforms of two pairs of wings almost touching at a dihedral angle of 10 degrees.

My latest model, plans of which are to be published, should make a useful starting point for the experimentally-minded modeller.

Ornithopters

Fig. 9. Waveform of the wings of a bi-plane ornithopter, 90° out of phase.





FLAPJACK

Full-size copies of the Flapjack plan are available as AM1716, price £5.75 including postage and packing, from Aeromodeller Plans Service, Argus House, Boundary Way, Hemel Hempstead, Herts. HP2 7ST. Model Pilots' Association members need only send £5.15.

Following his article discussing some of the theory of ornithopters last month, John White has now drawn the plans and offers building instruction for one of his advanced models. It sets a unique challenge and flies extremely well

This is the model John flew at Old Warden last year in less than ideal conditions – wet and windy. It finished up in a tree but the damage was not too bad.

The right John White

John White was Head of Upper School at Woodbridge High School and should not be confused with his name sake who is the enthusiastic CDH designer and competitor. Now retired, this John flew his latest 'bi-plane' ornithopter at Old Warden last year and at the Model Engineer Exhibition this year. It created considerable interest and amazement. The sight of the model beating its way up into the air like a large living creature was spectacular.

It started in 1949

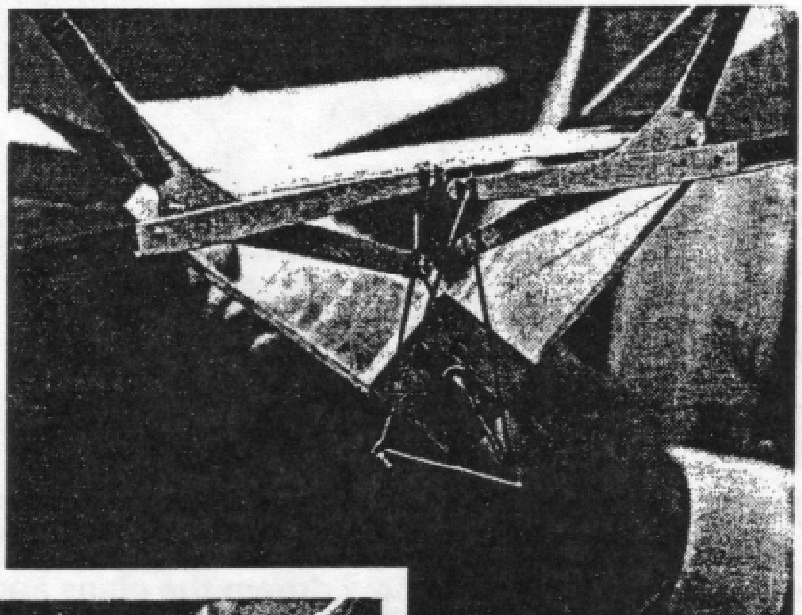
John's interest in ornithopters was aroused when in 1949 Aeromodeller published the plans of Parnell Schoenky's Flap Happy. He quickly came to the conclusion that a single pair of flapping wings operated by a simple crank mechanism was inefficient. When the crank was passing top or bottom dead centre the wings hardly moved. This caused the crank to crack over. It speeded up and then suddenly slowed as the wings acted as an air brake. The resulting vibration put a great deal of strain on the airframe, requiring it to be strongly built.

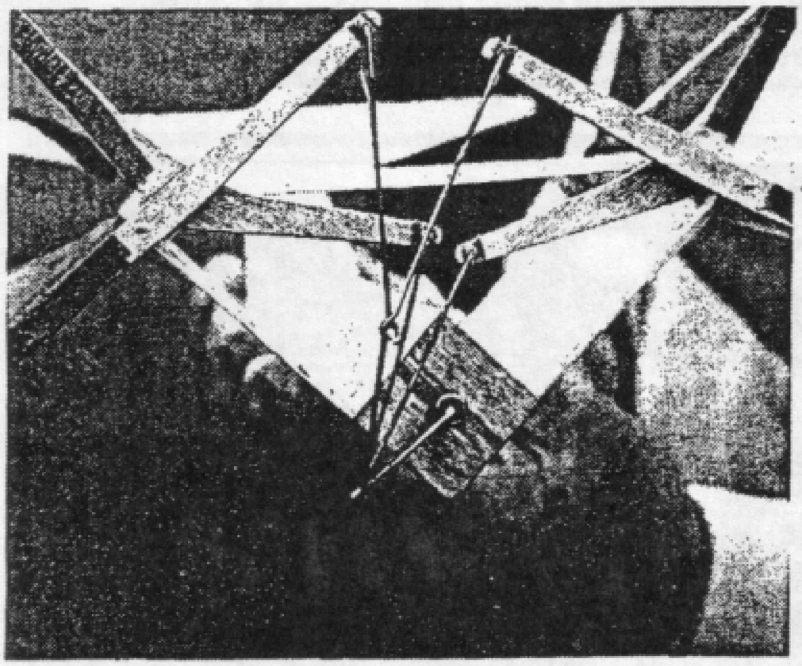
He then began to design and build models that used a second pair of wings. One pair to beat one quarter of a revolution out of phase with the other pair. When the crank was at top or bottom dead centre for the upper wings the crank was operating the lower wings at maximum power, and visa versa. The reduced vibration allowed the airframes to be made much lighter. Jack Holt of the old Hornchurch Club assisted him in the design of the rubber motors. His experiments resulted in 'DRAGONFLY' which set a record of 1 minute 55 seconds at Langley Aerodrome, Bucks on the 20th of June 1954.

Still experimenting

Recently he has been experimenting with electric-powered ornithopters. Since joining the Chelmsford M.F.A. last year his interest in rubber-powered ornithopters has been re-awakened. With the help and encouragement of the club's free-flight enthusiasts he has improved his design.

The construction of the model is very unusual so it was decided to put the step by step details of each stage of construction on the plan and not in the usual separate article. Many who buy an Argus plan neither have nor need the relevant Aeromodeller article, but for this model John's excellent diagrams and instructions are a must. We endorse Flapjack as an ornithopter that will provide hours of pleasure and could be the starting point for the experimentally minded modeller. There is much more to be learned in this fascinating branch of the hobby.





The key to John's brilliant achievement with model ornithopters is the phased flapping of two sets of wings. Here we can see the cranks in two positions in the sequence. It is fully explained on the plan. On the smaller version flown indoors, he tells us the arms have been reinforced with cyano.