'Copter

This is the first of a three-part series of articles which will endeavour to take the guesswork out of joining the helicopter scene. In the first part Author Jim Morley will describe how a helicopter works. Part II will outline the market choice and the final part will discuss flying and beyond.

THE TREMENDOUS ADVANTAGES of the R/C helicopter as a practical flying model are obvious, and the same as in the full-size aircraft world. Firstly you don't have to have a runway, nor even a large flying field. The nuisance value is very much less because the noise spread can be very much smaller, plus the absorbing fascination of the complex performance potential, and you have a challenge you can't turn away from. So many people have now overcome the difficulties that it must be well worth your while to have a go. What are the disadvantages?

The most serious disadvantage claimed is that helicopters are difficult to build, set up and fly because they are so complex. This is now completely out of date. A few years ago if confronted with a problem there was no guidance available which resulted in a very high 'failure' rate. Now, however, with a little bit of travelling you can meet up with an experienced flyer, or at least find a lot to read on the matter. Also R/C helicopters themselves have been developed to meet the need, being both simpler to build and easier to fly, more reliable and cheaper.

Almost convinced? Good, let's start with a description and at the same time get over the hurdle of confusing terminology. You are going to have to learn a few new words to understand, and you have to understand to succeed. You don't just steer a helicopter. I will start right at the beginning.

The helicopter — power-driven rotary winged flight

Given a big enough propeller pointed upwards and fed with enough power, an airframe can be made to lift clear of the ground, but the problem is how to control the resulting machine. The first problem would become apparent very soon, as the airframe would rotate in the opposite direction to the propeller, spoiling the ride somewhat. Fortunately there are various ways to stop this.

The 'Propellers' on a helicopter are called 'rotors'. There are tandem rotors and contra-rotating rotors, but the most generally accepted method of balancing the torque reaction due to the power transmitted into the rotor, is to have a tail rotor supplying a force at the end of an arm, the tail boom. See fig. 1.

Now, feed more power into the main rotor and the airframe will rise, ease off power and it will descend. To stay pointing the same way tail rotor needs to have variable pitch, which will also enable the helicopter to turn to order.

As well as turning, it is necessary to control 'attitude'. This is done by cyclic control of the main rotor blades, that is, varying their pitch as they go round 'cyclically'. There is a device on the mast that transfers the linear motion from the radio control servos into linear motion on the pushrod to control the main rotor blades, as they go round. This is the 'swashplate'. There is usually a dynamic servo mechanism between this and the actual incidence finger or horn on the main blade, but the end result is to give more lift on one side of the rotor disc than the other. Fig. 2.

To move forward the helicopter is tilted and there is then a forward component from the lift generated by the main rotor. Fig. 3. Sideways or even backwards motion is achieved similarly.

In the early days attempts were made to control helicopters by moving the C.G. around, now all helicopters have cyclic control, but they don't all have 'collective pitch' control. Collective pitch control is a means of obtaining more or less lift from the main rotor immediately, without waiting for it to speed up or slow down with power input changes. It simply applies more, or less, pitch onto all the blades at once — collectively. Fig. 4.

If you understand that, you understand how a helicopter flies.

Now for the model, applying radio control

From the previous description you will realise there are four things to be done. Height control is one, heading is another, while attitude fore and aft, and attitude sideways make up the remainder. If you have a control stick in each hand then backwards and forwards plus left and right on each of them can be interpreted by the model.

There are several variations of what is controlled by which stick movement, but it is convenient to think of the right hand stick as the mast top of the helicopter and this means having the two directions of tilt on your swashplate connected to the servos controlled by this stick.

Push the stick away from you, the swashplate tilts forward, causing more lift at the back of the rotor and less at the front, so the 'copter tilts away from you and moves away forwards. The sideways — or lateral movement is similar.

While your right hand is busy with the attitude your left-hand has to control height and heading. Simply because in a real aircraft you push the throttles forward to increase power, we can arrange forward movement of the left stick to increase power and collective pitch together, and hence go up. Note that power and collective pitch are coupled together or respond to the same stick movement.

This leaves heading under the control of left and right movement of the left hand stick. It makes a lot of sense to have nose movement follow stick movement, so that in forward flight it is simply a steering exercise. Refer to Fig. 5.

The Airframe

Armed with the above knowledge you could manage a helicopter, but there is a lot more to understand if you want to keep the model running and become proficient at flying it.

The airframe of a helicopter necessarily incorporates more mechanical parts than does a fixed wing aeroplane. To begin with, in order to get enough efficiency from the rotor to lift the model it has to be a large diameter. This demands a reduction gearbox and forced air cooling for the motor because, certainly whilst hovering about maximum power, the airflow is insufficient for cooling. The gear ratio from motor to rotor is about 10 to 1, and the tail rotor needs a drive at about half to one third engine speed. There is another gearbox at the tail rotor driven by a belt or shaft down the tail boom.

In order that you can start the motor there is a centrifugal clutch in the drive train. You start

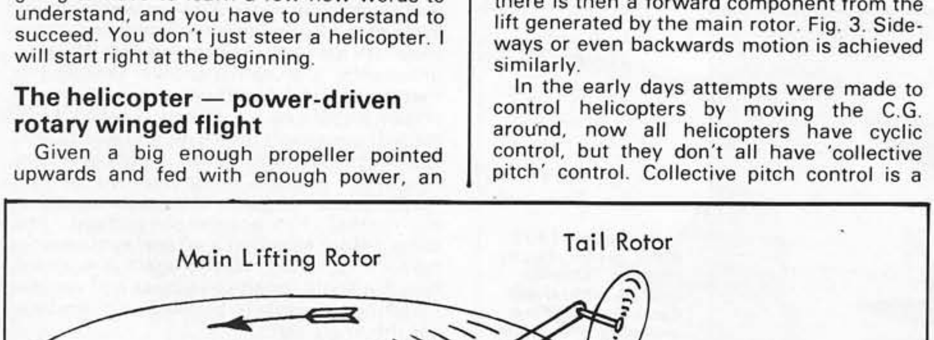


Fig. 1

Comprehension

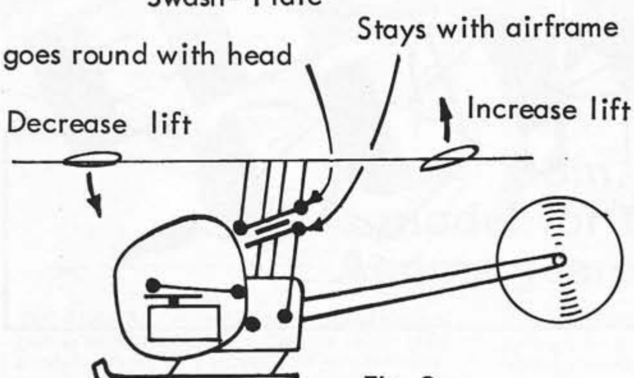


Fig. 2
Cyclic control

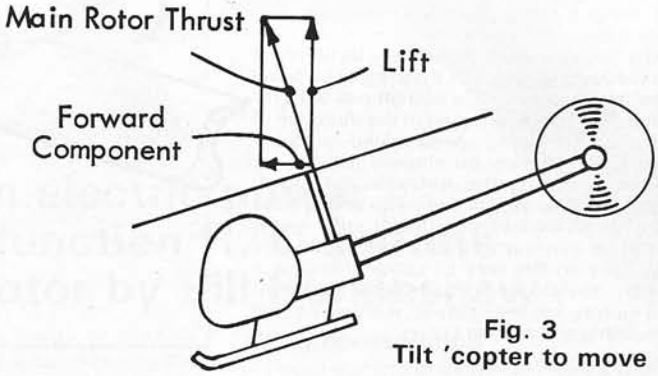


Fig. 3
Tilt 'copter to move

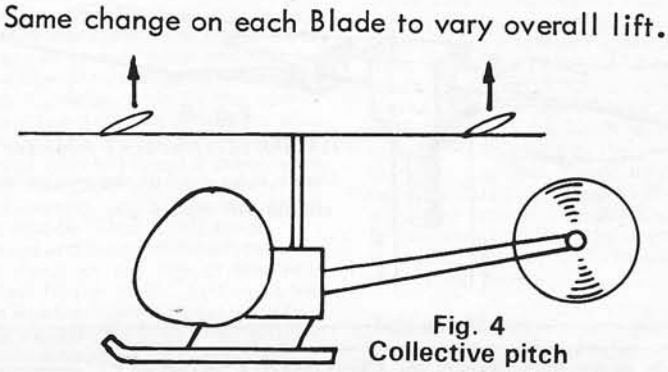


Fig. 4
Collective pitch

the motor with the throttle nearly closed, whilst restraining the rotor. It is usual to have a small V-Belt and an electric starter, but there are some models where you can apply a starter direct via a cone or even use a cord start. Some petrol-driven models have a recoil starter on board. There are many variations for solving this particular problem.

You may find that there are a confusing number of levers, control rods and bellcranks in a helicopter control system. Taken one system at a time they are simple enough, the designer has to avoid interaction from one control to another, although in some instances this is desirable. For minor improvement certain complications are introduced, for example very often two servos work from the command of one stick movement, one for throttle and one for collective pitch, although normally they can be coupled onto one servo. This not only eases physical installation problems, but enables differences in control to be introduced. More on this in the final article in the series.

The detail design of any model will promote discussion and argument about the merits or disadvantages of a particular compromise. It is all, however, with one purpose, to feed the power into the main rotor and control it with push-rods from the radio control servos.

At the beginning it was sufficient to say that the rotor blades changed incidence with the linear motion of push-rods from the swashplate. You will recall I said there was usually a dynamic servo mechanism at this point. I will now endeavour to explain the workings of the rotor head.

The rotor head

With the airframe the detail design is different, but the end result is the same. With the rotor head the design detail is different in order to get a different answer! Obviously the overall answer is the same, to provide lift and control, but there is a feature called 'following rate'.

In some ways the rotor head can be said to be tuned to enable you to do a balancing act. Try balancing a pencil upended on one finger, your reactions won't be able to cope. Now replace the pencil with a broom-handle and it will be easy to balance, but put it over at an angle and you would not be able to catch it up and stop it falling over. If the length of the broomstick was halved say, then not only would you be able to 'catch it' from the same angle, but you could also balance it. There would be an optimum length to suit your reactions and stage of experience or training.

Following rate is a bit like that.

Rotor heads without any stabiliser bar, called flybarless (or sometimes, quite wrongly, 'rigid rotor') would respond as the pencil in the above example. (Fig. 6). At the opposite end of the scale, the broom-handle, is the Hiller system stabilised with large heavy paddles, or fly-blades to give them their alternative name. See Fig. 7.

The Hiller system is really very clever and it is this that most suits models, even though full-size choppers have mostly left it behind. The idea is that the radio control servos, or the pilot, simply tilt the fly-blades, a relatively effortless task, and these then tilt the fly-bar, or stabiliser bar which in turn controls the incidence on the main lifting rotor blades to control the helicopter.

If you try to work out the sequence after applying a control to the fly-blades you will find that it is exactly the opposite to the obvious, this is because you are overlooking the gyroscopic precession forces applying themselves to the rotating masses. By varying the leverages, masses and areas of the stabiliser system you can vary the following rate a small amount.

There is another system in common use though not often on its own. This is the Bell stabiliser, where instead of paddles there is

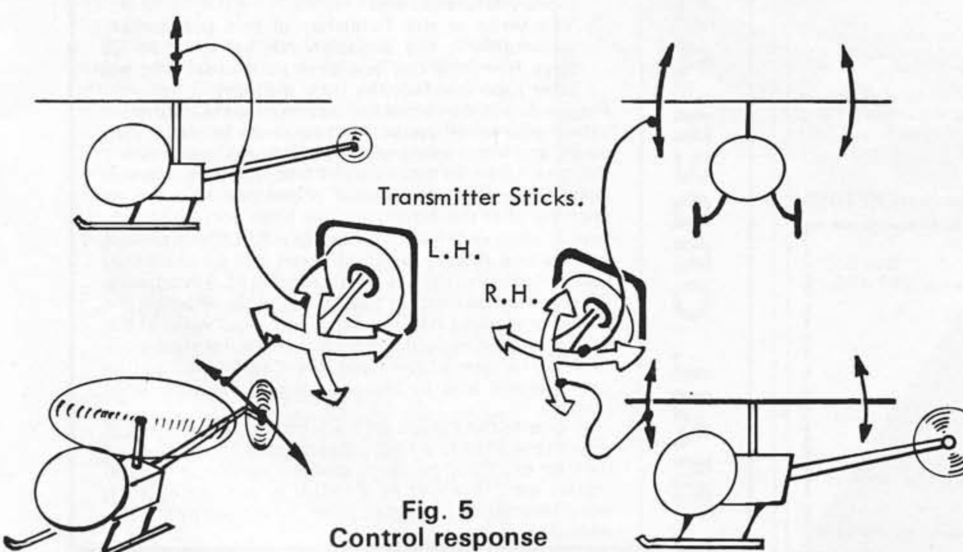
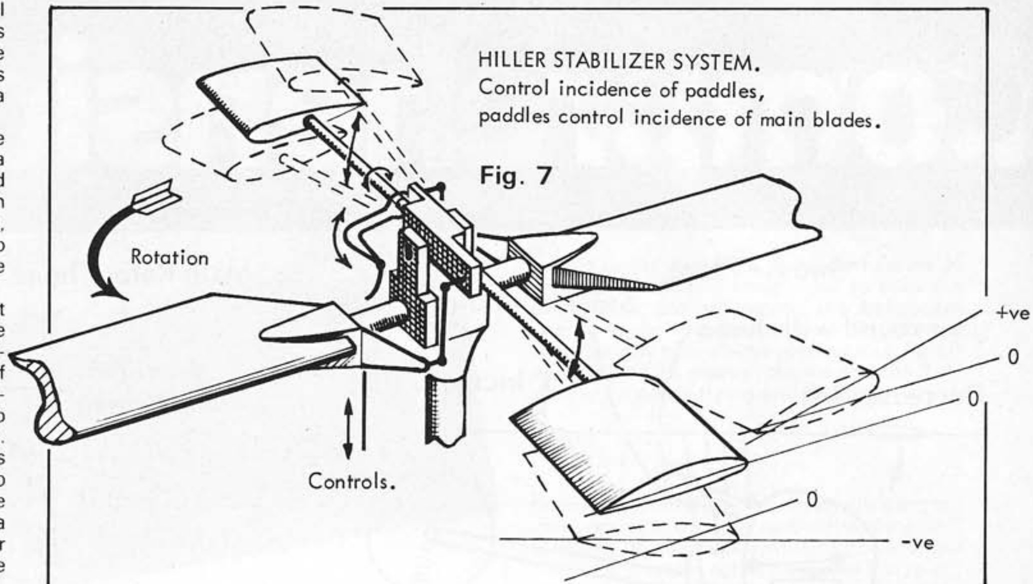


Fig. 5
Control response

simply a weight. This means that the control forces goes straight to the fly-bar and there is no aerodynamic damping built in as with the Hiller. More often a mix of the two systems is used, utilising the weight of the paddles as a Bell system weight. Refer to Fig. 8.

Another factor affecting the response of the helicopter to a control input is 'teeter'. This is a see-saw arrangement at the rotor head allowing the rotor to tilt. If it is quite free then the control over the airframe is quite different, like holding a weight on a string compared to the weight being sprung or damped, like having the weight on a wire.

The 'teeter' can be replaced by flexibility at the blade mounting, but there must be some 'give' to allow for blade oscillations with rotation. The blade swinging in the direction of flight, with forward speed added to its rotational speed must be allowed to move up without vibrating the airframe too much. Putting collective control onto the blades complicates the levers quite a lot, sufficient to know that that is what they are doing. You are now well on the way to 'comprehending a 'copter', so I will leave you to digest all that for this month, and the next part will give a guide to building and market survey.



HILLER STABILIZER SYSTEM.
Control incidence of paddles,
paddles control incidence of main blades.

Fig. 7

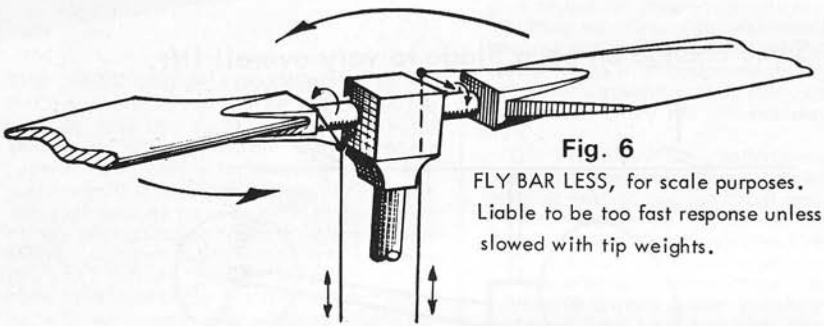
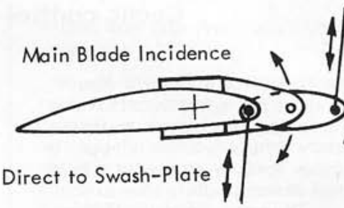


Fig. 6

FLY BAR LESS, for scale purposes.
Liable to be too fast response unless slowed with tip weights.



BELL-HILLER
MIX STABILIZATION

Fig. 8