THE MODEL 'COPTER

By ROY L. CLOUGH, JR.

Roy's Little Infant job (AT Sept. '52) in flight. Damper fins have been removed and rudder turned over. Model will fly steadily forward, descends via auto-rotation pitch changes.

Roy's continued research into the whirlybirds has produced some fine models including the first truly successful stable co-axial type. This is fascinating stuff,

In our previous series of articles, ("What's the Score on Helicopters?") the writer tried to present a simple basic understanding of the major forces involved in a rotary wing flying machine.

We saw that the problem of flight stability largely resolves into integrating the natural gyroscopic forces of a rotating system with its aerodynamic characteristics in such fashion that a reaction by either tends to maintain the positional integrity of the system with respect to the rotor mast.

This, in the practical application, requires a certain amount of independence between mast and rotor in order to prevent immediate displacements from setting up a chain reaction of self-aggravated wobbling, and a certain amount of interdependence in order that control may be effected, or imposed upon the rotor, and that the mast shall serve as a reference point, ruling the me of rotation of the rotor.

Thus it becomes quite simple to design a vertical-lofting or hovering model, by simply arranging the rotor to feather along its longitudinal, or span wise axis and by hanging the hub in a gimbal which permits a seesawing action, and positioning the blades by means of a flyweight or paddle bar so they will not roll over or develop flutter in a chord-wise plane A rotor such as this is said to be independent, for if all bearings are free it will rotate in its own optimum plane regardless of the position of the fuselage, or mast.

This is fine for an indoor model where gusts are not a factor, and when it is not desired to obtain forward flight. However, the completely independent rotor is not desirable, even for model work, because it has no reference point from which control can be effected. (In the practical sense it is well to point out that a completely independent rotor does not exist; there is always some friction in the pivots and gimbals which tends to position the blades at 90 degrees to the mast, but this residual friction is seldom much in a model) Therefore, we must build in a small amount of friction, either by making the gimbal fittings a bit stiff to begin with, or by providing a drag of some sort, which can be adjusted. When this is done the model will fly forward by simply changing the C.G slightly, since the reaction of the rotor, in seeking to justify its position with respect to the angle of the mast and aerodynamic pressures, will result in cycling pitch.

This is the simple way of doing it and it works quite well for models. By judicious use of a small weight arranged to slide fore and aft, the model will climb vertically or by forward at a fast clip in satisfactory fashion. By reference to the previous articles, note that sidewise flight can be obtained by raising or lowering the torque prop axis, or alternatively the weight can be attached to a wheel strut Keep this trick in mind, later, when building gas models, you may wish to position the gas tank in such fashion that the attitude of the model changes in flight; as for example, take-off directly into forward flight with the speed decreasing as fuel is consumed and with let-down in autorotation vertical.

Cyclic control of the rotor is a bit more complicated, but not greatly so, and undoubtedly it will eventually replace C.G shift control except in the simplest models. This is particularly true when we consider the advantages of such a system in contest flying.

A cyclic control system means having a control which can be moved to secure flight in any desired direction, without changing ballast, by altering the pitch of the rotor blades for a segment of their sweep around the circumference of the "disc "

The type of cyclic control we are interested in for model work is the so-called "indirect" or reactive control, in which the linkage is not directly attached to the rotor, but to an intermediary point from which the rotor is controlled. If we tried to attach the cyclic mechanism directly to the blade roots, and connected the other end of it to the fuselage, we would find that this would freeze the system, resulting in a stiff rotor and destroying the stability we gained by freeing the rotor from the mast in the first place

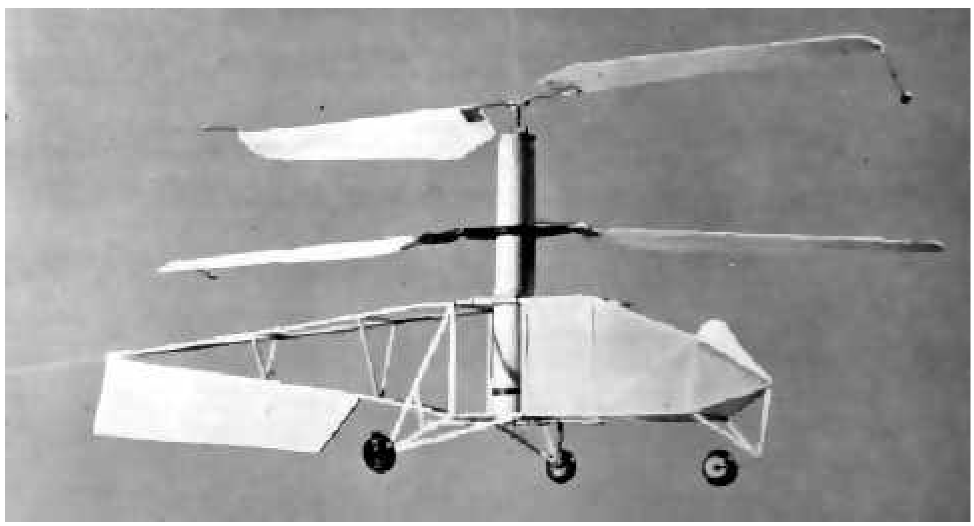
Therefore we must control the rotor from some point not rigidly attached to the fuselage. With the Bell system, this is the Young fly-bar control (see sketch). To work this connect the fly-bar to the longitudinal pivot with a jointed lever which can be cyclically pulled inward at the joint, thus changing the angle between the fly-bar and the blades, for a segment of each revolution The reaction of the blades to this deflection gives cyclic control.

The Hiller Paddle system (see "Rotor-matic" sketch) uses two short wings set upon a cross-arm, which is attached to the central pivot. The angle of these wings or paddles may be changed through a simple scissors type linkage, which is attached to a swash plate. When the swash plate is tilted the angles of the paddles change in rhythmic cyclic fashion with each revolution, and the rotor blades' reaction to this produces a longitudinal rolling of the rotor, which results as cyclic pitch. This system is very simple, as is the Bell, but in both cases avoid any considerable play in the linkages since this may result in excessive wobbling and erratic control. However, for most small models this may not be critical because of the strong damping effect (scale effect) present in models.

As a footnote to these two systems we can add that it isn't strictly necessary to duplicate the control systems of the originals in order to get satisfactory performance. Here is a simple dodge, which judiciously applied works most effectively Build the rotor, with its paddle beam or fly-bar in the simplest fashion and simply stick a wire up from the fuselage in such a way that the cross-arm bumps it gently at the same point every revolution Presto' The reaction gives you cyclic control.

Remember, however, that this is control by unstabling—the bumper wire should be quite flexible or the fuselage may sway excessively, and. while it sounds very simple, and it is, it can get out of hand by displacing the rotor too far if the jolts are too heavy.

Tandem rubber job. Rotors are Young fly-bar type; Power transmitted through bevel gears at each end of long motor which equalizes thrust. Brake on one rotor permits forward flight.

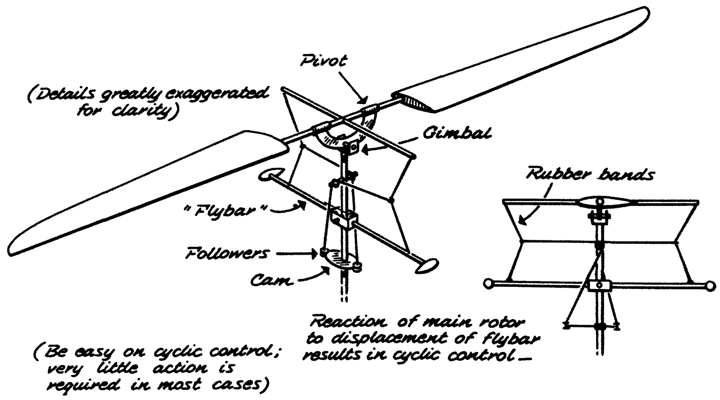


Co-ax close up. Dimensions not critical, but if large version is built top rotor should be hung In gimbal since tension of heavy rubber motor may not allow sufficient see-saw.

In an effort to develop a system, which would lend particular emphasis to the qualities desirable in model helicopter work, we have designed a two-part series of rotors, which we term the "bungee-dynamic series."

These rotors cover a wide field of application and include power delivered at the hub and power applied at the tip, which means the series covers rubber, internal combustion, rocket, pressure jet and ducted fan configurations In the middle of the series is our special pride and joy—a system which we believe to be the first truly successful, inherently stable, co-axial rotor arrangement, which positively controls the ancient problem of rotor clash

The basic rotor and its derivations are shown in the drawings accompanying this article We start with a two-bladed rotor (see sketch "Basic Rotor Design—Cyclic Control") which is see-saw mounted in gimbals and free to pivot, within limits in a span wise fashion This rotor is of the first part of the series, which we term "locked "

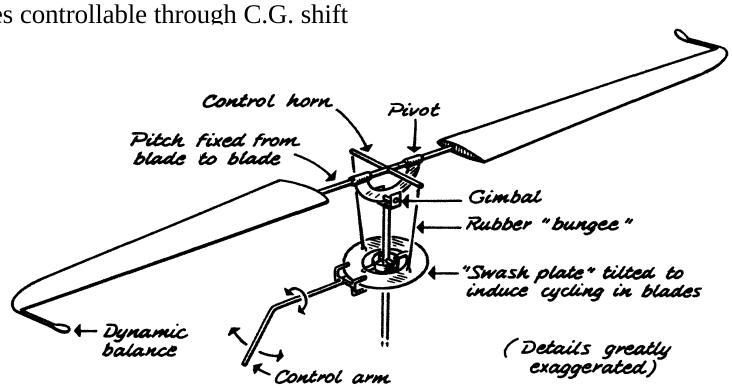


Model Interpretation of
YOUNG "FLYBAR" CONTROL

By this is meant that the pitch of the rotor blades relative to each other is Axed at all times (as in the Hiller) except as subject to collective pitch control. The blades are stabilized by means of dynamic weights, which protrude tangentially, about one chord length ahead of the Blades' leading edge. There is no fly-bar or paddle-beam; instead, we have a double horn to which are affixed two snubbers, or "bungees" which run to a swash plate which may be tilted to secure cyclic control. These elastic connectors replace the inertial damping forces of the fly-bar, or the aerodynamic damping of the paddle beam, and are simpler to work with than either of these.

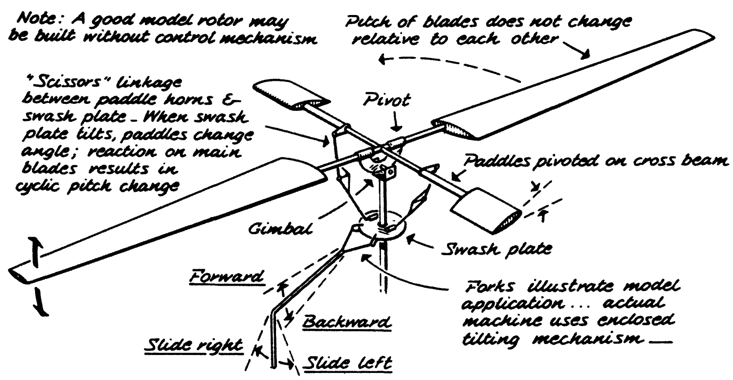
Because of the concentration of mass in the rotor tips we can use much lighter blades successfully— meaning balsa instead of birch or pine, and the corrective force is balanced at all times, exerting a positive, yet gentle steering action upon the system. This is the cyclic control version.

And if we desire extreme simplicity we just move the bungee connections 90 degrees, that is, amx them to the span wise pivot to exert a continuous corrective force upon the seesaw axis, and the machine becomes controllable through C.G. shift



BASIC ROTOR DESIGN – CYCLIC CONTROL
Bungee – Dynamic Series

From this point of departure we proceed to multi-blade applications —we may build a four bladed rotor simply by doubling up what has just been described, except that of course only one mast attachment, or swash plate will be required.



HILLER "ROTOR-MATIC" CYCLIC CONTROL

In order to build a stable co-axial machine, using rubber power as an example, we merely construct the lower rotor attachment with span wise pivots and attach it rigidly, that is, without see-saw gimbal to the drive tube with a bent wire "lead-around" interconnecting the blades.

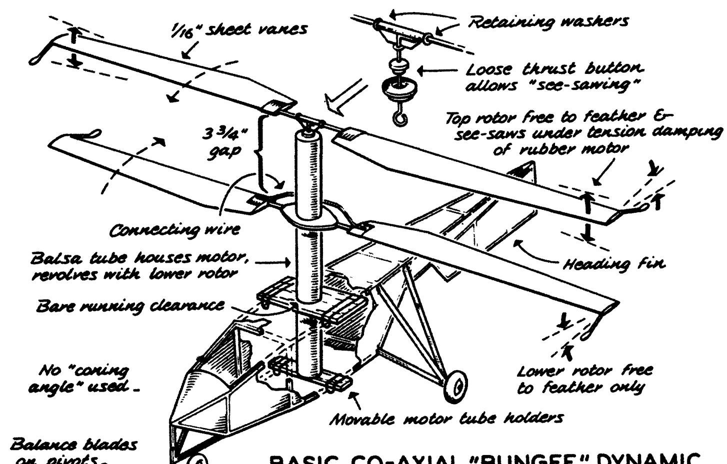
The upper rotor must be free to see-saw about ten degrees up and down, which allows plenty of leeway against clashing with moderate gap, and this may be accomplished, in a rubber model, by simply rounding the edges of the thrust button—the tension of the rubber motor being sufficient "bungee" action.

If we build a gas model, with shafting, then of course the upper rotor must be mounted in a gimbal and snubbed with rubber bands, permitting damped motion between stops. Now with such an arrangement as this we secure forward flight by trimming slightly nose-heavy. No other cyclic control is required. For heading control a simple fin, as shown, corrects for the downwash, which may tend to rotate the fuselage the same way as the lower rotor. The sketch ("Basic Coaxial 'Bungee' Dynamic"), incidentally, is all the plan needed by any reasonably able builder to turn out his own machine in short order.

One note on adjustment: The down wash’s tendency to rotate the fuselage is corrected by bending the fin. However, after doing so the machine may show a tendency to drift sidewise. This is due to the reaction of the air against the fin, so just move the rotor mast a trifle off-center to correct it, countering the side thrust with a bit of off-center lift.

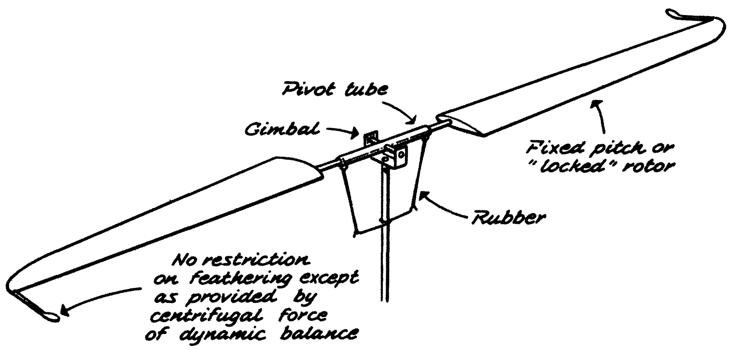
The second part of the series includes the unlocked rotors. These rotors may be built in any number of blades, from one, with counterweight, through two, three, four, five, or as many as desired. In the unlocked blade series (final sketch) we run into "dynamic pitch." By this is meant that the blades have no particular fixed pitch relative to each other or the mast, but seek pitch angles individually according to the speed of rotation. This is accomplished by positioning, the dynamic balances well below and ahead of the leading edge of the blades, which causes them to ride up under the action of centrifugal force until a balance is reached between the force exerted by the up-thrust of the counterweights and the aerodynamic pressure on the blades.

It is important with this system to locate the hinge line knowingly to obtain high efficiency, but in the practical application we find it works well even with rough approximation of position. The hub attachment of this system to the mast may be quite varied, from a simple rubber disc which functions as a universal joint, to separate snubbers for each blade pivot. This system gives us a built-in and fully automatic cyclic and collective control. Auto-rotational letdown is fully automatic (with a simple ride-out dog release on the mast) which solves a mechanical problem that can be knotty, and cyclic control is merely a matter of shifting the C.G.



BASIC CO-AXIAL "BUNGEE" DYNAMIC
Inherently stable configuration

This machine believed to be fist truly successful stable co-axial type to solve problem of control by C. G. shift and eliminate problem of blade clash. Could be flown with bungee cyclic control to lower rotor only. Model has been kept simple, no collective pitch used; hence letdown must be under residual power. Dimensions: Disc: 24". Mean chord; 1½ " Tube: 7½ " x 1" dia. (1/32" sheet). Fuselage: 3/32" sq. stock 18" long. Weight: 2 oz. Performance: Altitude: 20 ft. Forward flight: 25-30 ft. at 5-6 ft. altitude (Hand-wound). That's high performance on three loops of 3/16" flat!



C. G. RIG CONTROL
Bungee-Dynamic Series

There is just one precaution to be observed with this system in securing forward flight by C.G. shift. It is better to have the snubbers a bit too limp than a bit too tight, and don't overdo the nose-heaviness. The reason for this is that a condition of "over-cycling" will occur if the snubbers are too tight, that is, the blade pitch will adjust itself too rapidly, accelerating the cyclic action, meaning the model will nose down and dive into the ground.

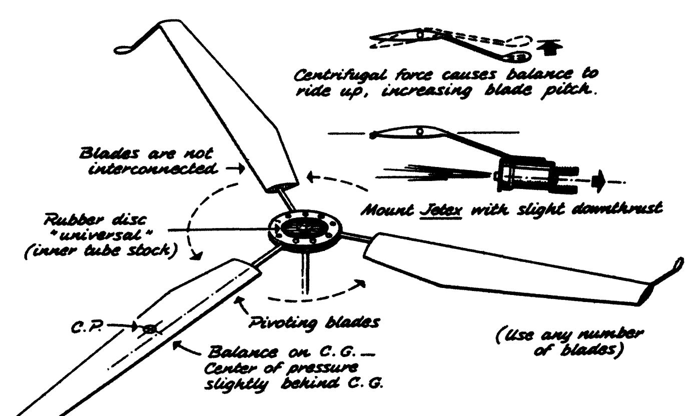
If the snubbers are too limp the worst that will happen is that the rotor will tilt backward and forward flight will proceed at a snail's pace. This adjustment is by no means highly critical—the admonition just given is of the same order as instructing a builder of conventional planes not to tilt up the leading edge of the stabilizer too far if he doesn't want the model to dive in.

Whatever system you elect to use, try to make your selection knowingly, based on what you want to do with it, compared with its characteristics. For example, the unlocked bungee-dynamic rotor is perfect for jet power, quite good for gas engine, and a complete bust for rubber—because it wastes too many revolutions in getting started. Rubber is a special case anyway, since the number of turns is always strictly limited by dimension, which isn't at all true in the case of jet or gas power.

For rubber models the best bet is to skip autorotation and bring the model down under residual power, or if you are the ambitious type, fly with a locked rotor, which unlocks and de-pitches itself when the power is exhausted.

Once again, we strongly recommend that the first model should be rubber power—it will give you a wonderful opportunity to get the "feel" of rotor wing flying, without introducing a lot of distracting complications.

(To be continued)



"UNLOCKED" BUNGEE DYNAMIC SYSTEM
Pitch is function of rotational speed
✓ Best for jet – Good for gas – Poor for rubber... Cyclic & collective pitch, fully automatic

With full size choppers more and more in the news this informative series will get you started off on the right foot in building your own model helicopter

CLOUGH'S CONCLUDING COMMENTS CONCERING 'COPTERS

By ROY L. CLOUGH, JR.

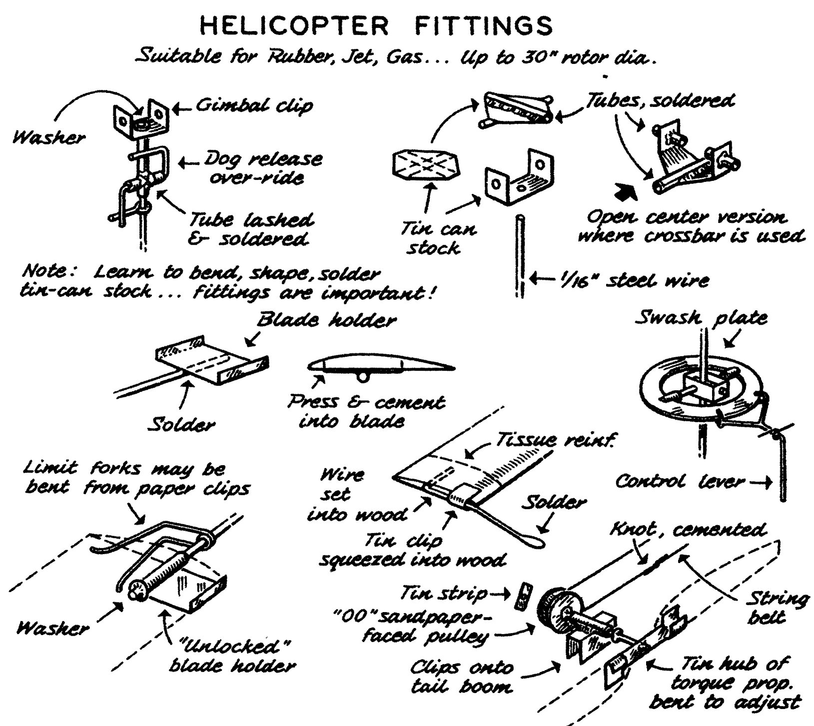
Once the reader has flown a rubber job successfully and wants to build a model capable of really big performance, it will be necessary to switch to gas engine or jet power. Let's deal with jets first. The Jetex motor is an excellent source of power for model helicopters; generally speaking two will be used, although it might prove practical to use up to four, although this complicates the problem or getting a number of motors ignited at the same time in order that the charges bum evenly to preserve the balance of the rotor. For that matter a one-bladed rotor, with the blade balanced by the motor, can be used very successfully—which I know sounds a bit contradictory, but the practical fact is that the burning charge getting out of balance in a one-bladed system is considerably less critical than, say, two or three charges consuming at an uneven rate in a multi-blade system.

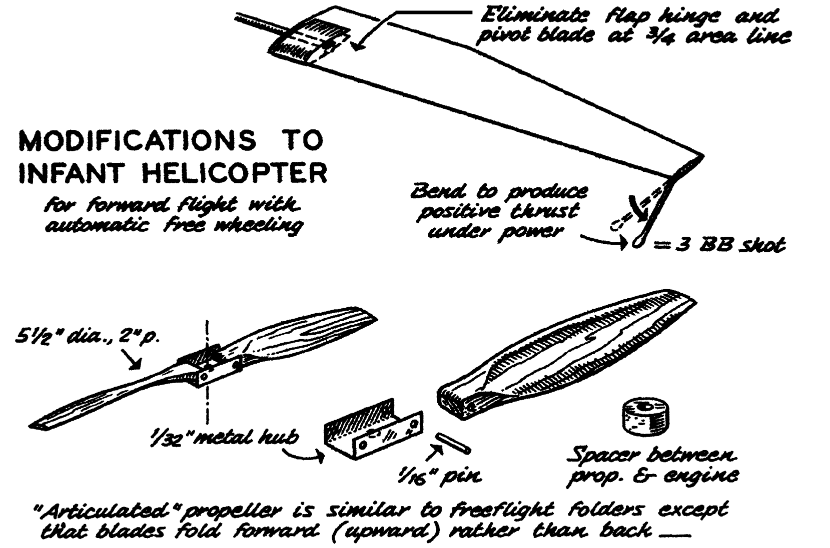
The reason for this seems to be that the thrust output of the Jetex varies according to the amount of fuel left at any given instant, and peaks at the last few seconds. Thus in a multi-bladed system we have several thrust peaks, and if they do not closely approximate each other the thrust load on each blade may vary widely, meaning considerable pitch variations in a dynamic pitch rotor. In a one-bladed, single-motor job, the thrust variation is inherently "in gear" with the single rotor blade. Unbalanced centrifugal loads due to fuel, charge consumption result in a narrow period of oscillation of the rotor mast, but since this vibration lies in a span wise plane the practical effect is not serious—for a model.

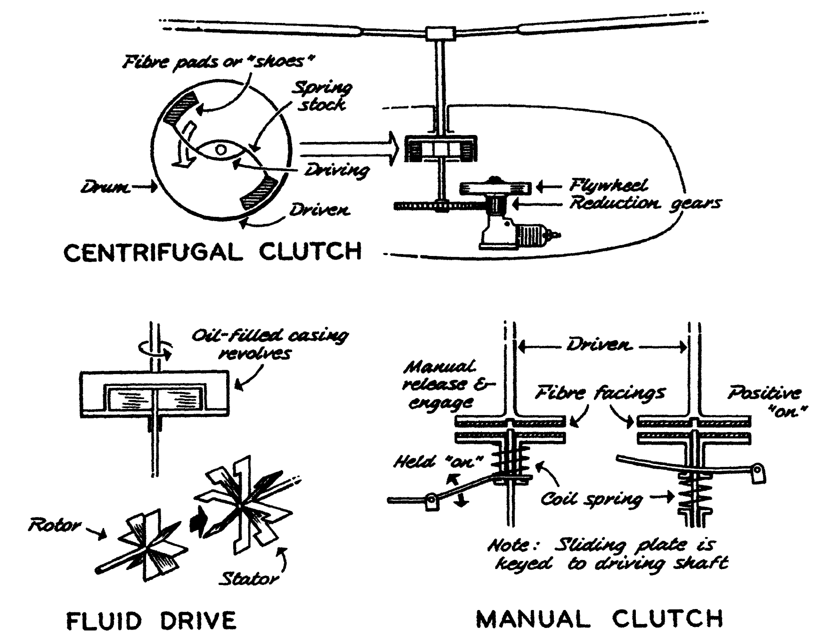
The jets replace the dynamic weights of the unlocked type rotor, being mounted below and ahead of the* rotor tips. The angle of thrust should be slightly downward, and it may be necessary to provide up-pitch limit stops to facilitate getting the rotor going. The balance of the rotor blade on its pivot should be slightly nose heavy with fuel charge aboard. Note this, because of the position and forces exerted in this type of rotor it is not necessary to use stable blade sections— use the highest lift cambered section you deem practical and don't worry about pitching moments; the orbiting of the tip weight clamps the blade firmly at whatever pitch the speed and dynamic settings call for, and transition into auto-rotation after burnout is smooth and easy with a good let-down.

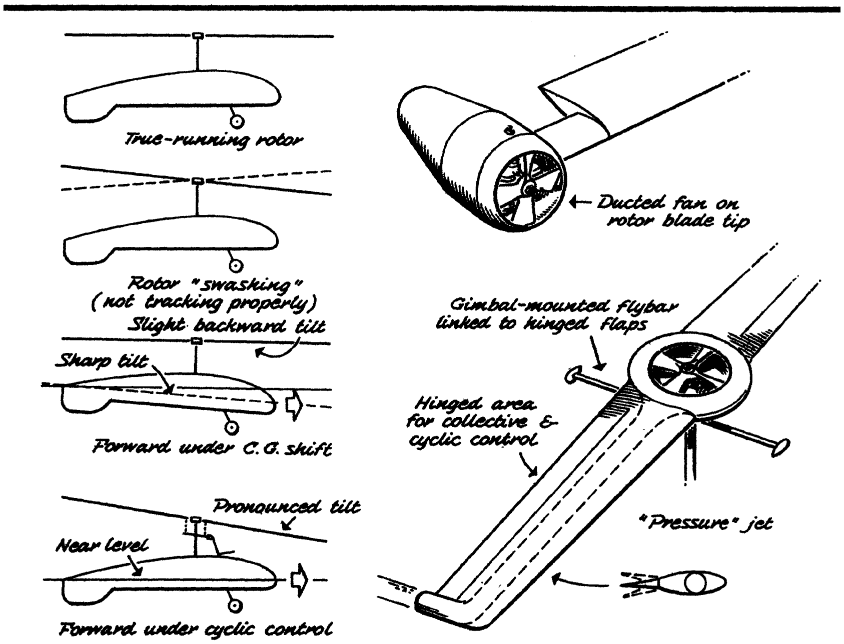
The adapting of a tiny internal combustion engine that screams out its very high power rating at speeds in excess of 10,000 rpm to rotors, which run under 2,000 rpm, offers an interesting challenge. This may be achieved in a number of ways.

The classical method is to reduce the speed and increase the torque through reduction gears. These should be of at least 5-1 ratio and there must be some sort of clutching arrangement between the gears and the rotor, otherwise it may prove to be impossible to start the motor, or gear teeth will be stripped by the high starting loads. A clutch satisfactory for this purpose should en-









gage smoothly and positively, and may be either of the manual engaging type, in which the release of a lever holding two faces apart permits them to be forced together under spring compression, or of the centrifugal type which engages automatically with an increase in speed. See center sketch on this page.

Clutches require access to tools and a knowledge of machining operations, but this should not deter a really determined builder. The ideal thing, of course, will 1% for some hep manufacturer to read this and produce a small lightweight clutch-reduction-gear unit at a reasonable price. Experience in the model racecar field indicates this can be done.

Reduction can be had by means of pulleys and belts, with a sliding engine mount serving as a "clutch," but belting is not the most satisfactory power transmission. I have flown a K&B .049 job with belt reduction, briefly. The belt begins to slip after a time and the model descends. For this job I used a round belt running over wood pulleys at 4.5:1 with a heavy application of a good belt dressing. The problem seems to be that the high speed of the engine pulley soon glazes the belt, causing excessive slippage. Howard G. McEntee has suggested using small Vee belts. This might work a lot better due to the better traction offered by such a belt, but obtaining Vee belts and pulleys small enough for the purpose has been a poser. When using belt drive with gas engines, great precautions must be taken to keep fuel spray 06 the belt and pulley. A baffle between the shaft and intake tube and exhaust ports is highly necessary, and frequent wiping of oozed oil from the end of the main bearing is a must.

Another angle, which I've been experimenting with lately, is to use a torque converter between engine and rotor. A torque converter is simply a specialized type of fluid clutch and operates without any direct connection. I use a small high-speed rotor connected directly to the engine shaft, running inside a larger rotor, which is connected, to the helicopter end. The casing is filled with castor oil. This device, in bench tests, appears to transmit a fair amount of power—with redesigning and a bit of finagling it should be quite evident. However, I have had a lot of trouble due to overheating, which causes some of the oil to ooze out past the bearings, and that results in lowered efficiency of power transmitted.

In any event power for the torque prop isn't hard to arrange. Turn this about two to three times as fast as the main rotor by means of a simple string belt running over sandpaper-faced pulleys. Remember that the torque prop should stop when the model goes into autorotation in order that it won't swing the tail around in a circle on the way down. Simply attach the driving pulley between the clutch and the ride-out dog of the rotor. We mentioned this before, the rotor release. Whether or not you plan for autorotation you must have a rotor release, which permits the rotor to override when the power quits. (Continued on page 66)

Clough on 'Copters

(Continued from page 26)

Otherwise the great amount of kinetic energy stored in the spinning rotor may twist off a shaft or strip gears or even shatter the blades if the system suddenly freezes when the motor stops. This unit can be incorporated in the function of the clutch or may be a separate item in the rotor hub: I prefer it to be separate since this simplifies the operation of stopping the torque prop when the motor quits.

Now, how about really simple gas motor hook-ups, requiring no gears or clutches?

Sure, it is possible and practical, and may be accomplished in several ways. One way is to use torque reaction drive—such as in the little Infant powered job of the previous article. However, don't use the primitive semi-articulate rotor system of that model, but build your rotor along the lines discussed in the previous issue for the rubber co-axial job, except use unlocked blades on the big rotor to get a good auto-rotational descent, and locked, but feathering blades on the small rotor attached to the engine shaft, say in a rubber mount, to permit a small amount of see-saw action. Because of the strong downwash of the small rotor a brake or fin is required to prevent fuselage rotation, but for simplicity this is hard to beat.

Propelling the rotors at the tips by means of propellers has been suggested many times by many people. It seems simple, but it can be very troublesome. The reason is two-fold. First, the props act as gyros running in a tight circle—meaning the engine shaft tends to twist upward or downward, depending upon rotational direction of the blade to which it is affixed; second, torque effects may add a bit of complication. You can, however, make such an arrangement work if you use my rotor configuration, the unlocked system, and play off torque and gyro effects against centrifugal loads. Use very light driving props of as high a pitch and small a diameter as possible, and place the thrust line of the engine angled toward, or away from, the chord parallel, depending upon which way you run the rotor; to help compensate for gyroscopic twist.

In connection with this, note that the props can be shrouded, converted into ducted fans, with stator vanes to eliminate torque effects. This makes a neat looking job, but auto-rotation suffers heavily from any bulky excrescence at the rotor tips.

Another method of drive is to use a pressure-jet configuration. Mount the engine in the fuselage, or in the rotor, as a blower supplying air under pressure to jet nozzle* in the tips of the blades. This system isn’t terribly efficient, but the great power-to-weight ratio of modem small engines will let you get away with it if you are careful. This produces very dean structures, smooth blades, and excellent auto-rotational and control characteristics—so in a way it might be said that the system is efficient after all.

There is one angle in designing pressure jet jobs, which I am not too happy about. From the standpoint of efficiency it is a fine thing to have the cylinder head and exhaust opening inside the duct, that is, behind the fan, in order that the motor may cool better, run faster from the supercharging effect of air being rammed into the intake, and the pressure augmented by the heat of the cylinder and exhaust gas efflux.

However, the oil sprayed by a 2-cycle engine tends to gum up the works and mess up the blower ducts. Tentatively I run my jobs that way anyhow and clean the ducts after each flight with a wad of cotton tied on a string, which is pulled through. Old-fashioned but effective.

I have a grave suspicion, nevertheless, that the drag of the air against oil-coated tubes may cancel out the gain produced by exhaust heat-gases. Have you, for example, ever noted the ripples and ridges that develop on the surface of an oil-coated wing exposed to prop blast? That means quite a bit of drag, and it seems logical to assume that the same condition obtains within the pressure ducts of a blower jet system. While it is true that a lot of the oil is blown out with the air and by centrifugal force, a lot of it still sticks to the inside. And that isn't so good. Probably, in the interests of tidiness, it might be well to advise piping the exhaust into the open, and eschew the theoretical benefits in favor of the practical considerations.

I have tried to present as many applications, suggestions, and observations as space will allow, in the belief that model builders win find more of value in something like this than they would in an article which dealt with the construction of one particular model and consisted largely of instructions to glue stick A to stick B and so forth. This 2-part article, together with the previous series covers, I fondly believe, enough of the basics of helicopter principles to permit anybody to turn out a very satisfactory job with a minimum experiment. Try it and see for yourself!