



ADVANCED MULTI DESIGN . . .

SOME time ago fellow WORKS (Western Ohio Radio Kontrol Society) club member Ray Nugen and I decided we were a bit weary of the rut that R/C multi model design appeared (to us) to be in, and decided to explore the virtues of swept wing design. Obviously this was not virgin territory since a number of swept wing designs had been built and flown by various individuals with various degrees of success. Almost universally, however, the opinion appeared to be that such designs were a bit nasty in stall characteristics and required considerable proficiency in piloting skill in order for the airplane to survive for a reasonable length of time.

Since I have long been enamored with the beauty of swept wing full scale aircraft, and being possessed with the desire for something different, we plunged in. After dusting off the aero texts and doing a little bit of horse sense reasoning we were encouraged to continue the venture.

Swept wing design for model aircraft would appear at first thought to be entirely unnecessary. Wing sweep is employed in full scale aircraft design to delay compressibility (shock) effects

and thus achieve a lower drag design for high speed flight. This of course is not required in model aircraft design since we are flying at no such speeds. It is also a means used to achieve a very stable design for rough air conditions which of course is of interest to modelers.

There are other desirable flight characteristics afforded by wing sweep in which we should be interested. First of all, wing sweep provides a dihedral effect which, essentially, functions equally both in the upright and inverted positions. The dihedral effect obtained is a function of sweep angle, angle of attack of the wing and wing lift coefficient (unit wing lift defined for specific flight conditions). Dihedral effect is defined as the rolling moment created due to sideslip (yaw). In a sideslip or yaw, the leading wing will create greater lift than the trailing wing since it will be flying at a higher effective angle of attack (due to the dihedral), thereby creating a rolling moment. The rolling moment created will increase for increasing dihedral angle. This is why we see rudder only ships with much more dihedral than multi designs, since the rolling moment

necessary to establish a turn must be commanded by yawing the airplane with the rudder. This dihedral effect will be somewhat invariant with change in wing angle of attack for straight wings but will change rapidly with angle of attack for swept wings. It is interesting to note that airplanes with swept back wings will have an increasing dihedral effect with increasing lift coefficient (angle of attack), while airplanes with swept forward wings will have a decreasing dihedral effect with increasing lift coefficient. The variation of dihedral effect with wing sweep is a complex relation and one that is almost impossible to estimate quantitatively by any analytical approach. We have therefore resorted to the experimental approach in our model designs. In essence, the higher the angle of attack and wing sweep the larger the dihedral effect. What we are obtaining is increased lateral stability in flying maneuvers which require increased angle of attack such as inside and outside loops. This is very desirable, of course, since the airplane will "groove" or track better, and will groove equally well in both inside and outside maneuvers. This improved di-

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hedral effect is also obtained at no sacrifice in roll characteristics since these maneuvers are flown at low angles of attack. We have found that inverted maneuvering is "duck soup" due to the increased lateral stability while inverted.

An additional effect of wing sweep is a change in stall characteristics of the airplane. Most of you undoubtedly have heard that swept wing airplanes have a vicious stall and will snap roll at the drop of a hat. To an extent this is true, and it is precisely this characteristic that we have been trying to exploit. A large number of current model airplane designs are extremely stable in order to assure smooth pattern maneuvers. This stability requires a sacrifice in spin characteristics unless excessive control movement is used to accommodate the airplane design deficiency. These airplanes also will not snap roll easily (some not all). A snap roll is essentially a horizontal spin. Unlike a conventional spin, it is usually entered at velocities above normal stall speeds. An intentional snap roll is commanded by application of full up elevator and rudder which causes the airplane to enter a high speed stall accompanied by simultaneous rotation.

The prime objective of the simple single snap roll is to exit the snap at the same altitude entered and in a horizontal level attitude. The difficulty of the maneuver is due to the stalled condition of the airplane and the rapid rate of rotation. There are many variations of the controlled snap roll such as a half snap, double snap, snap on top of a loop, snap from and to knife edge flight, etc.

There is also a maneuver known as the uncontrolled snap roll which has been the undoing of many a modeler. This occurs in some aircraft due to a number of things such as high wing loading, aft C.G. location, excessive control movement, excessive control rate, and, yes, sloppy flying. It might be worth explaining the uncontrolled snap at this point. I have flown a number of models, my own included, which exhibited this tendency. It has *always* been traced to one or more of the reasons previously cited. The snapping tendency has always been cured by either moving the C.G. forward or by decreasing the control movement and rate. You will say that the control surface rate of a reed system equipped aircraft is fixed since it is fixed by servo

speed, and I would have to agree with you. However, the airplane *pitch* rate is the important control consideration here and this can be controlled by varying the effective elevator deflection angle by "beeping." A number of models have been saved by being very cautious in controlling the pitch rate and thus preventing high speed stall. You might ask, why the airplane snaps when it stalls under such conditions. This is due to the fact, that, unless the model is absolutely symmetrical (equal wing lift at all angles of attack and airplane attitudes) a rolling moment will be introduced at the stall point since one wing will stall before the other. It usually isn't a violent rotation and can be handled if you are on your toes. Control rate is no problem in proportional flying of course, since the flyer can easily provide any rate desired by simply varying the control input rate at the transmitter. This is obviously limited by the servo speed limitation and ideally the servo speed should match the transmitter input capability, but, then this is another subject.

It is my feeling that some of the most beautiful (and difficult) maneuvers per-

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formed by full scale stunt aircraft are the snap roll maneuvers. One has only to witness a performance by Bevoe Howard and his Jungmeister to reach this conclusion. It is my contention that these types of maneuvers should be added to the AMA pattern since it places a larger demand on airplane design and on piloting skill. This appears desirable since we are constantly seeking growth plus a greater challenge in our sport.

A swept wing design stalls abruptly for a simple reason: the tips stall first, permitting a rapid movement of the center of lift forward on the wing. This of course creates an additional pitch up moment and thus a divergent situation. This characteristic can be modified by a change in wing sweep and by devices which delay tip stall such as sections that stall at a higher angle of attack or by tip "wash out." Wing "fences" will also tend to delay tip stall. For a given wing area, wing sweep also places the center of lift closer to the fuselage. In rough air, this gives us increased sta-

bility since the roll moment induced by gusts is decreased. As you change the angle of attack of a wing the lift changes, of course. Typically, the increase in lift for a straight wing for a given angle of attack change will be appreciably larger than for a swept wing. This simply means that when disturbed in pitch by gusts, the lift will change less for a swept wing resulting in a smaller flight disturbance and thus a smoother flight. This characteristic also contributes to smoother or "softer" pitch maneuvers when commanded.

One additional benefit is increased rudder control. Most conventional designs, which utilize minimum dihedral, control very poorly with the rudder. About all that occurs with application of rudder is a yawing moment (or side slip) with little induced rolling moment. I've seen several multi's bite the dust with loss of aileron control since the rudder would not command the necessary rolling moment to bring a wing up. Swept wing designs have very good rudder control and this characteristic saved a ship for me this year when an aileron servo went out. Rudder control is effective since, as the airplane is yawed by the rudder, the advancing wing generates substantially more lift than the retreating wing. This is due to the fact that wing lift is also a function of wing sweep. For a given angle of attack the lift will increase as the sweep is reduced. Effectively this is occurring in a yaw or sideslip since the advancing wing is flying at a reduced sweep angle in relation to the relative wind. The net result is a good rolling moment in the desired direction.

There is another feature of swept wings which is a product of their equal lateral stability when either upright or inverted. This phenomena is roll rate. A conventional wing with dihedral has a higher roll rate when inverted than when upright simply because it has less lateral stability when inverted. This means that the roll rate of the airplane will change when performing axial rolls. It is particularly noticeable when flying very slow rolls with proportional equipment and aileron deflection must be reduced while inverted to maintain the same roll rate. This does not happen with swept wing designs. It is a very apparent phenomena which I have noticed in flying the modified Taurus (with 5 degree sweep) and the "Phoenix" or "Expinkamental." Slow, constant rate, axial rolls are *much* easier to perform with the more highly swept wing airplanes.

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THE PHOENIX

FELLOW club member Ray Nugen and I have been experimenting with swept designs for over two years. In all, we have constructed 8 ships with wing sweep ranging from 5 degrees to 23 degrees per panel. We have flown the designs with both reed and proportional equipment. The designs (Ray's and mine) have been basically similar in proportions but different in size. My ships (named Phoenix) have had wing areas from 700-720 square inches. Ray's ships (named Expinkamental) are larger, having about 790 square inches. Both airfoils are originals and quite similar except that I have been using about 17% thickness and Ray about 13%. The airfoil used on the Phoenix wing is progressive to a thicker (percentage) section at the tip in order to delay tip stall and "soften" the stall characteristic of the wing. One ship used in the program, other than the original designs, was a modified Taurus in which the wing was swept about 5 degrees per panel. No

appreciable change in flight characteristics could be noted with this design. However, spins were difficult with this airplane and it showed absolutely no inclination to snap roll.

We found very early that care must be used in locating equipment in the airplanes since the center of lift is quite far aft on the fuselage. Conventional placement would create a nose heavy condition. Batteries, for example, should be mounted aft of the servo installation, and servos should be placed as far aft in the wing bay as possible. Care must be exercised with regard to weight in the nose since these airplanes tend to be nose heavy. You will notice in the Phoenix design that the nose moment appears to be quite short. This has been purposely done in order to alleviate nose heaviness. The effective nose moment is not short, however, since this is measured from the prop to the center of lift.

We have found these airplanes a

pleasure to fly. Not only groovy, stable in rough air, and spinning and snapping demons, but quite pretty to watch. Inverted flying is a pure pleasure and is every bit as easy as upright. Care must be exercised to keep the aircraft above stall speed (except when commanded) since the stall is abrupt. I definitely would not recommend these designs to the multi beginner. I don't mean to imply that the airplanes are vicious, since they most definitely are not. They will tolerate a reasonable amount of horsing around on the approach at slow speed, but they are a little less tolerant to sloppy flying under these conditions. One must only remember the most important axiom of full scale flying—maintenance of airspeed is the prime requisite for safe flying.

The trim is "peaked" when the C.G. is as far aft as tolerable for safe flying since they will snap and spin most easily under these conditions. This is a good trim premise for any design, for that

matter, since required elevator control deflections are decreased, and consequently, control drag is also decreased. When properly trimmed the design should never fail to snap or spin.

The design shown is the Phoenix I. This ship has the maximum sweep used in the series and in my opinion is the better of my designs since it is a bit groovier, very stable and has nice soft control response. Since the design is intended only for the proficient flyer (and builder) complete construction details are not given since I feel this would be an insult to your intelligence and ability, and should be left to your own personal preference. A number of the Phoenix I's have been built and I'm sure no two were constructed alike (except mine). Bob Noll of Endicott, N. Y., has even built foam wings for the Phoenix I and I understand he is building a second one with retracting gear, so it's builder's choice. I would recommend keeping the ship light since weight isn't

as important to good windy weather flying as in some designs. Wing loading should be kept down since you will recall that the maximum lift of a swept wing is less than for an equivalent area straight wing.

Using the C.G. location shown on the plans will make the airplane very docile. You may even have trouble making it spin. When you feel proficient move the C.G. aft $\frac{1}{2}$ "- $\frac{3}{4}$ " and note the improvement in spinning and snap rolls. Since no two airplanes ever fly alike I feel it is best to start with a safe C.G. location and work from there. My first Phoenix had the C.G. about $1\frac{1}{2}$ " aft of the indicated location on first flights, and it was a little touchy. Moving it forward made it docile as a lamb.

You may wonder about the wing section shown. It is a product of my contention that airfoil shape is not particularly critical in model design. After thumbing through a lot of NACA (NASA) data on airfoil sections I was

impressed by the "sameness" of the lift slope curve (change in lift with change in angle of attack). The "laminar flow" sections do seem to have a drag "bucket" at small angles of attack which seemed desirable in order to keep the induced drag down during maneuvers. It also appeared that the pitch change required for inverted maneuvering was about the same for most sections, so I sketched a slightly semi-symmetrical 17% thick section somewhat resembling the "laminar flow" types. I couldn't give you wind tunnel data on this section but I know that it works quite well and appears to prove my hypothesis.

Picture "A" shows the 4 remaining ships used in the program. Reading from bottom to top are the Phoenix I with 23 degrees per panel, Phoenix II with 15 degrees per panel, Ray Nugen's Expinkamental with 23 degrees per panel and modified "Taurus" with 5 de-

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The Phoenix

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degrees sweep per wing panel. These models all fly at about the same speed and are all on the light wing loading side.

The modified Taurus has been flown with both Controlaire reeds and F&M proportional. It does not like to spin and will not snap roll. It is bouncy in rough air but is pure pleasure to fly with the F&M proportional system.

The Phoenix I shown is the second Phoenix I that I built since the original was wiped out at the '63 NATS due to battery failure. It (and the first) is powered by a ST 46, weighs about 6 $\frac{1}{2}$ # and has 720 square inches and 23 degrees sweep per panel. It has been flown only on reeds and has the softest control touch of any R/C airplane that I have ever flown (and that covers a lot of territory since 1952). It does remarkably well on the small engine and has no trouble with vertical 8's. More power would help when flying off grass. It does quite well in rough air and flies as easily inverted as upright.

Phoenix II has a ST 56 for power, weighs 6 $\frac{1}{2}$ #, has 700 square inches of wing area and has been flown only with proportional control. It has 15 degrees sweep per panel and is very similar to the Phoenix I except for wing and tail sweep. This ship also flies well but I don't believe that it is as stable in rough air as Phoenix I. It also "grooves" very well inverted.

Ray Nugen's Expinkamental weighs about 6 $\frac{1}{2}$ #, has a ST 56 for power, has 790 square inches wing area and has 23 degrees sweep per panel. You will also note the "dive brakes" on the fuselage which are coupled to the throttle to assist in steepening the descent angle. This is the fourth Expinkamental and is a fine flying aircraft. Rolls very nicely and has never failed to spin or snap roll. It, too, has been flown only on proportional. Previous models were flown with reeds.

Well, there it is. I like bent wings. I hope you do too. If you have questions feel free to write, c/o RADIO CONTROL MODELER MAGAZINE.