XINGU

By KEN STUHR . . . A look in depth at the design concepts and possible construction methods required for the high performance F3B and equivalent sailplanes.

INTRODUCTION

At our local slope, the wind either blows very lightly or very hard. A storm front may intrude, pushing 25-40 mph winds, or some conglomeration of undefined, unpredictable meteorological events may produce pleasant but very light breezes of 5-10 mph. In this latter case, one just has to be in the right place at the right time to capitalize on the resulting smooth lift. Inevitably, one can count on a peaceful and relaxing flight, especially so on warm spring evenings.

So the stage was pretty well set for the design of my new light lift slope soarer. "XINGU" was created with all these considerations, plus a few more, like lateral maneuverability and crashworthiness, in mind. Based on my experience so far, XINGU meets the efficiency goal. It can be outflown, in simultaneous flight, by an Aquila or something else as big and light, but XINGU keeps on flying when the 2 to 2.5 meter floaters are forced to land. Specific claims like "flies in a 5 mph wind" make little sense because of the other variables involved (slope geometry, wind direction, lapse rate) so the preceding seems like the best testimonial. Also, XINGU's airspeed is roughly double that of the others, which means it will do well if the wind picks up. Use of ailerons has proved a great asset . . . they're fun to fly and provide fast and precise maneuvering near the ground. Also, the "elephant-ear" dihedral can be eliminated. The few hard landings experienced have resulted in a handful of intact pieces as the result of the successful crash protection system described below.

Recalling my previous comment on the Dassel, and noting the similarities in size, wing loading, and overall cleanliness with XINGU, I can't help but think that, using a wing section of greater efficiency than that of the Dassel, XINGU would probably make a potent FAI ship as well as slope soarer. XINGU uses the Eppler 387 wing section, which is more efficient, by a few percent, than the infamous E193. Use of foam/epoxy, plywood wing construction makes the near faithful reproduction of the E387 possible and attainable by the common man. The E387 was also chosen because its camber matches well with XINGU's intended flying condition, namely, heavily-loaded cruising at max L/D. Basic (unballasted) loading of XINGU turned out to be 15 ounces per sq. ft. with a wing weight of 14.5 ounces unfinished. Further, experience with the E387's sharp leading edge has proved to me the value of this feature in reducing the viciousness of low-Reynolds number stalling.

Aileron size was dictated by the low drag requirement coupled with one for *adequate* roll authority. By placing the ailerons far out on the wing, minimizing their span and relatively increasing their chord, lower drag due to (reduced) control deflection was hoped for. Sealing the bottom gap, coupled with the insignificant top gap, ensures a very low drag installation.

The fuselage was designed around a long moment arm. This increases boom skin friction drag but decreases drag due to tail download and control deflection. Also, a smaller horizontal tail can be used, thus amliorating the boom area increase. Though this is always a trade-off, it's usually beneficial in sailplanes. The long arm also increases pitch inertia and damping, making the glider less susceptible to unwanted oscillations.

Thus, the efficiency that seems apparent in XINGU results from a variety of sources that might well apply to all sailplanes. A quick inspection reveals no substantial control gaps or holes, no external pushrods, clevises, or horns, no blunt or thick trailing edges, no sagging film covering, but the most important element is one that only you as builder will be able to control. XINGU is as much a builder's airplane as it is a flyer's. Simply, your care and attention are required to produce the maximum efficiency. Lack of it can just as easily negate all of the beneficial design features. Your emphasis should focus on a nicely rounded and contoured body, thin, sharp, and straight trailing edges on smooth, flowing, wave-free wing and tail surfaces, and tight fitups between wing and fuselage and tail and fuselage. As one might suspect, aesthetics has contributed to XINGU's design as much as objective engineering principles, but, in this case, attention to eye-appeal has not compromised performance.

DESIGN FEATURES

XINGU embodies several features not commonly seen on sailplanes. A new technique for aileron hinging allows for quick construction and minimum drag by virtually eliminating the gap. Standard small hinges (like Klett) are used, as are usual building materials. It's an easy technique, and details are given in the construction description. Also, both wing mounting and the aileron drive system, though basically simple, employ all new techniques.

XINGU's wing is attached to the body with nylon bolts. This is something I've been doing for a while, but seems to have escaped the soaring community. Using the bolts as an internal means of wing fastening reduces drag compared to the rubber band technique and allows for wing release (see discussion below). The drawing shows 2x4-40 bolts, as used in the prototype XINGU. These *are* adequate for normal flight loads. The tensile strength of these bolts is very much greater than their shear strength, so do not substitute larger sizes, since this would defeat the wing release feature incorporated in XINGU. In fact, many airplane models use much-over-strength nylon bolts, and, in a crash, incur more structural damage because these bolts do not break, than for any other reason.

By way of explanation, understand that the occasional hard landing is synonymous with slope soaring. XINGU employs a wing release feature intended to free the wing from the body in such an event. Realizing that the wing and body have very great inertias as separate pieces, it suddenly seems very dangerous to have them constrained together during group impact. Impact with the ground is often pretty innocuous, but a wing can cause total destruction to a fuselage during the ensuing cart-wheel style landing. The best solution to this problem is to allow the wing to escape from the body, and a common sense design consideration would ensure that breakaway require less force than needed to break any other part of the sailplane. So we come to the 4-40 nylon bolts shown on the drawing. While these have more than enough tensile strength to stand flight loads, their shear strength is low enough to avoid landing damage. One might have to replace 2 bolts per landing at 10¢ apiece, but it's cheaper than the labor involved in a repair. The fuselage is beveled to anticipate the wing swinging clear during a release, so don't cheat on those angles. Use tape or an internal attachment to hold the fairing on the wing or fuselage. Also, the wing mounts are designed to put the bolts in tension during flight and shear during adverse landing loads, so do not deviate from the drawing. All things considered, it's worth the little effort involved, and it works.

Another unusual technique is the fitting of a plastic fairing around the aileron external pushrod. This cuts a few points of drag, and every bit counts for an otherwise clean sailplane. The fairing

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is vacuum-formed from .015 butyrate over a plywood triangular fin pattern and trimmed to shape with scissors and sandpaper. Small hardware and home built parts have been used to reduce drag. The 1/16 brass tube aileron pushrod uses a pin at the aileron horn to keep the joint small (no big clevis) and allow the fairing to be fitted. Epoxy circuit board bellcranks and horns are used so that slop in the control circuit can be controlled and minimized. These cranks just do not flex, and the holes drilled in them for their shafts can be held to close tolerances. This all adds up to no slop, no flutter, and precise control.

The lost foam process is used to make the body. This has been explained in other articles (see Spine-Tailed Swift, July '81 MB), but basically involves shaping a blue (polystyrene) foam plug, coating with fiberglass and epoxy resin, finish sanding, and finally dissolving the foam with a solvent. The process simplifies the production of a rounded, curvy fuselage like XINGU's.

WING CONSTRUCTION

The wing is a foam-cored, 1/64 birch ply covered structure. Construction principles are similar to other models in the pylon racer or pattern ship vein, but a few details should be mentioned. In the prototype, the wingskins were epoxied to the foam core. For reasonable finished weight, a roller was used to apply epoxy to the wing skins prior to the layup. Obtain a stiff-napped 3-inch paint roller and a length of drafting mylar or heavy paper. Tape the paper or mylar sheet to your table and pour out a small quantity of resin. Now, use the roller to spread the resin around the sheet. Strive for uniform coating of the roller with resin, neither too wet nor dry. When this has been achieved, move to the appropriate skin and begin rolling on resin. Aim to cover the skin with stipples or small blobs of resin. Do not wet the skin such that the grain becomes filled. When satisfied, place the skin in position on the core and press down. Lift to verify resin transfer, but be careful, because even an adequate amount of transfer is hard to see. Dyeing the resin black might be a useful trick. Remove skin and roll on a heavy coat along the very leading and trailing edges for extra strength; replace the core and position the outer core negative block as usual with this technique.

Before the opposing skin goes fully into position, brush extra resin on the core in the trailing edge region. Press the skin down and position its negative block. Evenly weight the core/skin/negative sandwiches on a flat surface and leave to cure.

Spruce is used for the leading edge. The large X-ACTO #226 blade is nice to carve the spruce tangent with the birch ply at the skin leading edge. This greatly reduces sanding, but be sure to use a block when you do get to the sanding stage.

Be certain to install the aileron pushrod sleeve tubes before skinning the cores. Use only the KAVAN flexible pushrod, the white plastic inner (.072 dia.) and the gold sheath. These have minimal clearance and thus minimal slop. A Dremel 1/8 router bit and the router attachment are hand-guided along the extended pushrod path to slot each core. Alternatively, 1/8-inch thick spruce with sandpaper on one edge can be used to make the slots. Epoxy from wing skin bonding will hold the sheaths in place.

Ailerons are marked and cut free from the wing after sheeting the cores and finish sanding the completed tips and leading edges. Mark top and bottom identically, cut through each skin *only* at first, using a new Uber Skiver #11 blade, and then make a final cut through the foam to free the aileron. The lower aileron skin and foam, 1/8-inch back from its leading edge, are cut free and replaced with a slotted 1/8-inch thick spruce leading edge. Be sure to leave the upper skin intact. Before epoxying the leading edge in place, slot with a flat file to receive hinges (use small Kletts or similar). The vertical face is beveled slightly to allow downward aileron deflection, but remember that much differential is intended for these surfaces, so down movement is small. Differential does double-duty here, keeping the lower gap small, and reducing adverse yaw tendencies. Do not permanently attach the ailerons until painting is complete. Allow hinge pins to project into aileron gap to allow later removal.

An optional 1/8 ply dihedral brace or tongue is used when joining the wing halves. If you plan to hi-start or winch XINGU, install this brace. The slot for this can be made after skinning the cores by using a 1/8-inch aircraft drill, some flat files and a long, 1/8-inch thick spruce sanding board. If you get the hole too big, the gaps can be filled with epoxy at the time of joining. This is all assembled at once, so use 1/2-hour epoxy. The center area is fiberglassed externally, as shown on the drawing, after joining the halves and removal of any excess surface glue. Weight of the unfinished wing at this stage was about 14.5 ounces.

The aileron bellcrank access hole is cut after skinning the cores and joining, glassing, and finish sanding. All related hardware is then installed. A ply skin disc can be glued back in place and recontoured to hide the hole, or a circle of drafting film, frosted side up, can be contact cemented in place to cover the hole. Fairings for aileron pushrods are vacuum formed thin butyrate (.015) and contact cemented or epoxied in place.

The aileron bellcranks and control horns are cut from epoxy circuit board, available from electronics houses. Five-minute epoxy will attach the horns to the aileron skin. The external aileron pushrod is 1/16 brass tubing, flattened, soldered and drilled on each end as shown on the drawing. Slots are cut in both the bellcrank and horn to receive the flattened ends. A brass 00-90 bolt is used to secure the rod at the bellcrank, while an epoxied-in-place music-wire pin is used at the control horn. Installation of the internal aileron pushrod is discussed below.

FUSELAGE & TAIL

Lost foam fuselage construction has been described in various construction articles, but a few pointers might help with this particular body shape. Use a blue polystyrene foam, and try to find HD 300, a dense Dow product that is quite rigid and workable. Despite its stiffness, I made my foam body blank from two halves, epoxied together, with the tip end of a fiberglass fishing rod blank trapped in between. This tip piece was about 20 inches long, and at the largest end, 1/4-inch diameter, and served to stiffen the tail boom during shaping. It was removed when the foam was dissolved. A file and coarse sandpaper glued to the fishing rod blank can be used to rough out accommodation grooves in each foam blank half prior to gluing. Afterwards, a wire hook can be epoxied into the tail end of the rod blank, allowing the whole body to be hung for convenience during the glassing operation. Once this has all been accomplished, shape the blank to the sections given on the drawing.

Epoxy resin must be used with the blue foam, but try to find a type that does not soponify or cure with a soapy film on the surface. Such a film greatly hinders handworking by clogging sandpaper. A resin of this type is called out at the end of this article. During the glassing process, it is a good idea to follow the dry layup philosophy, which usually eliminates cloth floating due to excess resin and the accompanying elbow-deep mess, not to mention a lot of extra sanding. To do this, use toilet paper to absorb excess resin from glass cloth after both have been applied to the foam plug. Use a lot of toilet paper, since it's cheap and the results are significant. The prototype XINGU used 3 layers of 4 oz. plain weave cloth overall, with a 4th layer forward of the body fairing trailing edge. Use one piece of cloth for each layer. Alternate seams from top centerline to bottom centerline, and slit if necessary to conform to the severe nose contours. Block sand any rough spots smooth, especially along the seams, between layers. After the final layer of glass, continue adding resin and lightly sanding between coats to fill the cloth weave. Stay with the toilet paper routine since, even though some resin is wasted, sanding time is reduced. When the weave becomes filled, finish block sand and re-resin if necessary. Work down to at least 220 grit.

At this point, use acetone or lacquer thinner to dissolve the foam. This takes some time, but does work. Bare weight was just under 7 ounces. Then, the wing-body fairing can be cut and all the other fuselage installations begun.

Build up the vertical fin as shown on the drawing. Glass and finish sand before installing. All of the interal workings can and should be installed through the rear spar of the vertical after finish sanding. Use 3/32 O.D. brass tubing for the stab rod bearings. The bellcrank pin ends flush with the fin surface and does not extend into the stab. Note that the bellcrank, made from 1/8-inch epoxy circuit board, has a 1/16 slot for the aft stab rod, not a hole. Also, install the pushrod sheath at this stage. Use 5-minute epoxy as shown on the drawing, and leave enough sheath to project the required length forward into the body. Drill a hole for the pushrod sheath and insert as the fin goes into position. Use 5-minute epoxy to butt glue in place on the body. After scuffing up the exposed epoxy resin, a polyester resin-micro-balloon putty is used to make the vertical fillet around a 1/32 ply dorsal fin. Wet a finger with saliva or water and use as a contouring tool.

The rudder was not operational on XINGU. Construct as a balsa/ply sandwich as shown. Cut a clearance piece from the core prior to laminating to allow for later hollowing of rudder; since the bellcrank projects back into the rudder, this hollowing is necessary. Tack glue in position on the fin/fuselage assembly and carve and sand to shape before glassing, finish sanding, and permanently epoxying.

Balsa/ply sandwich was also used on the horizontal stabs, but lightening holes were cut in the ply cores. The 1/16 music-wire attachment rods are used to ensure ample "compliance" of the stabs during hard landings. A simple but elegant fillet is used on the stabs, and the technique can also be used to fit up the wing. Find a release agent that will release epoxy glue and resin from the epoxy resin used on all the previous structure. Test it to be sure. A particular type is called out at the end of this article. Then coat the fin sides where the stabs will butt up and allow to dry. Rough shape the stab root end to fit the fin. Prepare a 5-minute epoxy/talcum powder paste and, working quickly, apply to *one* stab root end, avoiding stuffing it into the rod holes. Then assemble the stabs onto the vertical, using the 1/16 rods. Ensure that the position is as it will be with controls neutral, and that the paste entirely fills the gap between fin and stab, removing excess. Allow to cure for at least one hour. Pop apart and carefully block sand excess paste from top and bottom of stab fillet, clean up vertical, and there you have it! A perfect fit! Repeat for other stab. The stabilizers are fiberglassed with the same epoxy used on the fuselage and 2-ounce cloth.

INCIDENTALS

Wing mounts are pretty self-explanatory. Use 5-minute epoxy to attach, but thoroughly scuff up the body where the glue joints will occur.

Wing body fit-up is more involved. If you're lucky, the edges produced by cutting free the wing/body fairing will locate the wing without lateral tilt. If not, adjust by sanding until this is achieved. Once the wing mounts are installed, the gap between the upper fuselage edge and the lower wing surface can be filled using the same technique as used on the stab roots. Screw the wing into position while the epoxy paste fillet cures, then remove and block sand and fillet flush with fuselage contour. With the wing back in place, the fairing piece can be custom fitted to the wing upper surface and body using the same technique.

CONTROL INSTALLATION

The fuselage-mounted aileron servo can only be fitted after the wing pushrod is installed. White KAVAN inner pushrod (about .072 dia.) is used inside the already installed sheatning. DU-BRO KWIK-LINKS are used to couple the rod to each aileron bellcrank because of their small size. Threaded couplers, as called out on the drawing, are used on the outboard ends of the pushrods to attach the KWIK-LINKS. At the wing centerline, a DU-BRO ball socket aileron (two-ended) coupler joins the two pushrod halves (one from each wing). Adjustment of the aileron trim is difficult because of the close quarters, but because the pushrods don't vary much with temperature, there should be little need of this.

The actual installation of the pushrods is the unusual part. Assemble two oversized lengths of pushrod with KWIK-LINKS and threaded couplers on the intended outboard ends. Position the links midway on the coupler threads to allow for later adjustment, if necessary. Slide each rod into its sheath from the aileron bellcrank access hole, pushing in until the KWIK-LINKS can be attached to the bellcranks. Drill each end of a DU-BRO aileron socket to fit the white pushrod. The scheme here is to use the socket to join both pushrods to form a single continuous length. Mark and cut the overlength pushrod so that, with the ailerons and bellcranks at neutral, each inboard pushrod end projects completely into its respective aileron socket hole, but no further. Roughen the pushrod ends with #220 sandpaper and 5-minute epoxy each into the aileron socket. This will necessitate uncoupling and quickly recoupling the outboard links from bellcranks for clearance and alignment. At this point, providing all moves freely, the aileron servo can be mounted in the body, noting that the required neutral position of the servo can be accurately achieved by shimming. Strive to reduce slop in the total installation and you will be rewarded with smooth, precise control response.

The elevator pushrod sheath is epoxied in several places along its length as indicated on the drawing. It's best to connect the pushrod to the servo first, since this will give the proper direction and shape to the sheath prior to being "frozen." Don't omit this fastening, or the flying stab will gallop. Flex cables are not really a good way of actuating something like this, being unsupported all along their length, but the gluing shown will provide adequate stiffness.

Both battery pack and receiver were foam wrapped and stuffed into the prototype XINGU's nose, battery first. There's plenty of room for any modern gear.

FINISHING

An epoxy-glass fuselage like XINGU's can be very easily finished. Pinholes should be filled with a resin/talcum power mix using the same resin used to build the body. After dressing the surface with 360 or 400 grit sandpaper, you're ready to paint. An epoxy primer and paint are best, but a lacquer combination could be used. I used acrylic lacquer on the prototype, but my landings are done in grass, so the hard surface characteristic of an epoxy finish was not really needed. Costs for either approach work out about the same.

The stabilizer, being fiberglassed, should be finished with the same method used on the fuselage.

Birch ply covered wings can be filmed, resined, or glassed. Film coverings can be used, but they are not satisfying to me. Full fiberglassing is not recommended. Rather, one or two coats of thin epoxy resin, as used for the fuselage, should be used to fill the wood grain and seal the surface. Sand between coats and keep the coats *thin*. A final sanding with 400 grit paper preps the wing for primer. Again, either epoxy or lacquer might be used, depending on your particular flying style and site.

ASSEMBLY

When attaching the wing, eyeball the aileron socket into place while lowering the wing, and then install and tighten the 4-40 bolts. The fairing is fixed in position with tape or could use some internal rubber band of your own concoction.

FLYING

Balance as shown. Perform a few test glides just for security. When flying, adhere to the high L/D philosophy . . . Keep the nose down, the speed up, search over large areas for lift, and don't circle too tightly. I am still of the opinion that XINGU would do well in FAI and would love to hear from any who try. For that matter, your enquiries are welcome for whatever reason, though Model Builder Magazine or at the address shown below.

SUPPLIES

Molded epoxy fuselages and a special molded epoxy wing with integral, gapless ailerons are available to those wishing to build and fly XINGU with a bit less effort.

The following hard-to-find (especially in small quantities) items are also available:

- Low viscosity, sandable, structural epoxy resin
- Light glass and Kevlar cloth (1.4, 1.8, 2.0, 2.1, 4 oz/yd^2)
- 1-inch wide uni-directional carbon fiber tape (reinforcement)
- Kavan pushrod
- HD 300 polystyrene foam (fuselage plug)
- IB polystyrene foam (wing cores)
- Release agent for epoxy and polyester resins (non-fail!)
- 4-40 and 6-32 nylon bolts.

For details on any or all of the above, contact: Slope Associates, 2317 N. 63rd, Seattle, WA 98103. ●