HOW TO CUT AN ELLIPTICAL FOAM WING CORE

via the deformation method

By Jaromir Bily

When I decided to design and construct a new FAI (F3D) pylon racing aircraft, the full scale aircraft that I selected to base my model on was the Mace R-2 Shark, which is a famous Formula One racing aircraft. The Mace R-2 Shark still races each year at the Reno National Air Races. One of the most distinctive features associated with the Shark, which sets it apart from the other Formula One designs, is its elliptical wing.

ABOUT THE AUTHOR

Jaromir Bily lives in Melnik, Czechoslovakia, which is a scenic and historical town about 30 miles north of Prague. Melnik is best known to R/C modelers as the site of "Velka Cena Modely," which has become the largest annual FAI (F3D) pylon racing competition held in the world.

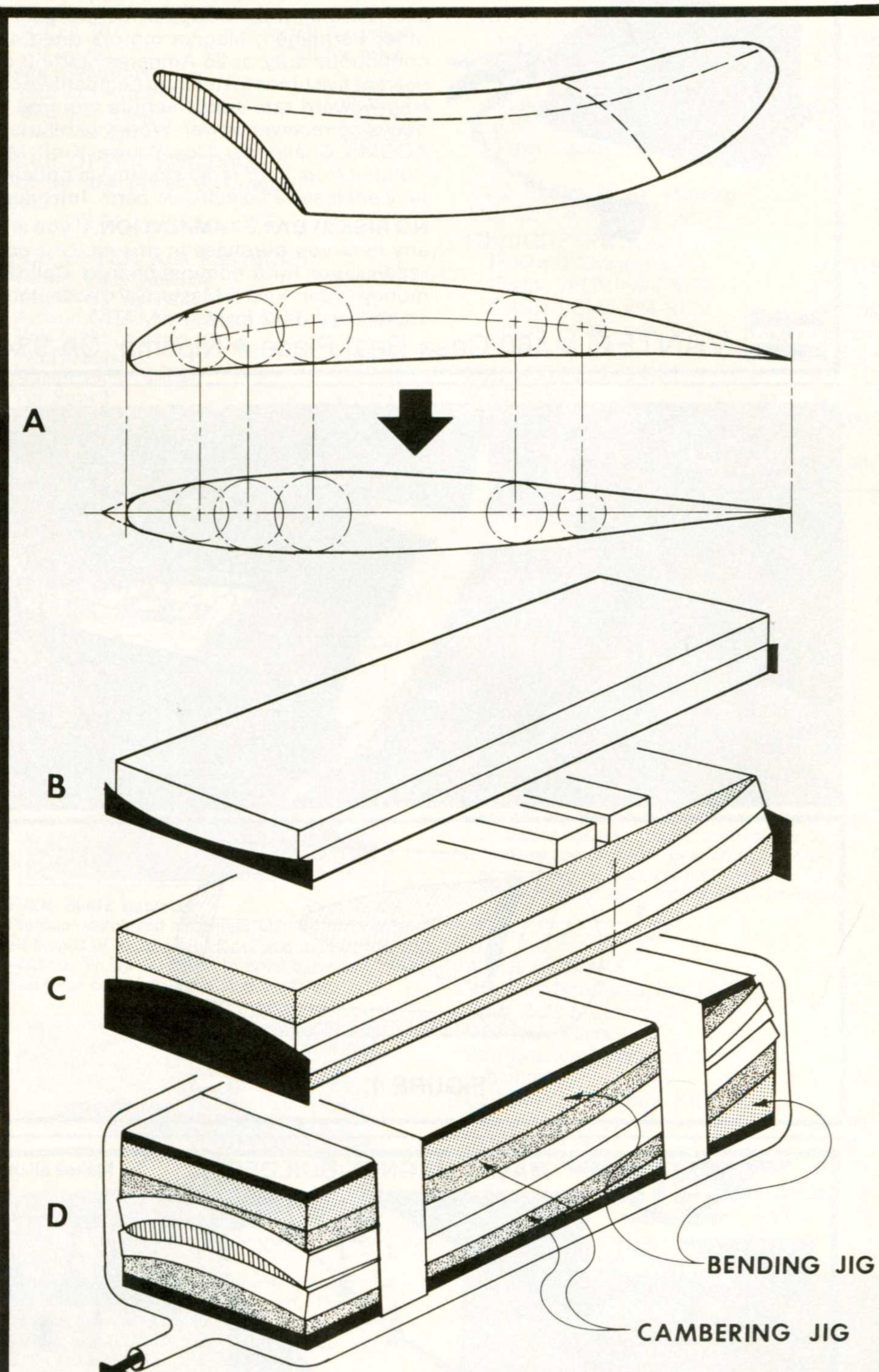
Jaromir is one of the most respected and well known R/C modelers in Czechoslovakia. While he has retired from active racing competition, he was one of Czechoslovakia's top FAI racing pilots, and his famous Mace R-2 SHARK design continues to be the most popular FAI racing aircraft in use today in Czechoslovakia.

In addition to his past racing skills and accomplishments, Jaromir is noted for his finely crafted models, innovative construction methods and techniques, and his outstanding flying skills.

Early in my design efforts, the question of how to best construct the foam core type wing came to mind. Certainly the elliptical wing could be constructed via the use of conventional straight tapered foam cores with large balsa leading and trailing edges, and tip blocks being used to ultimately achieve the required elliptical planform by extensive cutting and sanding. This method has been used in some scale model kits, most notably with the British World War II Spitfire, for example. However, this method does result in a heavier than normal finished wing.

As a result, the primary questions that I pondered were: "Could I cut elliptical foam cores with a conventional hot wire cutter? Would it be possible to do this and obtain the desired elliptical planform and airfoil accurately?"

The answer to both questions is yes,

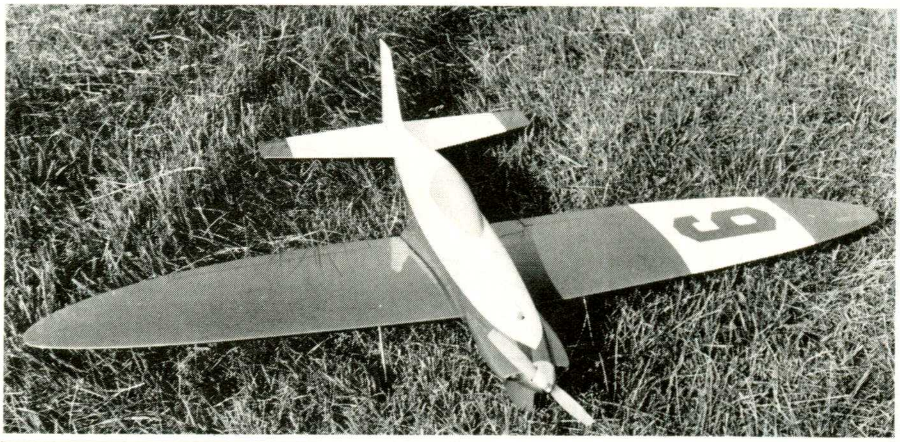


A — THE AIRFOIL STRAIGHTENED

B — CUTTING OF THE LOWER SURFACE (STRAIGHT PORTION OF WING)

C — CUTTING OF UPPER SURFACE (IN THE JIG)

D — SHEETING — CAMBERING OF THE AIRFOIL & BENDING OF DIHEDRAL



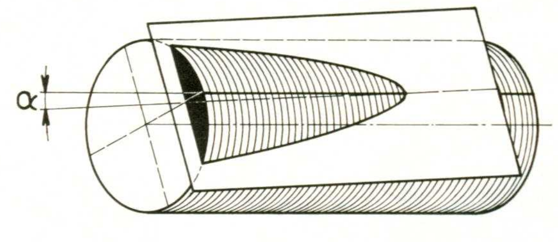


FIGURE 1

and is based on the following reasoning: An ellipse is a conic-section that is obtained, for example, by cutting a cylindrical shape on an angular plane. The degree of angle of the cutting plane will determine the shape of the resultant ellipse. The cut piece that results will have an elliptical plan surface, while the portion of the cylindrical base piece that was cut will determine the airfoil (see Figure No. 1).

By using this method, an elliptically shaped foam core can be cut to the desired airfoil shape. While my wing foam cores were cut for use on a racing aircraft, the same technique may be used to produce a symmetrical pattern aircraft type wing or even flat bottom type airfoils.

(Editor's Note: The following portion of this article may not be clear to all readers and some translating errors may exist, however, the accompanying diagrams and photos illustrate the process by which the author cut his foam core wings.)

Figure No. 2 illustrates the cutting

of the lower surface of the wing. Similarly, we could cut out even the upper surface, after exchanging the templates. The rate of wire shifting is the same on both ends.

Of course, such a wing would not be satisfactory. Why not? Follow these arguments: The wing plan is defined by unsuitable ellipse sections. Both leading and trailing edges look like they are broken just in half of the wingspan (see Angles B_1, B_2). The course of wing thickness is linear, so that the relative thickness of airfoil at the root and the tip of this wing is greater than in the half of its half-span. The required airfoil is to be found only at the root. In any different section of the wing, the airfoil is defined by a greater or minor part of this airfoil's outline. The more distant that this airfoil is from the root, the more different it is from the required one.

That is why we must think over the possibilities of how to correct the imperfections mentioned above.

Let's select an elliptical wing of wingspan 2a (see Figures No. 2a and 2b). The main half-axis of ellipse = a, and root chord = C_R. The airfoil of such a wing is, for the time being, symmetrical and its maximum thickness is to be found in 30% of its chord, which defines even the position of the ellipse's main half-axis. It is placed in 30% of chord too. The side half-axis of ellipse are $b_1 = 0{,}7\ C_R$, $b_2 = 0{,}3\ C_R$. Now let's draw the rear outline of quarter ellipse with axes a, b_1 (see Figure No. 3a). Further, it is necessary to make the airfoil outline template. Now let's make a jig for drawing airfoils from the template and a ruler. By means of shifting the template we can draw the upper outlines of airfoils in sections I-IV, and, after tipping over the template, even the lower outlines of airfoils. The outlines pass through crossing points of chords and the rear quarter-ellipse, while the crossing points of the airfoil outlines and chords represent the points of the front quarter-ellipse. That is why we have drawn only the rear quarter-ellipse (see Figure No. 3).

Now let's judge this new wing. The course of airfoil thickness lengthwise span is no longer linear, the wing looks as if it is "inflated" (i.e., it is convex along its span), while the relative thickness of airfoil is correct in every place. As we have already mentioned, the more different the airfoil is from the required one, the more distant it is from its root. Now, the airfoil in the half on the wing's half-span is the same as the airfoil that was nearer to the root before "inflating;" the wing is better now.

The wing described already

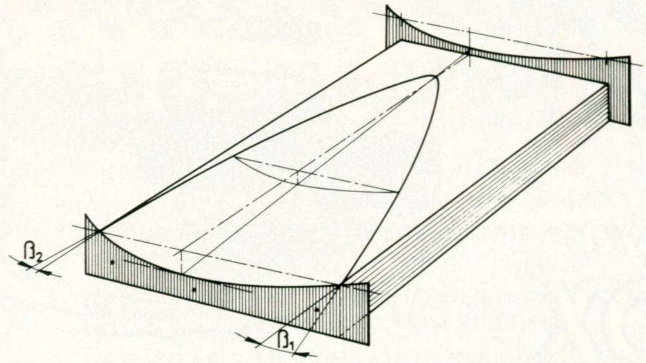


FIGURE 2

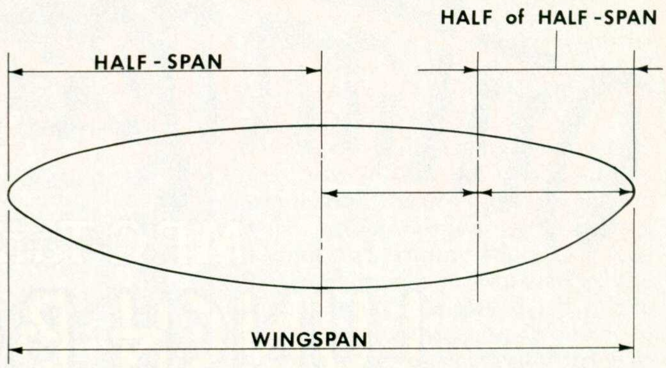


FIGURE 2a

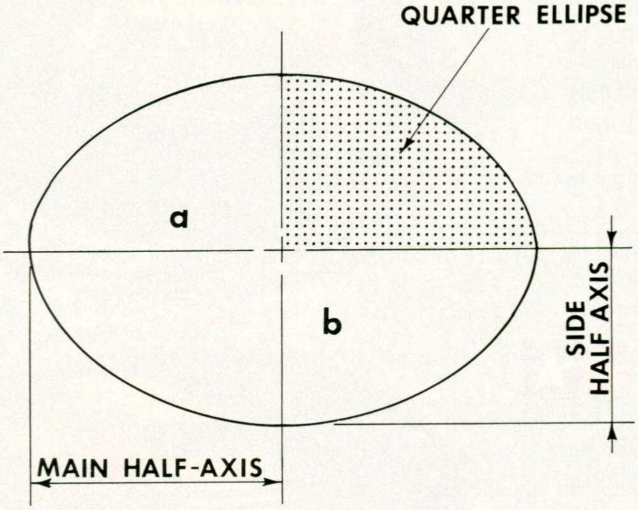


FIGURE 2b

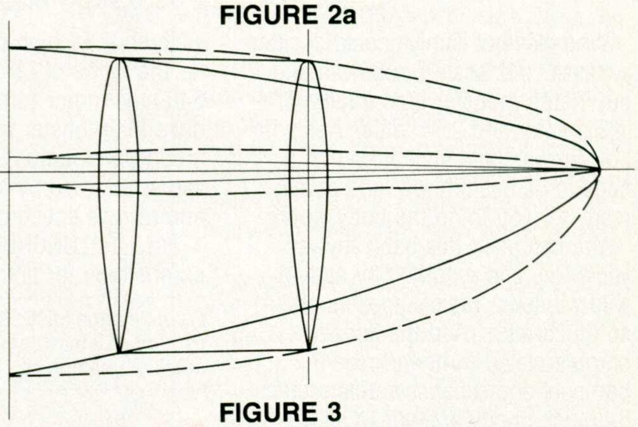


FIGURE 3

complies to our requirement of its planform and course of thickness, but this airfoil is acceptable, approximately, only up to its half of half-span. Nevertheless, the necessary improvement is at hand.

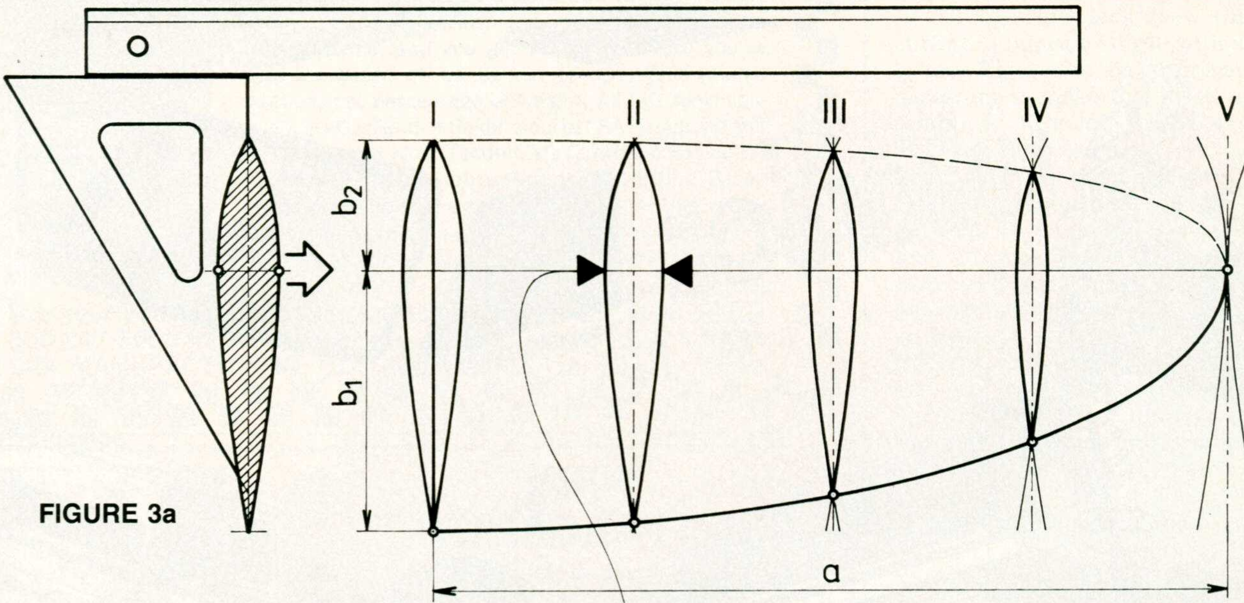


FIGURE 3a

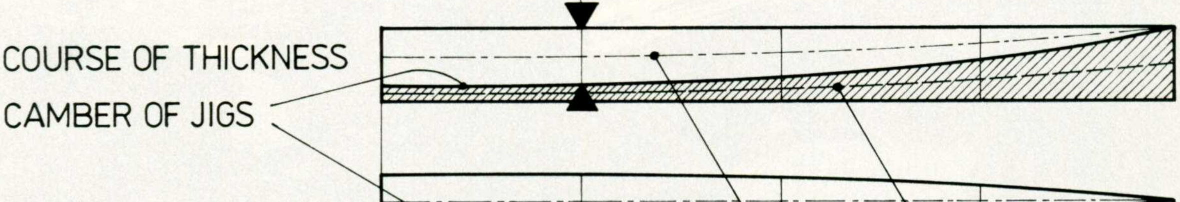


FIGURE 3b

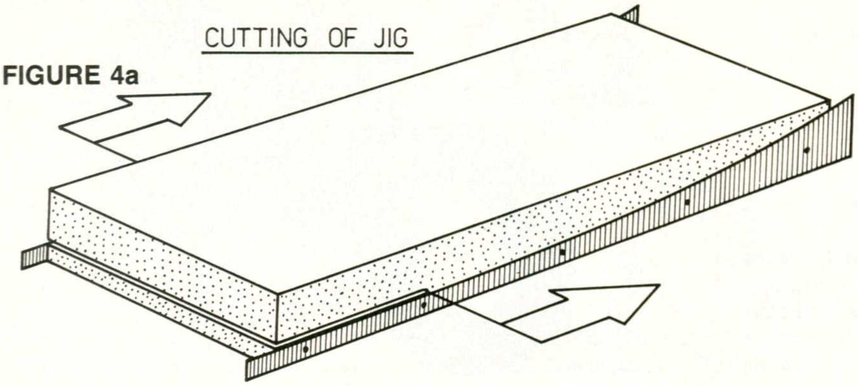


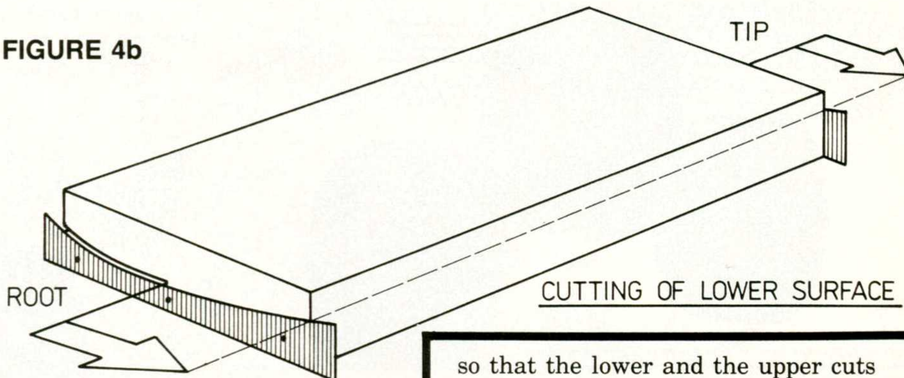
FIGURE 4a

Up to now we have used the same template both for the root and tip of wing. Now let's design the wing tip section templates that make it possible to obtain the required airfoil at section IV. Provided we are successful, the airfoils at sections I and IV will be absolutely precise, and the airfoils situated in sections II and III will be thicker only by some tenths of a percent than the reckoned ones. The wing section between sections IV and V may be regarded as being a well designed wing tip. The curvature of wing tip templates which will be located in the position of section V, are obtained by extrapolation from the airfoils in section I and IV. (Extrapolation is the opposite of interpolation.)

An attentive reader can object now, that the core after corrections is not possible to cut with a straight hot wire. This objection would be correct if you tried to use conventional methods. But you can help yourself by a simple wit: If it is impossible to bend the cutting wire on the plane perpendicular to the plane of cutting, then it is necessary to bend the cut foam block contrariwise. The course of required deflection, bending as it is known, is the curve of the wing's thickness course (see Figure No. 3b).

The procedure for core cutting is shown in Figures No. 4a, 4b, and 4c.

FIGURE 4b



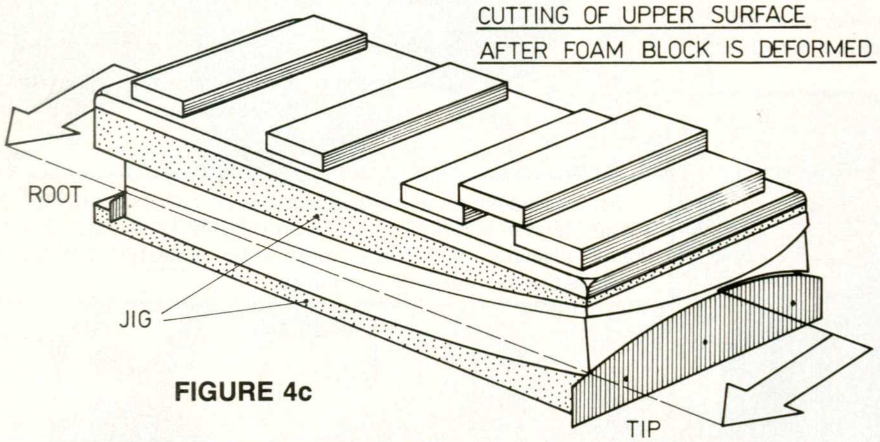


FIGURE 4c

Figure No. 4a shows the jig for bending a foam block, Figure No. 4b shows the cutting of the lower core surface, and Figure No. 4c shows the cutting of the upper core surface after bending the foam block. In every case, the rate of hot wire travel speed through the foam is the same at both ends; like when cutting a conventional rectangular wing.

The results are shown in Figure (photo) No. 5. The wing of the "Shark" has a biconvex non-symmetrical airfoil. The terminal templates angle of setting were corrected and the templates were located in such a way so that the lower and the upper cuts might pass by 2 mm. That is why the wing end is to be found "inside" the foam block.

From the front view, the lower surface of the core is flat, and the upper surface is cambered convex (see Figure No. 6).

The core is straightened as follows: When sheeting, we put the core into the jig for sheeting, which differs from the jig for cutting just by a half deflection.

For the sheeting, it is necessary to use epoxy resin, as contact adhesives are not suitable for this described method. Well, let's place the core with the fashioned wing skins between the remaining cuttings of the foam block,

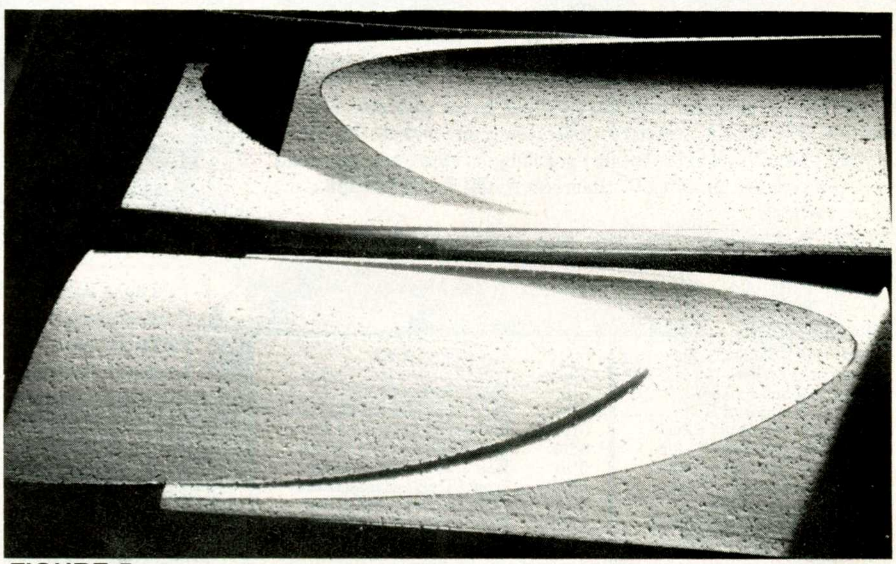


FIGURE 5

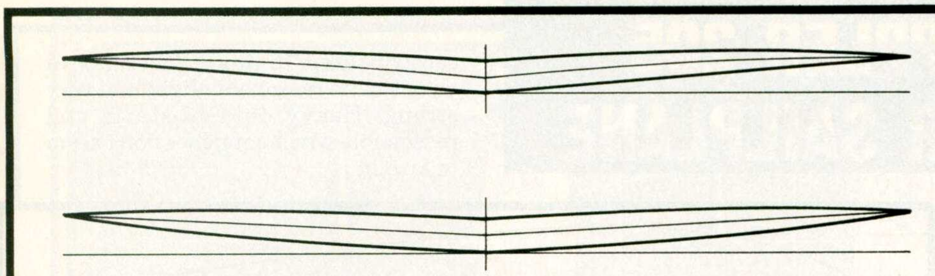


FIGURE 6

insert the block into the jig for sheeting, and then apply stiff cover plates to them and put the whole unit into a polyethylene bag. Then exhaust air from the bag with a vacuum pump or vacuum cleaner and let the resin harden (see Figure No. 7).

Naturally, the preparation of the required templates, including necessary corrections, is a rather laborious process. Nevertheless, as soon as the correct templates are at our disposal, elliptical wings are as easy to make as any other foam core wing. About twenty R/C modelers who have constructed approximately 30 "Shark" models up to this time, are well aware of this fact. Most of them constructed their wings by themselves, using their own templates.

As was mentioned, this method is usable for wings with symmetrical, semi-symmetrical, and flat-bottom airfoils. In the case of a wing with a non-symmetrical airfoil (see Figure No. 7a), it is necessary to check (best to do at section IV) whether the plan angle of airfoil chord is constant. If not, a small turning of the tip template may be necessary.

To prove this, Figure No. 8 shows the airfoil templates, while Figure No. 9 defines the jig's ordinates for my new "Shark II" wing. The wingspan is 1320 mm, chord 280 mm, area 29 dm^2. Dimensions of the foam blocks in mm: 40 x 400 x 660/670, respectively, for the jigs. The wing is covered with 2 mm balsa skins.

If we contemplate the described elastic deformation method of cutting foam cores to the end, we can conclude that it would be possible to cut out, for example, even a rectangular wing with an elliptical tip, which would have a U-shaped dihedral in bending and a chambered airfoil. See Figure No. 9 and informational sequence sketch. This is possible because a foam block may be deformed (bent) not only longitudinally, but also in its transversal course.

In the same way it would even be possible to construct a foam core of a propeller blade shape, for example. The functional surface of such a deforming jig would have to be twirled (twisted) in the opposite course of the propeller pitch.

I wish good luck for those of you who are going to construct elliptical foam core wings via the elastic deformation method of cutting. □

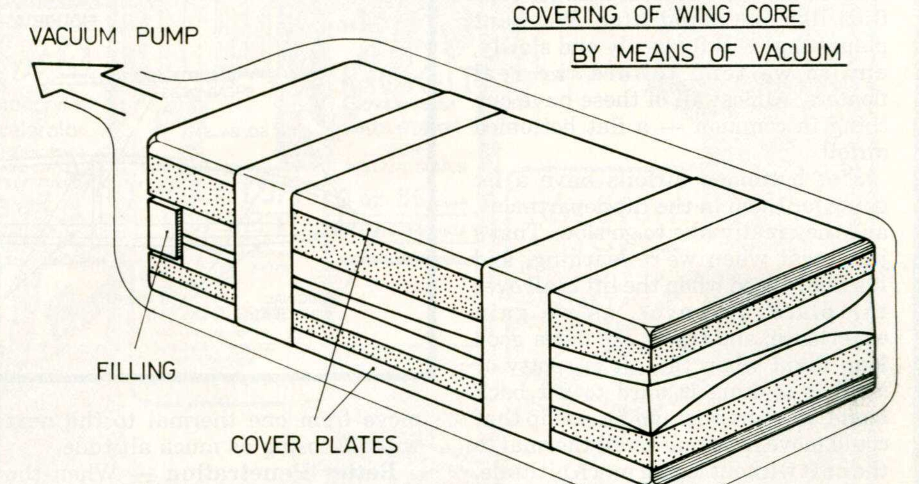


FIGURE 7

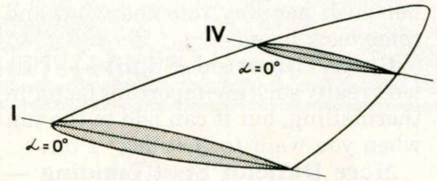


FIGURE 7a

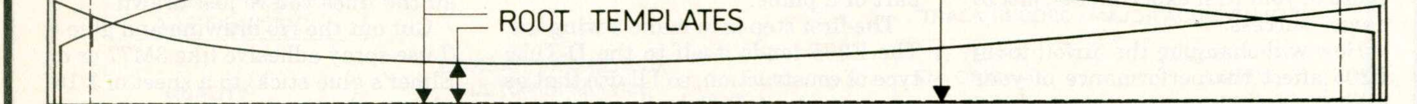
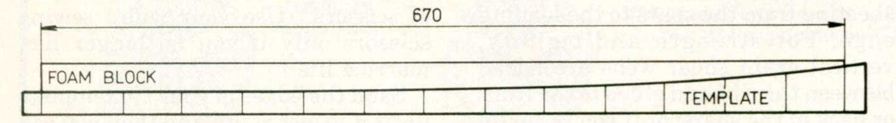


FIGURE 8



	JIG ORDINATES													
STATION	0	70	120	170	220	270	320	370	420	470	520	570	620	670
FOR CUTTING	18,8	18,3	18,1	18,1	18,2	18,3	18,6	19,3	20,4	22,1	24,2	27,0	31,5	37,2
FOR COVERING	19,4	19,2	19,1	19,1	19,1	19,2	19,3	19,7	20,2	21,1	22,1	23,5	25,8	28,6

FIGURE 9