Airfoils for Flying Model Aircraft

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With great thanks to Paul K. Johnson

https://airfieldmodels.com/index.html

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Introduction: About Airfoils for Flying Model Aircraft

Airfoils come in several flavors. The most commonly used airfoils for flying model aircraft are:

• Symmetrical

• Semi-Symmetrical

• Flat Bottom

• Modified Flat Bottom

• Under-cambered

• Reflexed

Each family encompasses a large selection of airfoils but we use very few of them due to habit or not having a clue about how to properly select a real airfoil. By "real" I mean an airfoil that has been designed and tested by the aerospace industry.

Data on real airfoils won't apply in our realm anyway. The airfoils are tested at larger sizes than the average model and things change as size changes. However, the airfoils should scale down comparatively.

For example, if one airfoil is tested to stall sooner than another airfoil, then the stall speeds may be much different when scaled down but both airfoils should still stall in the same order. That may not always be true, but it's a good rule of thumb.

If you are purpose-building something competitive that requires the best possible airfoil for the application then I can't help you. However, if you enroll at a school of Aerospace then you can probably get help there.

Secrets that shouldn't be secret

Almost nobody who designs model airplanes would have a clue how to pick an airfoil for their design based on real airfoil data. We learn from experience knowing that the subtleties between one airfoil and another close to the same shape will make a very small difference — one that would only be noticed by an expert pilot. These behaviors are not different enough to cause any problems in your design unless you do something like change a round leading edge to one that is razor sharp.

If a designer is agonizing over whether to use a 14% or 16% symmetrical NACA section he can choose either and the plane will still fly well. The difference may be that the 14% version flies and lands a little faster, but is smoother whereas the 16% version may perform aerobatics in a slightly smaller volume.

The difference won't be something like one airfoil is "right" and the other makes your plane loop back into the ground on take-off. Again, I'm comparing airfoils that are basically the same shape within a family. Note that there will be a huge difference between any under-cambered vs. any symmetrical airfoil.

If you want to design unique planes that fly for fun, then stay in the realm of reason and make your airfoil close to the shape of airfoils used by other planes of roughly the same type. Don't get hung up about it. If you can't decide then copy an airfoil in use on a model and scale it to the right size for your model.

I almost never use a real airfoil in my designs. I have airfoils that I've used on previous models so I know how they behave. For a new design I adjust the airfoil to behave more how I want it to on the new model. For example, I may thicken it to slow the model or make the leading edge radius smaller to allow sharper stall maneuvers.

If I need an airfoil of a type I have never used before then I pull out my airfoil books and look at drawings. The data is meaningless to me. I imagine the airfoil in the application and fly it in my mind. Watch the videos in my gallery and you'll see that it works well and I'm not seeing sport designs that fly better than mine.

Aircraft Design Comes First

These are the decisions I make before selecting a specific airfoil:

1. Specify desired flight characteristics (airspeed envelope, aerobatic capabilities, etc.).
2. Specify the wing-loading and power loading ranges. Be disciplined about designing to those goals.
3. Decide on a wing planform (chord(s), span, taper and sweep).
4. Determine the most appropriate airfoil family.

Because all designs represent numerous compromises you'll have to use the above to decide which characteristics are more important than others. Select a specific airfoil using whatever information you have.

Like Dogs, All Airfoils are Good

If the plane has undesirable traits it's probably not the fault of the airfoil assuming you choose one within the realm of reason. An airplane with a razor thin wing should fly well, albeit very fast. If the pilot tries to slow the plane down to Cub speeds for landing, it will snap over on it's back and probably be destroyed.

I have watched several web videos of scale planes snap-rolling into terra firma. In nearly every case the plane had a high wing loading which required the aircraft to maintain a higher airspeed to remain in flight.

Most of these videos provided clues to the problem such as the plane flying around with its tail dragging through turns (tail heavy) or the pilot trying to yank it around like a Kaos with aileron/elevator turns. The Kaos has a 20/oz ft2 wing loading. A precision scale SBD Dauntless might have a 60/oz ft2 wing loading.

Too many pilots believe themselves to be expert pilots but they're kidding themselves. They know how to yank and bank an over-powered, lightweight sport model. When they step outside the realm of lightly loaded, over-powered aircraft and into the realm of heavily loaded aircraft they often find that they get into trouble fast.

Aerodynamic Stalling

One of the main concerns of fledgling model airplane designers is how to avoid choosing an airfoil having wicked stall characteristics. All airfoils have a stall angle. This is the angle of the chord line of the wing to the direction of flight. When this angle is at or beyond the stall angle the air breaks away from the wing and the wing stops producing lift. In other words, the aircraft isn't flying any more. It's falling from the sky.

The leading edge radius takes the lead role in stall characteristics. A sharp (small radius) leading edge typically has a shallow stall angle. That means it will stall sooner than a blunt leading edge.

There are other factors as well, but they become too technical and less practical. Just know that if you want your plane to have gentle stall characteristics you should use a larger radius leading edge. The smaller the radius you use the more you risk having a plane that will stall suddenly and sharply.

A tip stall occurs when a wing tip stalls before the wing root. In most cases this causes the aircraft to roll over. If the plane is close to the ground it's usually a total loss.

There are several ways to avoid or delay tip stalls.

- Build the wing with washout.

Washout simply means the wing is built with a twist so that the wing tips are at a lower angle of incidence than the wing root. Washout also limits aerobatic capabilities.

- Sand the leading edge such that it becomes more blunt toward the tip.
- Avoid high aspect ratio wings having a high taper ratio.

Taper ratio is the length of the tip chord divided by the length of the root chord. Aspect ratio is the wing span divided by average wing chord. High aspect ratio wings, such as sailplanes, with high taper ratios tend to be more prone to tip stalls than low aspect ratio wings, such as deltas.

Some CAP aerobatic planes tend to tip stall easily due to the taper ratio and sharp leading edge.

MyRule of Thumb for Airfoil Selection

Choosing an appropriate airfoil family for any given design is usually simple. If the plane is to be a precision aerobat then a symmetrical airfoil is most appropriate because it flies the same in any given attitude.

If the plane is to fly slowly or carry a load but is not intended to do aerobatics then a flat-bottom or under-cambered airfoil should be considered.

By the way, when I say flat-bottom I don't mean a true flat-bottom airfoil. Some airfoils are called "modified flat bottom." This is an airfoil having a straight line from the main spar to the trailing edge but curves up to the leading edge from the spar.

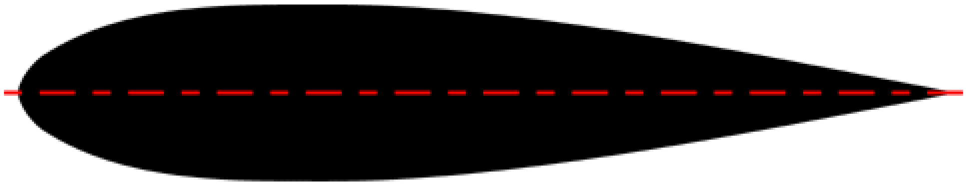
A modified flat-bottom airfoil is actually a semi-symmetrical airfoil, but most modelers consider it to be a flat bottom airfoil because most of the underside isn't curved. I'm right, they're wrong, but if you say semi-symmetrical then they'll picture something other than what you're talking about.

Note: Any airfoil that is not symmetrical is a cambered airfoil.

The terms "flat-bottom" and "semi-symmetrical" are not used by the aerospace industry and they probably laugh at us when they hear us use those terms. Nevertheless, this article is for us, not them, so I will continue using these incorrect pretend names so you aren't shunned by your fellow modelers who don't like it when you talk too fancy.

Symmetrical Airfoils

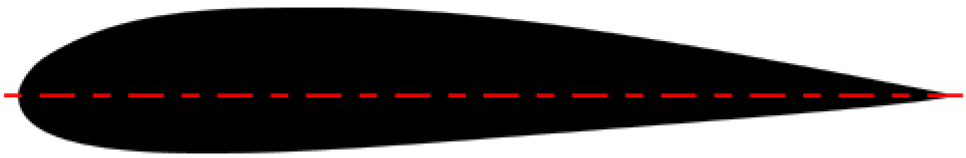
- Use for aerobatic airplanes - particularly monoplanes.



A design intended to be aerobatic should always have symmetrical flight surfaces (wing, horizontal stabilizer and vertical stabilizer). Flat surfaces (which are symmetrical sections) work well for tail surfaces to a point but aren't as good as a true airfoiled section.

Semi-Symmetrical Airfoils

- Use for secondary trainers, sailplanes and sport aerobatic biplanes. If the biplane is intended to do precision aerobatics then a fully symmetrical airfoil should be used.



Secondary trainer manufacturers make a big deal out of semi-symmetrical airfoils but they are over-rated. If a beginner moves up too quickly and hasn't mastered his primary trainer yet then a secondary trainer with this type of airfoil is probably the best bad choice. Otherwise, a lightweight, well behaved model with a symmetrical airfoil makes a good secondary trainer.

Sailplanes often use highly refined and tested airfoils that provide the best lift to drag so that they can scoot across the sky quickly in their search for thermals and then climb easily in the lift.

Sailplane designers tend to take a lot of care in their airfoil selection. They have to because the airfoil is the only thing making their plane fly. They don't have an engine to fall back on.

Flat-Bottom Airfoils

- Don't use true flat-bottom airfoils for anything.
- So called "modified" flat bottom airfoils are excellent for slow, gentle flight.

True flat-bottom airfoils are a poor choice for any design. They are next to impossible to trim properly because they are extremely speed sensitive. It may be possible to trim this trait out, but it means spending hours tweaking the wing incidence, decalage and engine thrust.

I've never flown a model with a flat-bottom airfoil that could even come close to being trimmed as it was built. I don't particularly enjoy cutting the tail off my planes numerous times attempting to get it right.

The rest of this discussion refers to modified flat bottom airfoils.

Flat bottom airfoils are used for powered aircraft that are willing to make the compromise of having more drag in exchange for slow flight or high lift capabilities. They do not penetrate the air well but can stay aloft at very low speeds. I have built a handful of models having flat bottom airfoils that can hover right in front of me because the aircraft's minimum flight speed was below the wind speed.

For example, if the model can fly at 10 MPH and the wind is blowing 15 MPH then the model can fly backward (relative to the ground) at 5 MPH. As far as the air is concerned (which is the only thing the airplane cares about) the aircraft is flying forward at 10 MPH.

An aircraft that is identical except for having a symmetrical airfoil will have a higher minimum flight speed.

Under-Cambered Airfoils

- Use for scale models, sailplanes and some high-lift situations.

I don't know much about under-cambered airfoils. They are mostly used for scale aircraft from the dawn of aviation. They tend to have high lift and are sometimes used in free flight models and some very small radio control aircraft.

Reflexed Airfoils

- Use for flying wings.

A reflexed airfoil has a trailing edge that is turned up slightly. The airfoil shown above is extremely exaggerated to get the point across. I haven't tested it but it probably has five times the amount of reflex it needs. If you print the image and scale it to your design, then don't hand launch the model — it will probably loop, hit you in the back of the head and kill you instantly.

Most airfoils have a natural tendency to pitch forward. If you were to push a wing forward or just drop it, it would rotate or tumble forward all the way to the ground.

The horizontal stabilizer prevents an aircraft from doing the same thing. Flying wings don't have a stabilizer so the wing must be self-stabilizing. The reflex provides this stabilization.

Note that a true reflexed airfoil isn't necessary and often isn't used with flying wing model aircraft. A lot of designers fake it by adjusting the elevons so they are slightly up. Thwing! and my JGRC Aggressor both use faked "reflex" and fly very well.

Airfoil Thickness

Airfoil thickness is simply the percentage of the wing chord that the airfoil is deep at it's thickest point. For example a wing having a chord of 15" that has a 10% thick airfoil will be 1-1/2" (1.5") thick.

How thick should the airfoil be? I find that wing thickness is a compromise between speed and lift. A thicker wing has more drag but more lift and is capable of slower flight. Thicker wings also tend to "bounce" around more in the air because they can't cut through it as easily.

A thinner wing has less lift but is faster. The shape of the leading edge plays a part in this as well.

One other thing to note is that as wings get thicker they also become stronger. If a wing is thick it is easy to build it strong using conventional construction techniques. If the wing is thin then more exotic techniques are required to prevent the wing from breaking in flight.

Of course there are limits to everything. I've seen airfoil listings that are thicker than 30%. The thickest wing I have built was about 20% and I didn't like anything about it in flight.

From as far back as I can remember through the 1980's, most sport designs had airfoils in the range of 14% to 16% thick. These airfoils have proven to be safe with few or no bad habits at reasonable wing loadings and can slow down nicely to land. I normally use airfoils from 12% to 18% depending on the airplane. For an extremely fast model I may use an airfoil around 10% thick.

In the 1980's several things happened that changed the way we design model airplanes. Pilots came to desire aerobatic models that fly at speeds below Mach 1, four-stroke engines became widely available and the new Turnaround Pattern competition required planes to fly at a more constant airspeed.

A thin airfoil simply isn't going to slow down when the airplane is diving toward the ground even with the engine at idle. More drag was needed, but it had to be smooth, clean (non-turbulent) drag. In other words, airfoil shaped. The easiest way to create this drag was to build a thicker wing which also creates more lift at slower speeds. These models also had to revert to old-time, lightweight construction techniques because lighter planes maneuver better and fly slower.

Drag increases exponentially with airspeed. Frontal area, drag and airspeed are inseparable so you need to have a feel for how they work together to decide how thick the wing should be. This is an area where I really can't speak scientifically. I have a good feel for how it works and do pretty well with that knowledge.

Airplane	Engine	Propeller Pitch	Top Speed	Airfoil	Flight Characteristics
Average weight Stik	.45	6"-7"	80 MPH	15% symmetrical	Smooth flying, medium to large aerobatics, reasonable landing speed.
Lightweight 3D model	.45	4"-5"	50 MPH	18% symmetrical	Slow flight, aerobatics in small area, very slow landing speed, buffeting at high speeds and susceptible to gusts at low speeds.
Lightweight Floater	.40	4"-5"	45 MPH	16% semi-symmetrical	Hovers in steady winds, very low flight speeds, minimal aerobatics, difficult or impossible inverted flight, landing at a crawl.
Sport-Aerobatic Biplane	.60	6"-7"	65 MPH	13% semi-symmetrical	Very aerobatic in a smaller area. Tumbles well. Requires more "down" for inverted flight.
Speed Demon	.40 (piped)	8"-9"	100+ MPH	<12% symmetrical	Flies fast, lands fast, extremely large aerobatics.

Carefully match the power plant and propeller to the airframe instead of matching the propeller to the power plant alone. All airplanes have a maximum airspeed at which they will fly smoothly. If the engine has more power available after this speed is reached you won't see more speed, but the model will begin to buffet or worse - something might flutter off.

Part 1: How to Plot a Model Aircraft Airfoil

About Airfoil Plotting

How you choose the airfoil you want to plot is up to you. I have enough experience building flying models that I can usually pick a good airfoil by looking at it without knowing much about it. Unless an airfoil is radical, some things will clue you in to its performance, such as the maximum thickness of the airfoil, where the maximum thickness falls, reflex, camber and leading edge shape.

If the application is critical, then I go to one of the popular online forums, such as RC Universe, and present my design specifications and questions. I always get good feedback - sometimes more than I can digest or understand. But I end up with some good choices of airfoils.

Once you know what airfoil you want to plot, it is time to get busy. One thing to note is that there are several computer programs that will do all this for you - many of them are shareware or freeware. Plotting an airfoil is much faster using a computer if you understand the program. Some programs are designed to create wing ribs and will print a ready-to-use pattern.

I still manually plot my airfoils because it only takes me about 10 minutes to do it and my printer never works. A computer program can print an airfoil more accurately than I can draw it.

Which brings up the next point - accuracy. Is it important? Yes and no. Yes, you should try to draw as accurately as possible, but in the end, you probably will not have the exact airfoil you plotted anyway.

If you manually plot the airfoil, then your drawing will be slightly inaccurate to begin with. Even a printer is not 100% accurate. Cutting and sanding the ribs introduces more inaccuracies. The sheeting may or may not be the exact thickness you accounted for - especially after sanding it. Finally, you apply a finish.

When everything is said and done, you will have a close approximation of the airfoil you chose, but it will not be exact. Just be as accurate as you can in each step and do not sweat it too much. Your plane will fly fine.

Obtaining Airfoil Ordinates

There are a variety of places you can find airfoil ordinate listings. I have Theory of Wing Sections by Ira H. Abbott and Albert E. Von Doenhoff. This book not only covers the theory, but also has a good list of airfoil ordinates to choose from. Martin Simons' Book, Model Aircraft Aerodynamics, also has a large listing of ordinates that you can use and presumably, these are airfoils that Mr. Simons feels are appropriate for model aircraft. There are also various airfoil databases available for free on the internet. A web search will provide you with an extensive list of foils to choose from.

Part 2: How to Calculate Airfoil Ordinates

Some airfoils have a large number of ordinates. I've seen sets of ordinates having over 1,000 points. If you are manually plotting an airfoil you do not have to plot every ordinate. You only need enough so that you can draw the airfoil with reasonable accuracy.

I would say plotting 20 points each top and bottom is accurate enough for most airfoils. In areas where there are tighter curves you should plot points closer together. Examples are near the leading edge or the reflexed portion of that type airfoil.

Coordinate Standards

Airfoil ordinates are simply points that define the shape of the airfoil. The numbers are given in percentage of the wing chord. There is more than one standard, but they are all easy to figure out.

The standards I know of are as follows:

1. Stations from 0% to 100% chord. In this case, multiply the chord of the airfoil you are plotting times percent of the station/ordinate pairs in percent. In other words, if the number given is 1.25 then multiply times 1.25%. If your calculator does not have a percent key, then multiply times 1.25 and then divide by 100.

Ordinates of this type are presented in two sets of ordinate pairs - one for the upper portion of the airfoil and one for the lower.

2. Stations from 0 to 1. In this case it is straight multiplication of the chord times each of the station/ordinate pairs. This standard also differentiates between the top and the bottom of the airfoil.

3. The last example is the style used for computer programs. This is listing of ordinate pairs with no differentiation between the top and bottom of the airfoil. Numbers are from 0 to 1. The listing starts at the trailing edge of the airfoil and moves forward defining the underside of the airfoil and then the leading edge, the top of the wing and back to the trailing edge again.

It sounds more complicated than it is - again, it is simple multiplication.

Calculating the Ordinates to be Plotted

For this example I will be plotting a NACA 2412 airfoil. The NACA 2412 is a semi-symmetrical airfoil (cambered) that is stable and somewhat fast although it would not be the best choice for an extreme speed aircraft. It would be a good choice for a one-design club racer because it has no bad habits and will not get to speeds that the average pilot can't handle.

The first table below is the set of ordinates for the NACA 2412. The listing uses standard (1) above.

I will be calculating ordinates for and plotting an airfoil having a 9" chord. Multiply all stations and ordinates by the chord. Again, the numbers given in the ordinate listing are percentages. That means you multiply the chord by the station or ordinate in percent.

To find the second station for example, multiply 9" x 1.25%.

The leading edge (L.E.) radius is also multiplied by the chord to get the actual radius. This is also a percentage.

The second table contains the resulting numbers after multiplying them by the wing chord. All numbers are in inches for this example. Calculating and plotting works the same regardless of your number system.

This particular airfoil has stations that are identical for both the upper and lower surfaces but that is not always true. Be sure to pay attention to what you are doing. I have made the mistake of assuming the stations were the same when they weren't which resulted in some strange airfoil plots.

NACA 2412 Ordinates			
Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	0	0	0
1.25	2.15	1.25	1.65
2.5	2.99	2.5	- 2.27
5.0	4.13	5.0	- 3.01
7.5	4.96	7.5	- 3.46
10	5.63	10	- 3.75
15	6.61	15	- 4.10
20	7.26	20	- 4.23
25	7.67	25	- 4.22
30	7.88	30	- 4.12
40	7.80	40	- 3.80
50	7.24	50	- 3.34
60	6.36	60	- 2.76
70	5.18	70	- 2.14
80	3.75	80	- 1.50
90	2.08	90	- 0.82
95	1.14	95	- 0.48
100	0	100	0
L.E. radius: 1.58			
Slope of radius through L.E.: 0.10			

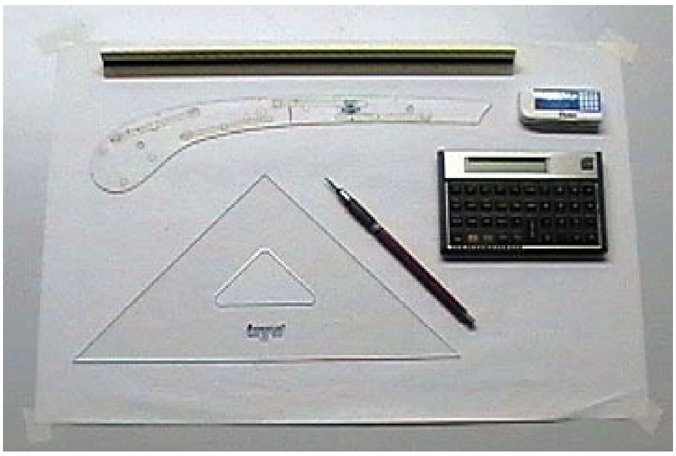
NACA 2412 (9" Chord)			
Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0.000	0.000	0.000	0.000
0.113	0.194	0.113	-0.149
0.225	0.269	0.225	-0.204
0.450	0.372	0.450	-0.271
0.675	0.446	0.675	-0.311
0.900	0.507	0.900	-0.338
1.350	0.595	1.350	-0.369
1.800	0.653	1.800	-0.381
2.250	0.690	2.250	-0.380
2.700	0.709	2.700	-0.371
3.600	0.702	3.600	-0.342
4.500	0.652	4.500	-0.301
5.400	0.570	5.400	-0.248
6.300	0.466	6.300	-0.193
7.200	0.338	7.200	-0.135
8.100	0.187	8.100	-0.074
8.550	0.103	8.550	-0.043
9.000	0.000	9.000	0.000
L.E. Radius = 0.142			

Now that you have the numbers they need to be plotted on paper. The ordinate/station pairs are simply (x, y) coordinates. The Station is X and the Ordinate is Y.

Part 3: Plotting and Drawing an Airfoil

An airfoil can be drawn with a minimum of drafting instruments.

You will need a sharp pencil, accurate scale (ruler), and a good curve. I use ship curves because they better match the shape of an airfoil. French curves are more common, but tend to have curves that are too sharp.



If you do not want to buy ship curves then an adjustable curve might work. I've tried few different types of adjustable curves and none of them were satisfactory to me. Your results may vary.

If you must use French Curves, try to find one that is at least twice the length of the airfoil you are drawing. You can also bend a stick of wood which is surprisingly accurate. I use a piece of 1/8" x 1/4" spruce to draw long curves, such as fuselages, when I draw plans.

The calculator only needs to be able to multiply, so any calculator will work.

Draw a centerline slightly longer than the airfoil chord.

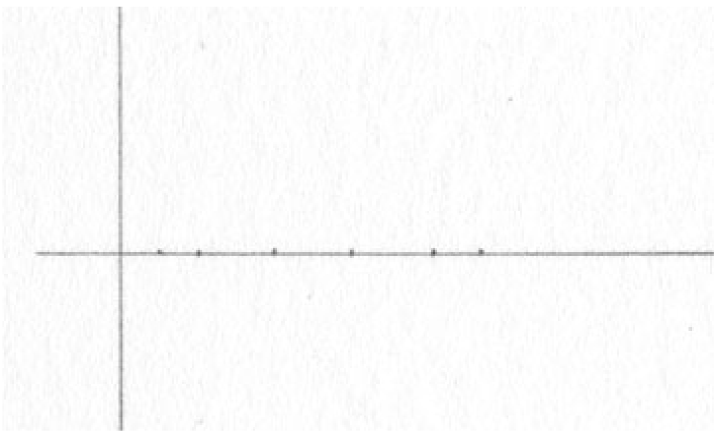
Draw lines to represent the front of the leading edge and the rear of the trailing edge.

The chord of this airfoil is 9" so that is the distance the lines are spaced.

Make tick marks along the centerline to indicate the station locations.

The intersection of the leading edge and centerline is point (0, 0) for this ordinate standard.

Some ordinate standards have the trailing edge as point (0, 0). If you aren't sure what standard you're using, just plot the points. If you are using the same standard as I am here, the airfoil will point to the left.



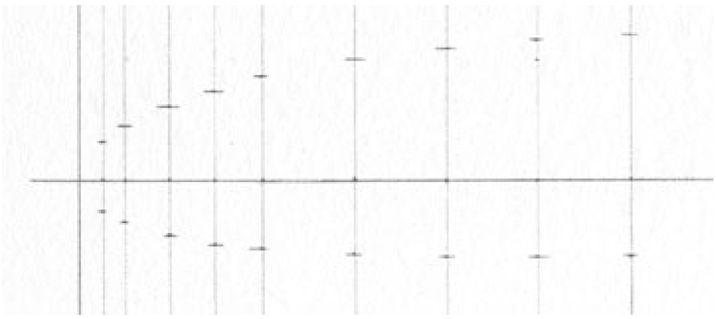
If you plot the points backwards, the airfoil will point to the right. Either way you end up with the same airfoil.

Draw vertical station lines through the ticks you made in the previous step.

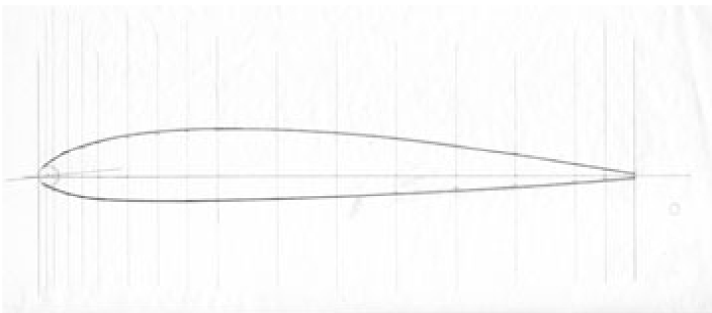
If the stations are different for the upper and lower portions of the airfoil then you should probably make ticks for one side. Then draw the lines. Repeat for the underside of the airfoil.

Tick off the ordinate locations at each station.

The trailing edge of this airfoil tapers to 0" thickness. However, I will sheet this wing with 1/16" balsa. That means I will have to fudge the airfoil somewhat to account for the sheeting.



The next image actually represents two steps combined into one. I neglected to scan the drawing between steps



Draw the slope of radius through the leading edge.

Slope = Rise over Run = y divided by x. In this case the Slope is 0.1.

To draw the slope line, start at point (0, 0). Measure back 1" (x) along the airfoil centerline and from there measure up .1 inch (y). Draw a line through point (0, 0) and the point you just marked.

The center of the circle representing the leading edge is found on the slope line by measuring from point (0, 0) to a distance equal to the radius of the leading edge.

For example, if the diameter of the leading edge is 1", then measure back 1/2" (radius) along the slope line. That is the center of the circle that represents the leading edge. Draw the circle.

Using curves that match the point best, draw the airfoil outline. Normally I use several different curves by selecting the curve that best matches the airfoil in any given section.

The airfoil is tangent to the leading edge.

Because of the thickness of the sheeting, it is not possible to draw the exact outline through the plotted ordinates. However, the finished product will be close enough that in our realm, nobody would notice the difference in the flight characteristics.

Be as accurate as you can but do what needs to be done to make the wing something that can actually be built and not just a theoretical ideal.

Establishing the Rib Pattern

The airfoil outline is complete but it can't be used as is. The actual outline will not be a part of the pattern unless the wing has no sheeting.

What we need to do is subtract the thickness of the sheeting from the pattern and draw the location of structural details such as the Leading Edge, Sub-Leading Edge, Spars, Ailerons and Trailing edge.

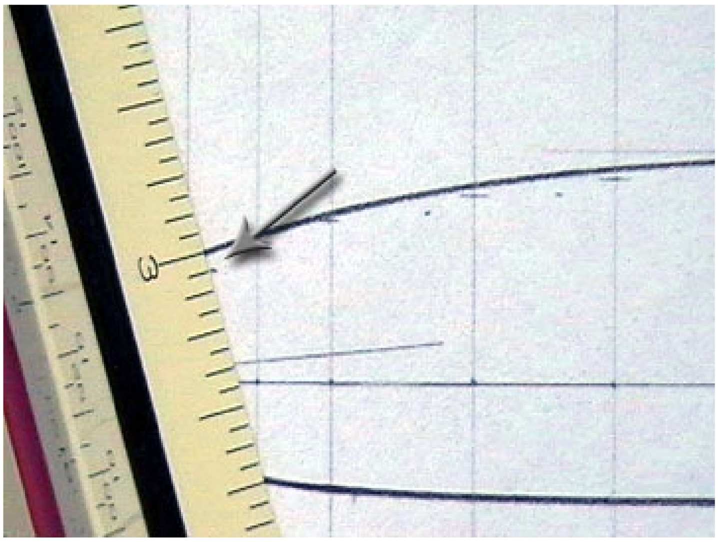
The order in which you do these things in does not matter as long as you know what's what.

In this example, the Leading and Trailing Edges are 1/4" wide. The Sub-Leading edge is 1/8" wide and the Main Spars are 3/8" wide. The Aileron is 1-1/4" wide.

Main spars are located where the wing is thickest for maximum strength.

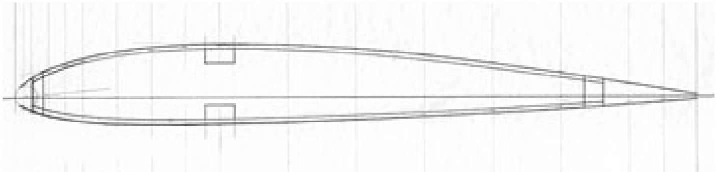
Work your way around the perimeter of the airfoil and make tick marks inside the airfoil outline to indicate the thickness of the sheeting.

Arrange the scale so that it is perpendicular to the airfoil at the point from which your are measuring for best accuracy. I normally eyeball this, but better would be to use an adjustable triangle that is adjusted to be perfectly tangent to the airfoil at each point.



Make enough tick marks to draw an accurate outline.

Draw the rib pattern using the tick marks. The rib pattern outline should be parallel to the airfoil.



Finish any other details necessary. If some ribs are different than others, which is usual, then you should probably cut two patterns at the same time.

For example, you may want to add landing gear cut-outs to the second pattern. I usually draw unique cut-outs directly on the ribs after cutting them out using a single master pattern. Matching ribs from each wing panel are stacked and cut at the same time.

I tend to draw my pattern and glue it directly to whatever will be used for the template. If you think you might want to save the original drawing then make copies.

Most copiers do not make exact size reproductions

Copiers either enlarge or reduce from the original to a small degree. Usually it is by such a small difference that it is not a problem. Be sure to check before you start cutting patterns and ribs. If the pattern off by an unacceptable amount you'll have a really bad day if you find out that the wing you just built doesn't fit.