



PEAK OF FLIGHT

N E W S L E T T E R

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Cover Photo: The SAFIR rocket kit from Aggressor Aerospace Rocketry. Get your own at: https://www.apogeerockets.com/Rocket_Kits/Skill_Level_3_Kits/SAFIR

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Carve an Airfoil into a Glider Wing

By Tim Van Milligan

A couple of local modelers recently asked me about gliders, and how to sand an airfoil into a wing. So I thought I'd give you my opinion.

The first question had to do with a curved wing, such as the one used on the Cirrus Breeze rocket glider kit (http://www.apogeerockets.com/Rocket_Kits/Skill_Level_5_Kits/Cirrus_Breeze_Rocket_Glider). Where do you point the high-point of the wing airfoil?

The technically correct answer is that it depends on the airfoil that you are sanding into the wing. Every airfoil has a set of coordinates that give the exact shape of the wing, so that it can be duplicated precisely if you wanted multiple copies of the same glider. Each airfoil, unfortunately, is different. They have different shapes depending on their purpose.

These different airfoils can be quite complex, and difficult to make. To be honest, I'm lazy too, and sanding airfoils is not my most favorite thing to do. And if the airfoil is under-cambered, meaning that it is slightly cupped on the bottom surface, it is even more difficult to sand by hand.

Generally, what I do and what I recommend, is to make a simple flat-bottom wing. What this means is that you only have to sand on the top surface of the airfoil.

The most famous flat-bottom airfoil is the Clark-Y airfoil. The high point for this airfoil shape is approximately 30% along the chord from the leading edge. The exact coordinates are shown in Figure 2.

"Station" means distance from the leading edge of the wing as a percentage of the total chord length. Think of it as a number line. So for example, say we wanted a big wing, with a chord length being 10 inches long. Then the first row in the chart is a percent of the total distance. I selected 10 inches, because it is an easy number to work

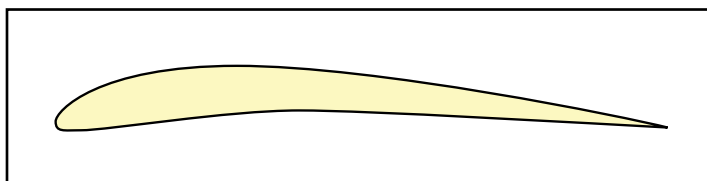


Figure 1: An under-cambered airfoil is typically more efficient, but harder to create.

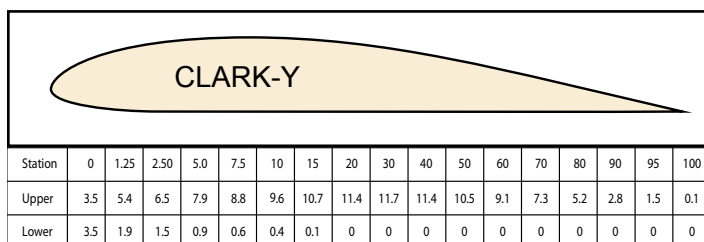


Figure 2: The coordinates for the Clark-Y airfoil. Because it has a flat bottom, it is easier to shape.

with. You'll note that the station starts at 0, the 1.25, 2.5, etc. The first point is 0, which means it is zero percent of the total distance. In effect, this is the leading edge point. The next point is 1.25. So this is 1.25% of the total length of the wing chord. 1.25% of 10 inches is .125 inches. The next point on the number line will be .25 inches back.

You'll notice that there are a lot of points close to the leading edge of the wing. The reason for this is that the curvature of the wing changes a lot near the front, so we need a lot of points to define it correctly.

The next two rows are upper and lower coordinates. These are like the y-axis of a chart. There are two numbers, because we have to define both the upper and lower surfaces of the wing.

These numbers are also measured in percent of the overall chord-length of the wing. For example, the high point on the upper surface is listed as 11.7 in the chart (it occurs at station 30). So the 11.7 means it is 11.7% of the total chord length of the wing. If our wing is 10 inches long, then 11.7% is 1.17 inches.

In real life, your glider wing won't have a chord of 10 inches long, unless it is a really big rocket. A real-life example might be the Cirrus Breeze kit, which has a root edge wing chord of 2.64 inches. If I was using a Clark-Y airfoil on it, the high point would be 30% back from the leading edge, which is .792 inches (found by multiplying $2.64 \times 0.3 = .792$ inches).

The thickness of the wing at that point is found by multiplying $2.64 \times .117 = .308$ inches.

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I don't know if you noticed it, but a wing that is 0.308 inches thick would be considered "very beefy." The thickness of the wood that we provide in the kit to the modeler is 3/16 inches thick (0.1875 inches). So I don't expect you to make an exact Clark-Y airfoil, because the provided wood is much too thin.

But what is "doable" is to make a wing that resembles a Clark-Y airfoil, even though it won't be thick enough. As mentioned previously, we typically use this airfoil shape because it has a flat bottom, so you only have to sand the top surface (see Figure 3).

That gets us back to the original question: "where is the high point on this airfoil?" In general, the high point on most airfoils is between 25 to 30 percent back from the leading edge. The Clark-Y airfoil fits this generalization, since it has its high point at 30%.

But I like to use 25% for my own wings instead of 30%, because it is easy to find. I just divide the length in half, and then that length in half. That is what I show in the video on how to sand the airfoil at: http://www.apogeerockets.com/Advanced_Construction_videos/Rocketry_Video_127.

Do you have to be exactly at 25%? No. We've already significantly modified the Clark-Y airfoil, so we don't have

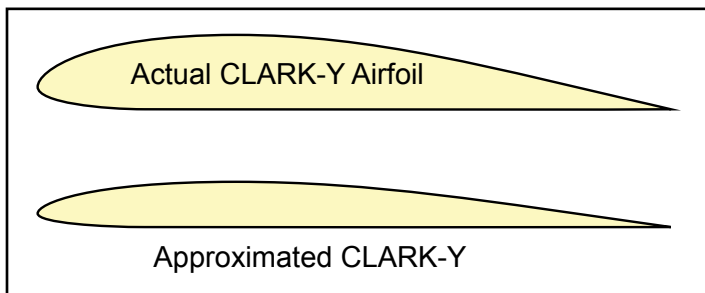


Figure 3: Since most wings are thinner, you can approximate the curvature to utilize the wood you have.

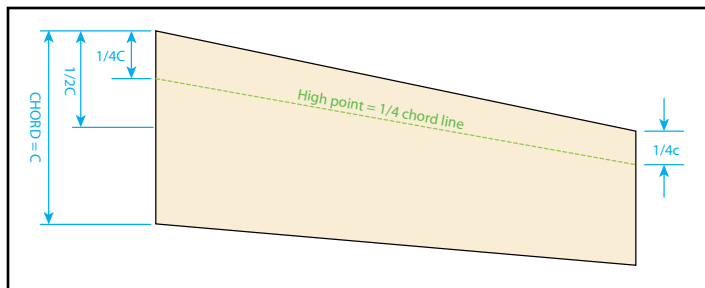


Figure 4: For a straight tapered wing, finding the quarter-chord line is easy. Find the 1/4 chord of both the root edge and the tip edge, and connect the points by a straight line.

to be exactly at a distance of 25% from the leading edge. Anywhere in the ball-park will be fine.

That brings up the question: "how important is the airfoil really?"

In reality, the answer to this question is depends on something else. That something else is how well the glider is trimmed for flight.

On a glider that is poorly trimmed for flight, such that its balance point is in the wrong spot, the exactness of the airfoil's shape really isn't important at all. The glider won't fly well when it is out of trim, and therefore the airfoil shape isn't going to make any difference.

In other words, if you had to decide to spend 10 minutes of your time between shaping an exact airfoil, or trimming the final glider for flight, you should always spend the extra time trimming the glider for flight. Note: for information on trimming gliders for smooth flight, see *Peak-of-Flight Newsletters*, issues 204 and 205 (<https://www.apogeerockets.com/education/downloads/Newsletter204.pdf>). The advantages of a well trimmed glider are more significant

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Carve an Airfoil into a Glider Wing

than using an exact low-drag airfoil.

If you want to experiment with glider trimming, and see how much of a difference it makes to the flight, I would recommend the Condor boost glider kit (https://www.apogeerockets.com/Rocket_Kits/Glider_Rockets/Condor_Boost_Glider). It has a wing that can be repositioned along the fuselage boom of the glider, and you can easily get a feel for how slight changes to the position of the wing compared to the CG can have a profound effect on performance. Plus, it has a wing that has been rough-hewn to an airfoil shape (see Figure 5). It doesn't take much effort to get a good airfoil into the wood.

When you get the trimming down, then having a good



Figure 5: The Condor boost glider wing has been rough hewn to approximate an airfoil. All the builder needs to do is smooth it out and round over the leading edge.

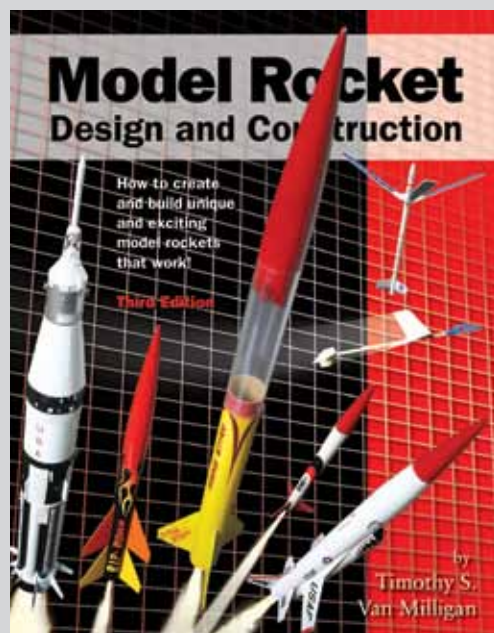
airfoil in the wing of your glider or in the fins of your rocket becomes more worthwhile. The vehicle will have significantly lower drag, allowing it to boost higher into the air, and it will glide nicer and longer on its journey back to the ground.

The next question that might be going through your mind is: "is the modified Clark-Y airfoil good compared to other exact airfoils?" Personally, I think it is good enough. But I'm not a super expert on glider performance. In the gliders I build, I'm still concentrating on getting the models trimmed correctly. I really haven't played with making a lot of gliders to the point where having a superior airfoil is going to be noticeable. There are some modelers that are in this category of flight, but there aren't that many of them yet (hint, hint). So for me, having a Clark-Y type airfoil, or something similar to it, is good enough.

If you want to find the best airfoil, you'll want to talk to some of the zen masters that have been involved in free flight gliders for a long time, or do a search on the internet. If you're that person, you might want to do a follow-up article to this one, and report back with your findings.

"What do you do if your wing is not rectangular (like shown in Figure 4)? Where do you put the high-point then?" This is the original question that my friend was asking me. On the Cirrus Breeze kit, the wing shape is curved, and both the leading edge and the trailing edge have a curvature to them.

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Carve an Airfoil into a Glider Wing

The answer is to break up the wing into chords, and find the 1/4 chord point of each of those (see the top drawing in Figure 6). From there, you draw a line connecting the 1/4 chord points. The more sections you break the wing into, the more curved the final line will become. Ideally, you can smooth out the curve and mark it with a felt-tip pen (see the bottom drawing in Figure 6).

What is the easiest way to shape the airfoil?

This is where technique and skill come into play. To be honest, it takes a lot of experience to shape an airfoil. I suggest that you start with sandpaper for your first few glider wings. As you gain practice, you can switch to a wood plane. It will shave off the wood faster.

But using a wood plane is tricky. If you don't have good

technique, it is easy to take away too much or gouge the wood

The technique that I use for shaping the airfoil into a glider wing can be seen in my video: http://www.apogeerockets.com/Advanced_Construction_videos/Rocketry_Video_127

Conclusion

In this article, I just wanted to cover some of the basic considerations you'll have to make when making a glider and carving the airfoil into the wing. I personally don't put too much effort in making the optimum airfoil, but I do spend some amount of time carving and shaping an approximate airfoil into the wing. But I also invest the time to properly trim the glider for flight. You end up with a glider that flies much better and really wows spectators.

Additional references on airfoil shapes used for this article: <http://www.airplanesandrockets.com/resources/airfoil-plotting.htm>

About the Author

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. Before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (<http://www.apogeerockets.com>) and the curator of the rocketry education web site: <http://www.apogeerockets.com/education/>. He is also the author of the books: "Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics" and publisher of a FREE e-zine newsletter about model rockets.

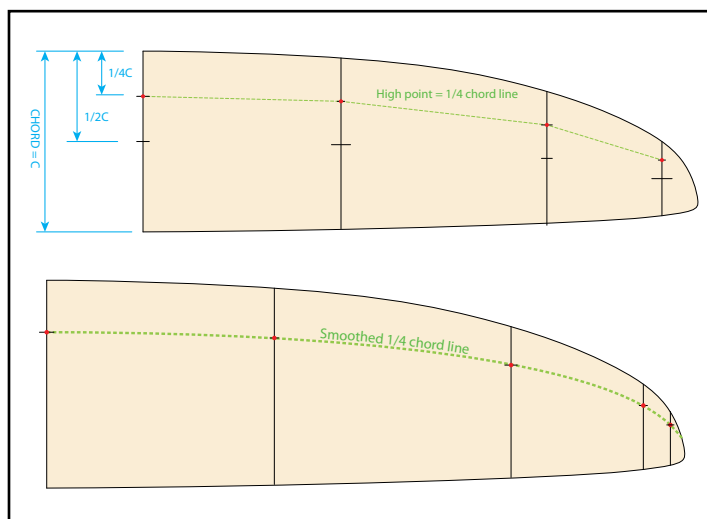


Figure 6: To find the quarter-chord line for a curved wing, you need to break it up into sections, and find the quarter chord of each line. Then connect the points (top). Finally, the line can be smoothed out (bottom).

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