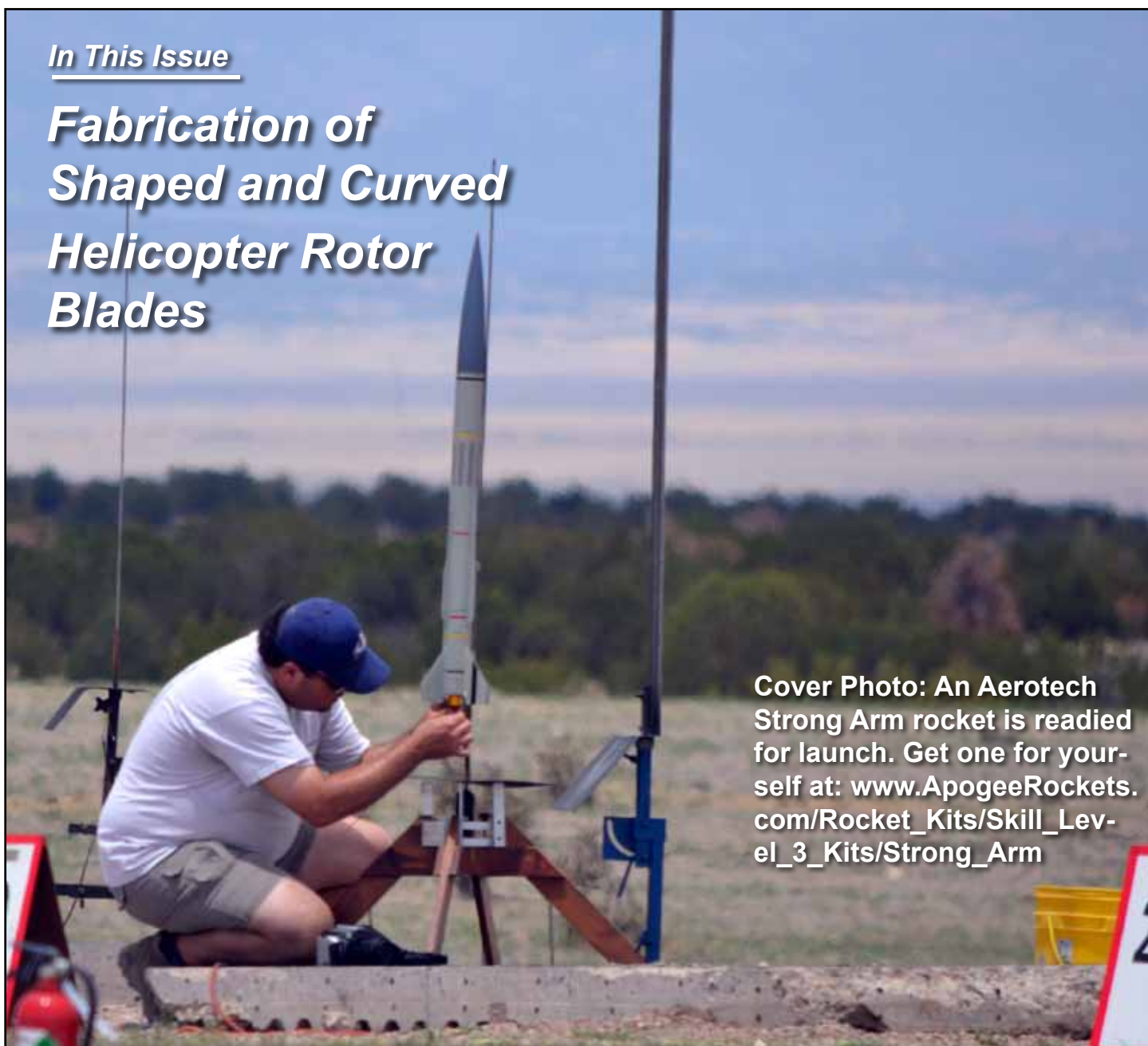


# PEAK OF FLIGHT

N E W S L E T T E R

## In This Issue

### ***Fabrication of Shaped and Curved Helicopter Rotor Blades***



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## Fabrication of Shaped and Curved Helicopter Rotor Blades

By Tim Van Milligan

About four or six years ago, I saw a cool “curved blade” on a helicopter recovery model. It caught my eye, because it looked swoopy like a propellor from an airplane. This design came from a model built for FAI competition (see Figure 1), so I suspected that it was pretty efficient.

Unfortunately, at the time, I didn’t pursue how the blade was made, so it just faded away into my old memory.

This summer, as I was helping my daughter prepare for a rocket contest, I came across more information about this unique curved blade. It was in a Powerpoint presentation entitled “*Model Rocket Helicopter (Gyrocopter) Duration*,” by Trip Barber. This document is available for download at the NAR web site (visit [www.NAR.org](http://www.NAR.org), and navigate to the *FAI Spacemodeling* section, which is part of the *Contest Flying* portion of the web site). The report gives a brief summary of why these curved blades are used, and how to make them. The purpose of this article is to expand on that information, in hopes that you’ll give them a try too on your next helicopter recovery model.

### Why Use These Curved Blades?

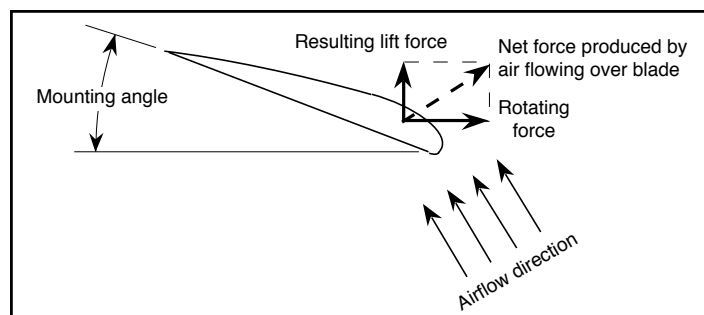
There were three good reasons that I can think of to use shaped and curved blades.

First, because they are curved, they provide for a lot of

blade area that will fit into a compact area. So if you wanted to put them into a tube, like in an FAI model, they will fit more easily than flat helicopter blades.

Second, according to Keith Vinyard in the report, a curved plate produces lift from -20 to +20 degree angle of attack, so it spins up quickly, and the optimization of twist angle with respect to the air stream is not as critical as with a flat blade. I’m not sure of the accuracy of this, but it sounds really interesting.

And the third reason to use the curved blade is that it can be shaped to provide a twist. This twist is necessary to create the forces necessary for the model to start rotating. If a portion of the blade isn’t angled downward as shown in Figure 2, then there will be no lift force that drives the blade to spin the model.



**Figure 2: When the rotor blade is angled downward, the lift drives the blade forward and creates a force to counteract gravity.**

Unfortunately, if the entire blade is angled downward, then you lose a lot of efficiency because the tips of the blade are at an improper angle for providing lift to counteract the pull of gravity. In other words, the rocket descends faster if it isn’t optimized.

By twisting the blade, you have one portion that is pitched downward (the inner portion closest to the axis of rotation) that drives the rotation, and the outer portion that is pitched upward to provide maximum lift to slow the descent of the model.



**Figure 1: An FAI-Competition style gyrocopter that uses shaped and curved blades.**

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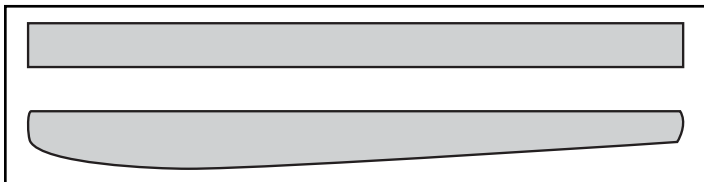
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## Shaped and Curved Helicopter Rotors

The unique thing is that a “shaped curved blade” can accomplish the twist easily. And by “*easily*,” I mean that it doesn’t take a lot of effort to make them.

### What Is A Shaped Curved Blade?

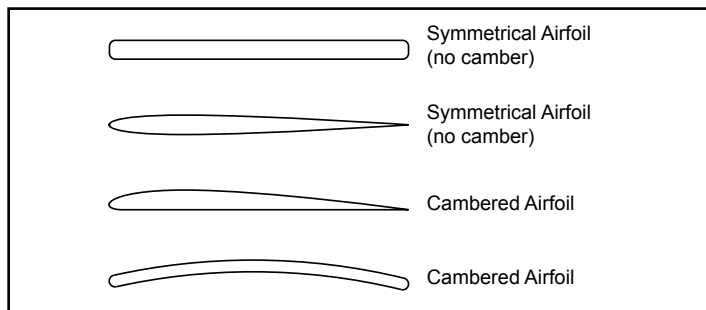
Shaped, in this case, means the blade is not a regular rectangle. One or more edges of the blade are not parallel to the opposite edge. Figure 3 shows the difference between a shaped blade and a rectangular blade.



**Figure 3: A rectangular blade shape versus a “shaped” rotor blade.**

The key concept, that took me a long time to realize when I saw pictures of these blades, is that the curved edge is NOT the trailing edge. We usually associate the straight edge to be the leading edge, which penetrates the airflow. But in this case, the curved edge is the front edge.

The shape would mean nothing, if the blade were not curved. This is also very important. The basic “shaped



**Figure 4: When flying at zero degrees angle of attack, symmetrical airfoils don’t produce a lift force. But a cambered airfoil will.**

blade” is curved (wrapped) around a cylinder. What this does is give the airfoil some camber (an aeronautical term used to describe the arched shape of the blade thickness). By creating camber (as seen in Figure 4), the airfoil will generate a lift force in one direction as it moves through the air.

There are many things going on here. First, the airfoil is changing along the span of the blade. Near the root edge, which attaches to the axis of the rocket, the airfoil is wide and fat (Section A-A shown in Figure 5 on the next page). It has a lot of camber too, which means it is arched significantly. And towards the tip of the blade, because the shape

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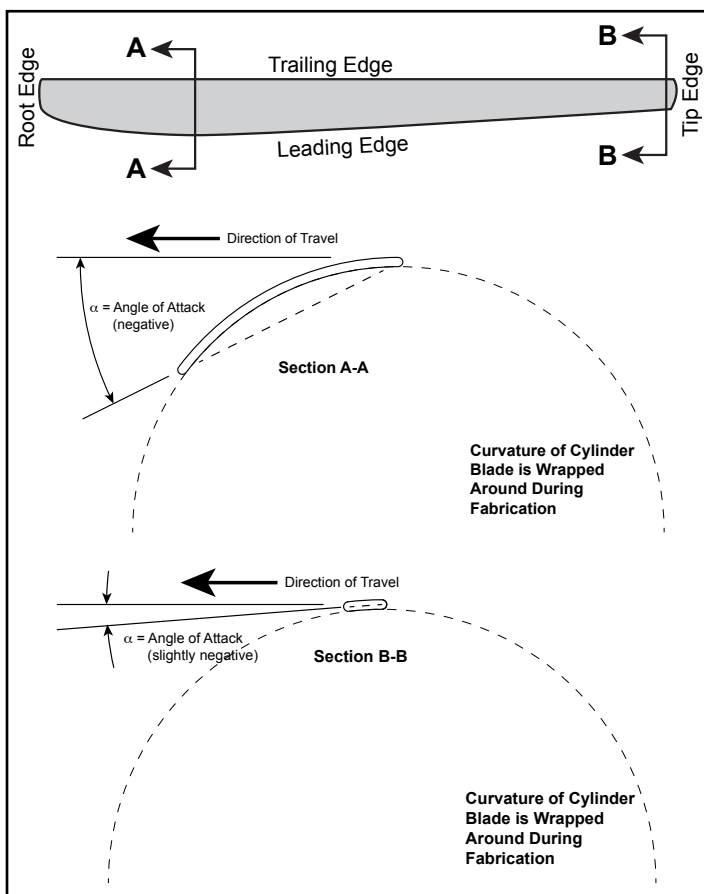
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## Shaped and Curved Helicopter Rotors



**Figure 5: The rotor blade angle-of-attack changes from the root to the tip, because of the curvature built into the wood when it was rolled around a cylinder during fabrication.**

is more narrow, the airfoil has less camber.

The other thing going on here is that the chord angle of attack changes. If you draw a straight line from the leading edge of the blade to the trailing edge near the root edge of the blade, you'll see that it is angled. In other words,

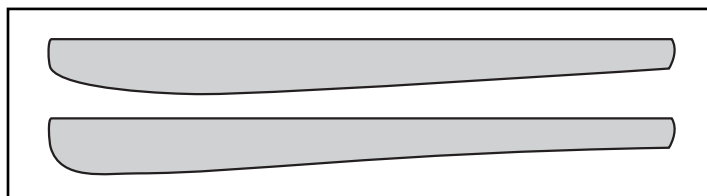
the leading edge is lower than the trailing edge. What this means is that the blade is pitched down, and is at a negative angle of attack.

At the tip (the portion furthest away from the axis of the rocket, and shown in Section B-B in Figure 5), the leading edge and the trailing edge are almost at the same level. This means that this portion of the blade will be at near zero degree angle of attack as the model rotates.

Essentially, by shaping the blade and curving it around a cylinder, it is possible to create a twisted blade. And this is exactly what is needed for a blade that is optimized for high rotation speed and high lift at the tip.

### ***Fabricating the Shaped Blades***

The first part in making a shaped-curved blade is to cut out the shape from a piece of balsa wood. Thinner wood can be curved easier, so for your first experiment, I suggest using 1/16 inch thick balsa wood.



**Figure 6: The shape of the blade can be varied to find the optimum shape.**

To be honest, I don't know the best shape to use, or where to put the maximum width of the blade shape. For example, I don't know which shape shown in Figure 6 will give the slowest descent speeds. This is the one piece of information that I wasn't able to find out in my research. I'm sure there are some theoreticians that know the answer, and if I find out, I'll let you know. So the shape of the rotor blade for my models was the upper one shown in Figure 3.

Continued on page 5

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## Shaped and Curved Helicopter Rotors

I do know, from simple geometry, that the widest portion of the blade (Section A-A shown in Figure 5) can't be greater than  $\frac{1}{3}$  the circumference of the cylinder you plan on wrapping the blade around. That assumes you are building a three-rotor blade model. It also assumes that your blades won't overlap each other. Overlapping (meaning the blades tuck over each other as they are folded together for launch) might be an option, depending on your design. But for starters, we'll assume they don't overlap.

And the widest portion of the blade needs to be nearer the hinge where the blade will attach to the rocket's axis.

### Curving the Airfoil

As complex as this rotor airfoil is, making the curve is relatively easy. All you need to do is soak the wood in ammonia-water. The ammonia softens the lignin in the cell

walls of the balsa, making it more bendable. Then it can be curved around a cylinder without cracking the wood.

When I was doing my first experiment, I didn't have any ammonia handy. So I grabbed a bottle of Windex, which I knew by the smell had some ammonia in it. I then simply placed the blades on a piece of plastic sheet, and sprayed them down as shown in Figure 7.

Since the wood was thin, the fluid saturated the fibers quite quickly. But I let them sit and soak for about 10 minutes, just to be sure they were pliable.

For the cylinder, I found a PVC pipe. It was around 1-1/4 inches in diameter, and I thought this would work fine for a test. Plastic works well, because it doesn't deform when it gets wet. I've since tried a dowel that was  $\frac{1}{2}$  inch



**Figure 7:** Wet the balsa with an ammonia solution to soften the fibers of the wood.




**Figure 8:** Tape the ends of the blades around the cylinder. Make sure all the blades are oriented the same direction.

in diameter to make small blades for this article, and that worked just fine too.

Getting the blades to lay down on the cylinder wasn't hard. I wrapped tape around each of the ends to hold them

Continued on page 6



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## Shaped and Curved Helicopter Rotors



**Figure 9:** Wrap a long strip of cloth over the blades to hold them against the curvature of the cylinder. Make sure it is tight.

where I wanted on the plastic tube (see Figure 8). Next, wrap a long strip of cloth around the blades in a spiral arrangement. You can pull up the tape holding the blades down as you wrap the cloth over the blades. You can leave the tape on the ends, but it then takes longer for the water to evaporate out of the wood. The reason to use cloth is that the water in the wood can evaporate quickly.

Since Colorado is so hot and dry this time of year, in about two hours my blades were bone dry. In parts of the country where there is more humidity, it will obviously take a lot longer for them to dry out.

When the wood is dry, you can remove the cloth, and you'll find the most beautifully curved blades you've ever seen.



**Figure 10:** They look like Pringles potato chips once the blades are dry.

The other cool thing about the blades is that once they have a curvature in them, the longitudinal moment of inertia increases significantly. In other words, they are stiffer than the wood was before it was applied to the cylinder. Resist the urge to see how stiff they are... Trust me based on my stupid experience; you can break them if you try to bend them.

### Sand Them Down

If you want to save time, sanding the surface of the blades to smooth them out should be done after they have dried out. The water makes the wood swell a bit, so if you sanded them prior to soaking them in the ammonia-water, you'll have to re-sand them.

I also rounded the leading edge, and thinned out the

Continued on page 7

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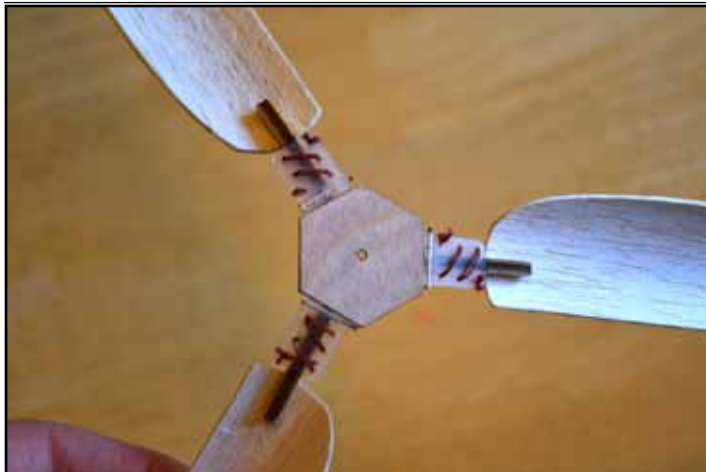
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## Shaped and Curved Helicopter Rotors



**Figure 11:** In FAI-contest style gyrocopters, a post is typically used to attach the blades to the hinges.

trailing edge (the straight edge of the blade).

At this point, the blade is done, and is ready to attach to the hub.

### Attachment to the Hub

The hub is where the blades are mounted to the axis of the rocket. It will require some type of hinge arrangement. And because the hinges are flat, it can be tricky to come



**Figure 12:** For small rotor blades, modify the plastic hinge by cutting the flap to conform to the blade.

up with some sort of arrangement to attach to the curved airfoil on the blade. A single post is what is used in FAI style rockets, as shown in Figure 11.

Another option, particularly on smaller blades, is to trim one flap of the hinge to be narrower, so that they can be glued directly to the underside of the curved airfoil (See Figure 12).

Figure 13 shows a partially completed helicopter model

Continued on page 8

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# PEAK OF FLIGHT

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## Shaped and Curved Helicopter Rotors



**Figure 13:** When wrapped around the rocket, the curved blades make a compact, low-drag rocket.

with the curved blades mounted on the outside of the rocket. It is a much more compact arrangement than using flat blades, and therefore the drag should be lower on the rocket. That means the rocket flies higher for the same amount of total impulse.

In conclusion, I'm really happy to have discovered this type of helicopter blade. I can think of all sorts of configurations that I'd like to try out. As I've said before, I really like helicopter recovery models, and I am always looking for ways to make them more efficient.

### 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://](http://www.ApogeeRockets.com)



**Figure 14:** The curved blades also slip into a body tube easier than flat airfoil blades.

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