Apogee Components

PEAK OF FLIGHT

NEWSLETTER

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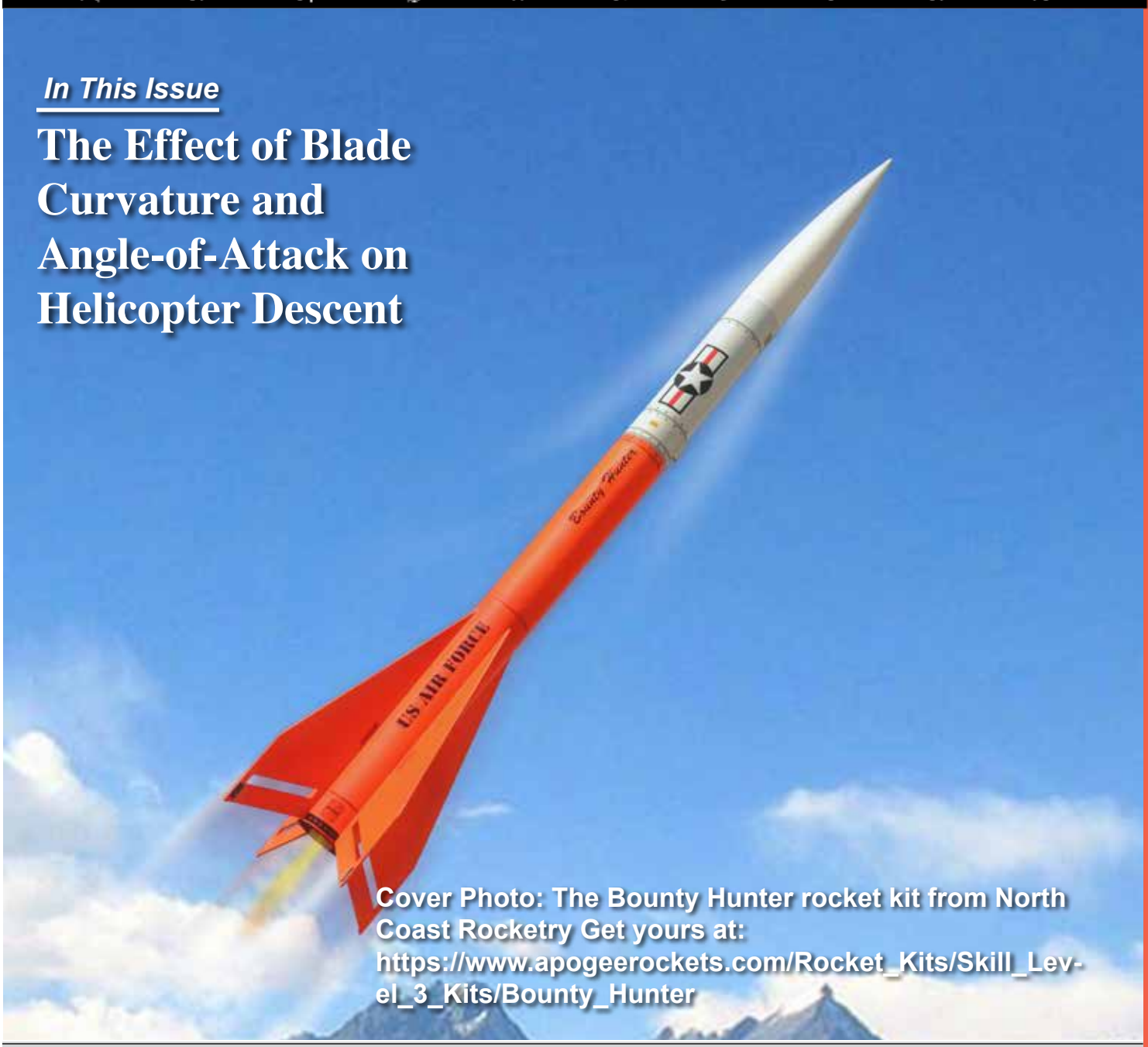
The Effect of Blade Curvature and Angle-of-Attack on Helicopter Descent



Cover Photo: The Bounty Hunter rocket kit from North Coast Rocketry Get yours at: https://www.apogeerockets.com/Rocket_Kits/Skill_Level_3_Kits/Bounty_Hunter

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The Effect of Blade Curvature and Angle-of-Attack on Helicopter Descent

By Ashley Van Milligan / Introduction By Tim Van Milligan

Introduction

How much difference do helicopter blade airfoils make? Over the last year, I've been corresponding with Chris Flanigan about helicopter rotor blades for the Rotary Revolution rocket kit (https://www.apogeerockets.com/Rocket_Kits/Skill_Level_4_Kits/Rotary_Revolution). Chris is almost as much of a helicopter rocket fanatic as I am, so when he talks, I listen. He wrote me this email:

> *"I've done some analysis to try to identify better airfoils for S9A {the name given to the FAI competition category that the Rotary Revolution kit falls in to}. The analysis results predict that thin cambered blades are significantly better than flat bottom blades. Best aerodynamic performance comes from an airfoil formed by wrapping the blade around a ~6" diameter cylinder. This airfoil shape has better aerodynamics than a blade formed around a 40mm mandrel or 1.5" PVC pipe. However, blades formed on 1.5" PVC pipe are significantly stiffer than the blades from a 6" cylinder. The stiffer blades are easier to handle and (I think) eject more easily from the body. So the "best" blade might be a compromise between aero performance and structural stiffness."*

This email came to mez about the same time that my daughter Ashley was looking for an R&D project to do for this year's NARAM. She is an avid competitor, and I thought that testing this hypothesis would be an easy project. After all, she watched her older sister do a similar project last year at NARAM (see *Peak-of-Flight* Newsletter #381 at: https://www.apogeerockets.com/education/downloads/Newsletter381.pdf)

She understood the concept, so she decided to test this and see if Chris Flanigan was correct. The following is the text of her R&D report that she presented at NARAM 57 in Tucson, Arizona in late July.

The Objective of the Work

I got this idea when my dad was talking to Chris Flanigan. He mentioned that according to his research, blades on a larger pvc pipe would work better that the ones we used in our rockets. So I decided to see if it was true.

The Approach Taken

Step 1: The first thing I did was to choose which blades I would use for my research project. These blades were: The Standard Blade (which is used on the Rotary Revolution rocket kit from Apogee Components), The Tapered Blade, Allison's Optimum Blade, and The Rectangular Shaped Blade. The Tapered blade and the Rectangular shape were suggested by Chris Flanigan. The blades were made from 1/32" thick balsa wood.

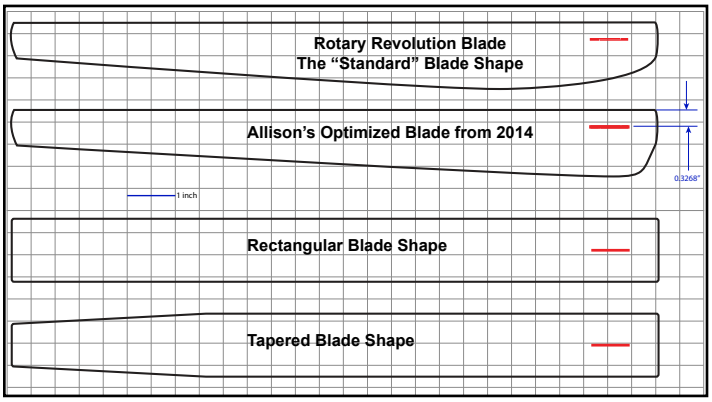

Image 1: The different blade shapes used in this experiment.

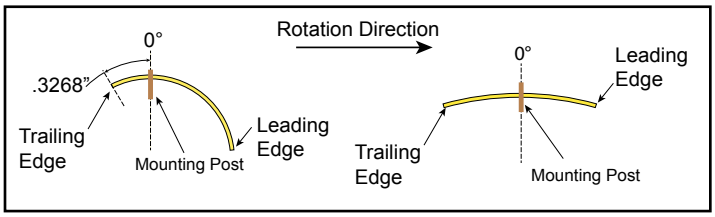

Image 2: Comparison of blades wrapped around 1" (left) and 4" PVC pipe. Blade curvature at root edge.

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Image 3: Blades are wetted, taped to the PVC pipe, and then held into place with a cloth strip.

Originally, the Standard Blade and Allison Optimum Blade were on a 1 inch PVC pipe. I used these because they are what I am comparing against. The Tapered blade and the Rectangular Blades were on a 4.5-inch PVC pipe.

Next I needed to get the blades curved so they would spin better. To get the blades curved I soaked them in ammonia water. Then I had to tape the blades on the PVC pipes because this was the curve I wanted to get. After I taped the blades I wrapped them in cloth. The cloth helps keep the curve and dries the blades (the cloth was a piece of ripped off bedding sheet).

Image 4: Hub assembly for 0º AOA.

After this I stuck the blades outside in the sun to dry for about 2 hours. I had to do that for the 4.5-inch PVC twice because there were so many blades.

Step 2: The next thing that I did was find the part where the blades are put on, which is called the hub (I used the one my sister used last year for her R&D project). Also, to keep the blades from coming out of where they are, I made wedges.

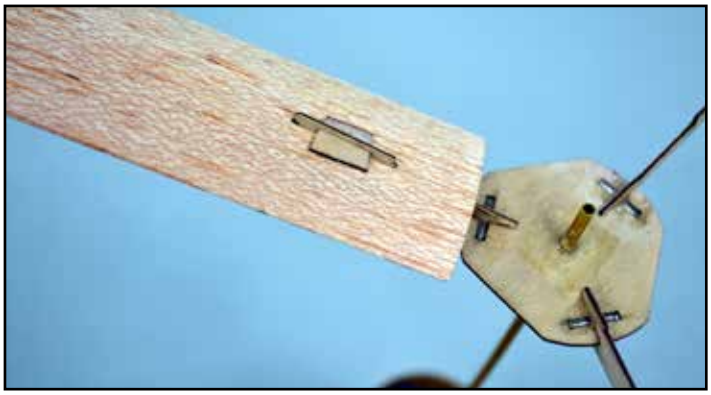

Image 5: Wedges hold the blades on the hub.

Step 3: Before I went to the bridge for a drop test I weighed each blade. After I weighed each blade I found the heaviest blade of the set. Then I added clay to the lighter blades to make them all equal weight. I did this for each set

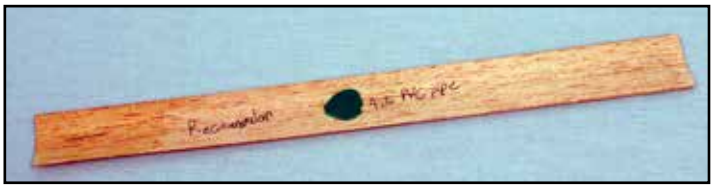

Image 6: Adding clay to the lightest blades to make them and equal weight.

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of blades. I then found the balancing point of each blade. I drew a line to mark the balancing point. I did this for all the blades. I added super glue over the lined area to help the clay stick better to the blades.

Next I put the blades on the hub. I put the blades on a hub set to 0 degrees. I checked to make sure the hub part with the blades weighed 20 grams. I added more clay to equal 20 grams. I used 20 grams, because that is what a competition rocket usually weighs.

Image 7: 32 foot drop test.

Blade Shape	Time #1	Time #2	Time #3	Average Time
Standard Blade (1" pvc pipe)	3.34 (Wobbly)	5.34	3.87	4.18
Rectangular	2.8 (no spin)	3.32 (no spin)	2.21 (no spin)	2.78
Tapered	5.16	4.5	5.0	4.89
Allison's Optimum (1" pvc pipe)	6.30	5.85	5.37	5.84

Image 8: Data Table #1: Blades mounted on arm at 0º Angle-of-Attack.

Step 4: Now it was time for the drop test. We went to a bridge that was 32 feet and 2 inches high. We measured this using a string with a weight attached to it.

We dropped each of the four different shapes 3 times to see which helicopter blades stayed in the air the longest. If a drop-test hit the bridge we had to redo that test. My dad was timing it while I dropped the rockets. The times were recorded. We dropped it 3 times because I needed to find the accurate time.

Step 5: Because the rectangular blade shape didn't spin, my dad suggested that we angle the blade to try to get it to spin. So we came home and my dad built a new hub where the blades would be mounted at a 3 degrees angle (Image 9). He also put supports under the blades to keep them from rotating on the mounting post (Image 10).

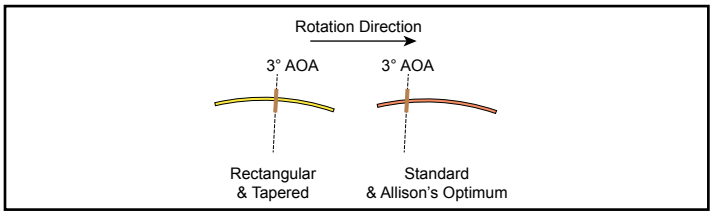

Image 9: 3º Mounting post position diagram.

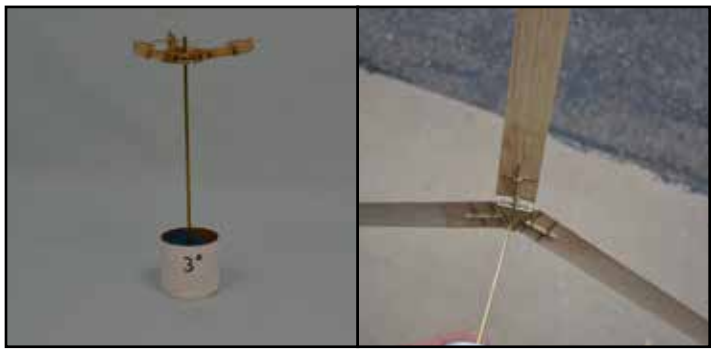

Image 10: Rectangular blade realigned to 3º.

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Step 6: I also realized that if the Standard and Allison Optimum were not on the 4.5-inch PVC then it would not be an accurate test. So I decided that I would put the Standard and Allison Optimum blades on the 4.5-inch PVC pipe, and I made new blades for the second drop test.

Blade Shape	Time #1	Time #2	Time #3	Average Time
Standard Blade	5.70	6.84	7.10	6.54
Rectangular	(no spin)	(no spin)	(no spin)	- - -
Tapered	2.68 (slow rotation)	3.0 (slow rotation)	3.93 (slow rotation)	3.20
Allison's Optimum	6.1 (hit bridge)	4.13 / 6.1	29.31 (caught wind gust)	11.41

Image 11: Data Table #2: Blades mounted on arm at 3º Angle-of-Attack.

Step 7: We went out again and dropped the Rectangular, Tapered, Standard, and Allison Optimum on the 3 degrees angle-of-attack (Image 11).

Looking at the results the Rectangular still did not even spin, and Allison's Optimum blade did even better with a larger curve and at a 3 degree angle of attack.

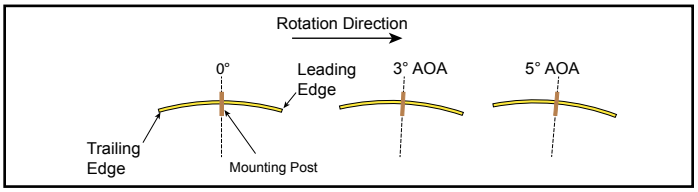

Image 12: Adjusted mounting position diagram with 5º change.

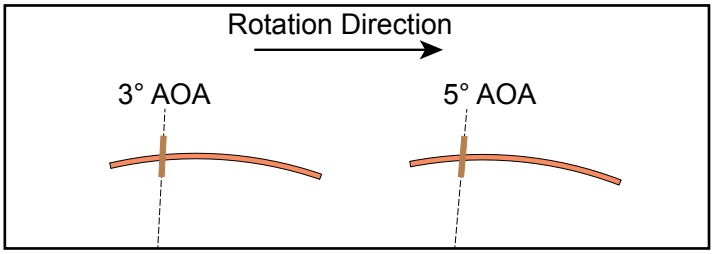

Image 13: Mounting post position for Allison's Optimum Blade Shape.

Blade Shape	Time #1	Time #2	Time #3	Average Time
Standard Blade				
Rectangular	2.94 (very little spin)	3.35 (very little spin)	3.68 (very little spin)	3.32
Tapered	4.53 (took long time to start rotating)	4.31 (took long time to start rotating)	5.38 (hit bridge) / 3.91	4.53
Allison's Optimum	4.97 (wobbly)	3.5 (hit bridge)	3.8 / 5.28	4.39

Image 12: Data Table #3: Blades mounted on arm at 5º Angle-of-Attack.

Step 8: Since the rectangular blades didn't spin my dad made a new hub tilted at 5 degees so we hoped the blades would spin (Image 13). I had to make new blades to fit the new hub. Since the "Standard" blades did not work as well as Allison's Optimum, I decided not to use it.

Step 9: We went out to do our final set of drop tests (Image 12).

Allison's Optimum shape didn't work the best because I thought it was unbalanced. So the last time the tapered worked the best.

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List of Any R&D Reports Previously Entered By Me

None

The Facilities Used

Apogee Components and a bridge

The Money Spent On Project (Budget)

1/32 balsa wood	$10.00
1/32 plywood	$5.00
1/16 plywood	$5.00
kite string	$0.50
Brass tube	$3.00
BT/60	$0.50
Clay	$0.20
4.5-inch PVC pipe	$7.00
1-inch PVC pipe	$3.00
Total	$34.20

The Conclusion Drawn

As you can see from the data that the Allison's Optimum blades on a 3 degree angle-of-Attack worked the best.The rectangular work the the worst.The one question that I couldn't answer was why the Tapered worked but the Rectangular didn't.

References to Previous work done on subject used For Research

"Finding the Best Gyrocopter Blade Shape and Best Place to Attach the Blade" By Allison Van Milligan. NARAM-56 R&D Project, July, 2014.

The Equipment Used

Stop watch

Scale(In grams)

Super Glue

1-inch PVC pipe

4.5-inch PVC pipe

Clay

BT/60

Brass Tube

Kite String

1/16 Ply Wood

1/32 Plywood

1/32 Balsa wood

Further work

I'd like to find out why the tapered blade rotated, but the rectangular one didn't.

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