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PEAK OF FLIGHT

NEWSLETTER

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Finding The Best Gyro-copter Blade Shape And Best Place To Attach The Blade

Cover Photo: Quest Zenith II rocket kit takes off. Get your own at: www.ApogeeRockets.com/Rocket_Kits/Skill_Level_2_Kits/Zenith_II

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Finding the Best Gyrocopter Blade Shape and Best Place to Attach the Blade

By Allison Van Milligan

Editor's Note: *This article is a synopsis of my 13-year old daughter Allison's R&D project that took 1st place in A-Division at NARAM-56 in July, 2014. The idea for her project came as a result of being selected for the USA National Team and was going to compete in Bulgaria at the World Space Modeling Championships. She wanted to win a Gold medal in the Gyrocopter event.*

At the time, I had created the hub for the gyrocopter (see www.ApogeeRockets.com/Education/Downloads/Newsletter375.pdf), but we were unsure if it had the best blade shape for the slowest descent time. That is what Allison wanted to research.

Allison's design worked fine at the World Spacemodeling Championships. Unfortunately, she had one flight where a single blade did not deploy properly, and the model didn't spin up. That one single DQ put her out of the running for any kind of medal.

What is important about this project is the method she used to test each shape she came up with. I'm still not 100% sure that she came up with the best shape, which is why the Rotary Revolution kit (www.ApogeeRockets.com/Rocket_Kits/Skill_Level_4_Kits/Rotary_Revolution) still has the original blade shape. More research is needed!

The objectives of the work

I am trying to find out the most effective gyrocopter blade shape and the most effective place to attach the blade to the gyrocopter hub.

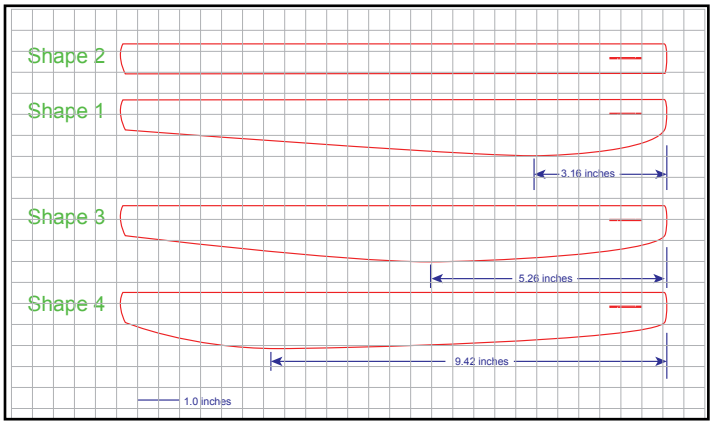
I will test multiple different blade shapes and different attachment places on the gyrocopter hub.

The results of this experiment will help me have the best gyrocopter I can compete with in the World Space Modeling Championships this August (2014) in Bulgaria.

I made all the gyrocopter blades the same length, they all had the same leading edge and top and bottom curvature. On the blades that the shape changed on, the only thing I changed was the curvature on the trailing edge. On the blades that I changed the attachment on the hub, or the position on the X-axis, I moved the slot in four different positions to test this.

The approach taken

Step 1: I designed all the different blade shapes and slot positions on the computer. For the blade shapes I made a shape in which the high point is at the top of the blade, I made one with the high point in the middle, a blade with the high point at the bottom of the blade, and a blade with no high point at all. See Drawing 1.



Drawing 1: Different Shaped Blades

For the position of the slot I measured four different places along the X-axis (see Drawing 2). Slot 4 is .8" away from the trailing edge, Slot 3 is .6548" away from the trailing edge, Slot 2 is 0.15" away from the trailing edge, Slot 1 is my original which is 0.3268" away from the trailing edge.

Blade Number	Testing	Blade Shape	Slot Distance From Leading Edge	Slot/Shape Number
1	Shape	Original	.3268"	1
2	Shape	No Curve	.3268"	2
3	Shape	Fat Point in Middle	.3268"	3
4	Shape	Fat Point at Bottom	.3268"	4
5	Slot	Original	.15"	2
6	Slot	Original	.3268"	1
7	Slot	Original	.6548"	3
8	Slot	Original	.8"	4

Data Table 1: The Blades Tested

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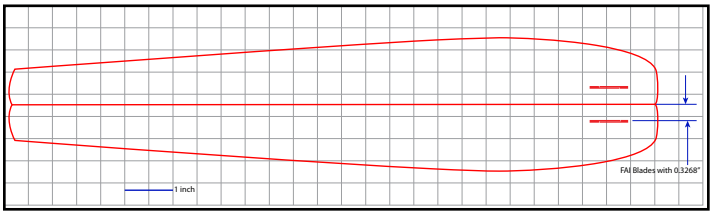
Finding The Best Gyrocopter Blade Shape



Drawing 2: Blades with Different Slots

I made a drawing like this for all the different slotted blades, changing the position of where the slots are.

Step 2: I cut out all the blades and the hub on the laser cutter at Apogee Components.

Step 3: I had to curve the blades. I did this by spraying all the blades with Ammonia. I just used Windex® because it has Ammonia in it. I sprayed all the blades with that.

Then I drew a straight line down a 1" PVC pipe. I taped all the blades I could fit on it. Then I ripped up an old sheet into long skinny stripes. I then wrapped the blades in the sheet so it would hold the curvature until the blades dried.

I set this outside in the hot Colorado sun until all the blades dried.

There are a couple reasons for the style of blade that has a curved shape. First, it changes the angle of attack over the length because it twists the blade. The twist is used to create the forces for the helicopter to start spinning. If a part of the blade isn't at an angle-of-attack, there won't be a lift force that makes the blade spin.

{Note: There is a detailed description of curved blades in Peak-of-Flight Newsletter #342. This can be found at: www.ApogeeRockets.com/Education/Downloads/Newsletter342.pdf}

Photo 1: Wrapping the blades to form the curved shape.

Second, in FAI, we want to make the blades as easy as possible to be put in and come out of the body tube. The curved shaped makes it fit easier to slide into a tube than a flat shaped blade would.

This shape changes the angle-of-attack by having the fat part at the angle-of-attack because that keeps the blade spinning and it still keeps some of the lift force. But the thinner part of the blade keeps all the lift force going up. I am trying to figure out the best balance of these to increase the duration time so I can win FAI. When I asked other team members nobody had an answer; they all just said that this shape works well.

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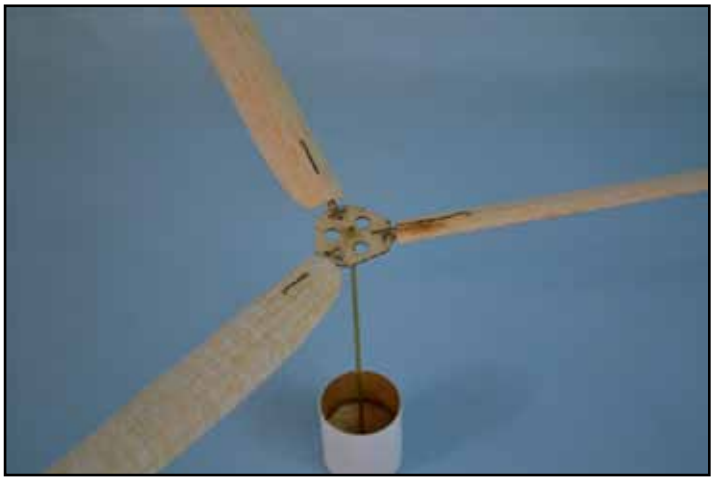

Photo 2: The special "drop hub" that my dad and I made in order to drop test the different blade shapes. The blades could be easily removed so each shape could be tested.

Once they were dried I unwrapped the bed-sheet and took the blades off. I did this on all of the different blade shapes.

Step 3: My dad and I made a special hub that I could attach all the blades to by popping them on and off. It had a bucket where weight could be added. See Photo 2.

My original plan was to have a hub that could run a piece of kevlar through it and it would go straight down so that would eliminate variables. The kevlar would be held perfectly straight at the bottom and top. I got this idea from Patrick Peterson and Chan Stevens from their R&D report 2011.

Step 4: I put SkyLoft (a nylon mesh, similar to Bounce fabric softener sheet) on the back of the attachment slots to keep them from ripping.

Step 5: I did some preliminary test drops with my original blades and my hub. But it didn't work well. The hub kept getting caught on the kevlar because of friction. The blades were off balance so I put some clay on the hub to balance it out. That made it a little bit better but it still wasn't working good enough to fall perfectly straight. So my Dad had this idea to make the tube that the kevlar goes through longer. It started at 1/2 inch long, and then changed it to be about 6 inches long. Guess what?! That didn't work either! So the only thing left that I could do was redesign the hub.

Step 6: I had to redesign the hub. This time I made the part that sticks through the blade taller. I also put a slot in this so I could put a little piece of wood so that it would hold the blade down and in place. These tabs made it so that I could change the blades quickly from one set to another. See Photo 3.

Step 7: I rebuilt the helicopter hub the same way I built the other hub just with different parts.

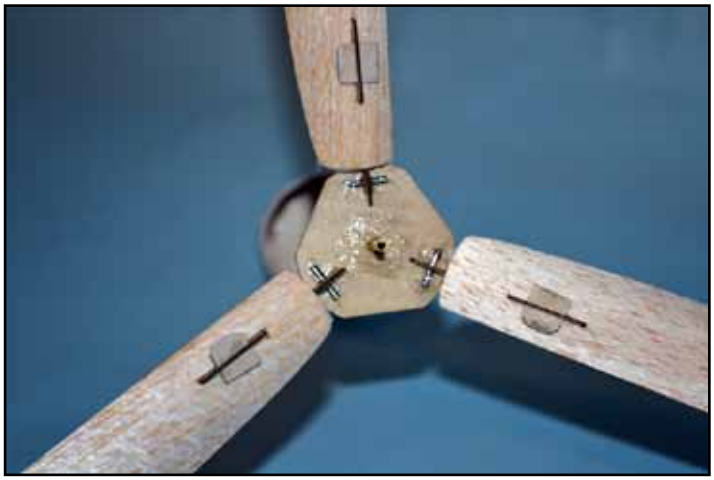

Photo 3: The top of the hub. Small wedges of wood held the blades in place.

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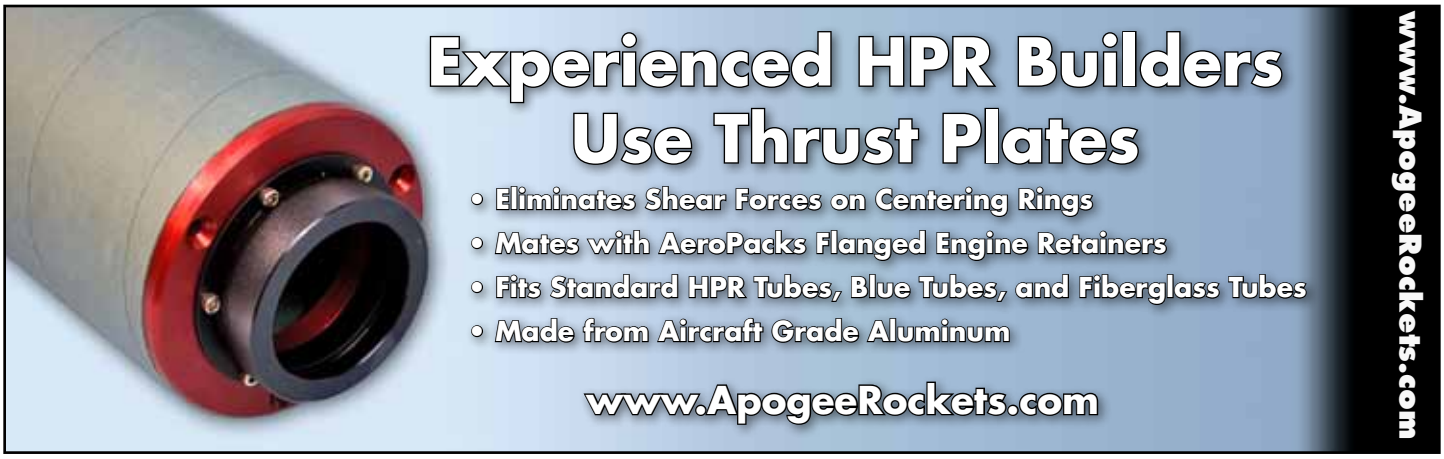

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Step 8: I tested this new hub. And this time it worked well in a simple drop test. I decided that I wasn't going to put the hub down a piece of kevlar because the friction made it slow down.

Step 9: Preparing for the drop tests: I put a set of blades and the hub on a scale. They all had different masses so I decided to make them all 20.0g so that I could really see which blade works the best. I chose 20 grams because that is the approximate weight of an FAI gyrocopter. For the blades and hubs that didn't exactly weigh 20.0g I added clay inside of the little bucket part of the hub.

Step 10: I had to make sure all the blades were balanced. To do this I put a piece of string through the hub, my dad held it horizontal and tight while I spun the blades. The blade that landed at the bottom I put a little mark on. Then, I spun it again and if that blade landed on the bottom again I put a little bit of clay on the other blades until they were perfectly even (so it was random which blade ended on the bottom after it stopped rotating). Then I put the hub and blades on the scale an made sure that they still had a mass of 20g.

Photo 5: Balancing the blades.

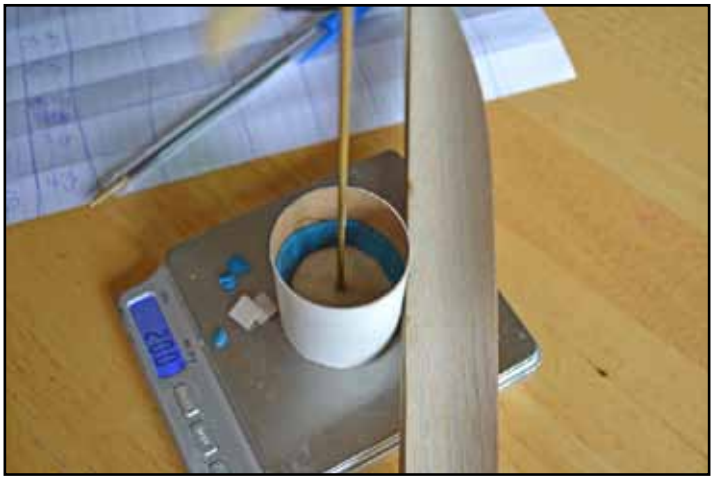

Photo 4: Weighing the blades. Clay was added in the bucket to make sure they all had the same mass.

Step 11: It was time to do the drop tests. My dad climbed up on the roof with the blades and a piece of string with a safety-pin tied to one end. The string allowed me to attach the blades while my Dad pulled it up to do another drop.

While he was up there I stood on the ground; I said 3...2...1...Drop! My dad dropped the helicopter hub and blades while I was timing it with a stopwatch.

After recording the data: when it had hit the ground I checked to make sure that the blades weren't broken or anything, my dad sent the string with the safety-pin on it

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Photo 6: My dad on the roof dropping the helicopter blades and hub fixture.

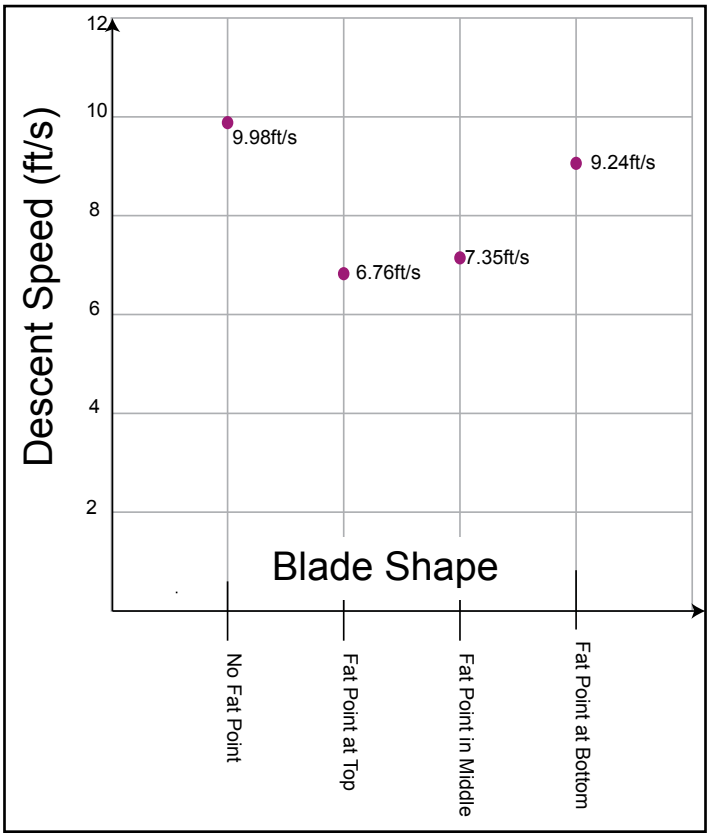
down, I picked it up, attached it on the brass rod, my dad pulled it up. We dropped each set of blades four times and averaged the results. With the averaged result I found the speed.

Step 12: I went back inside and had to repeat this until all the blades had been tested.

Step 13: Once I had found out which blade shape and slot distance worked the best, I decided that I needed to make a couple more blades to come up with the very best blade. My original blade shape was the one that worked the best and a slot at 0.3268” from the X-axis a the leading edge of the blade.

Blade #	Weight	Drop Height	Total Weight	Drop 1	Drop 2	Drop 3	Drop 4	Drop Average	Speed	Notes
1	3.7g	23ft 8in	20g	3.53s	3.50s	3.34s	3.63s	3.5s	6.76ft/s	Little wobble
2	4.5g	23ft 8in	20g	2.15s	2.46s	2.22s	2.63s	2.37s	9.98ft/s	Stopped & Restarted Spinning
3	3.5g	23ft 8in	20g	3.52s	2.41s	3.51s	3.45s	3.22s	7.35ft/s	Wobbled
4	3.4g	23ft 8in	20g	2.61s	2.54s	3.01s	2.08s	2.56s	9.24ft/s	Takes a long time to start spinning
5	≈5.3g	23ft 8in	20g	1.72s	1.53s	1.96s	1.68s	1.72s	13.7ft/s	Spun really fast
6	3.1g	23ft 8in	20g	4.19s	4.41s	4.35s	2.97s	3.98s	5.94ft/s	Worked really good
7	3.1g	23ft 8in	20g	2.67s	2.71s	2.44s	2.03s	2.46s	9.61ft/s	Spun pretty good
8	4.7g	23ft 8in	20g	2.29s	2.68s	2.03s	2.45s	2.36s	10.03ft/s	Average spin

Data Table 2: Results from round one of drop tests.



Graph 1: Results for the different blade shapes.

Step 14: To place a different slot in the blade I made the new slots based on the best one so far. I placed a slot half way between 0.3268” and 0.15” which is 0.2384”. The next blade I made was half way between 0.3268” and 0.6548” which is 0.4908”.

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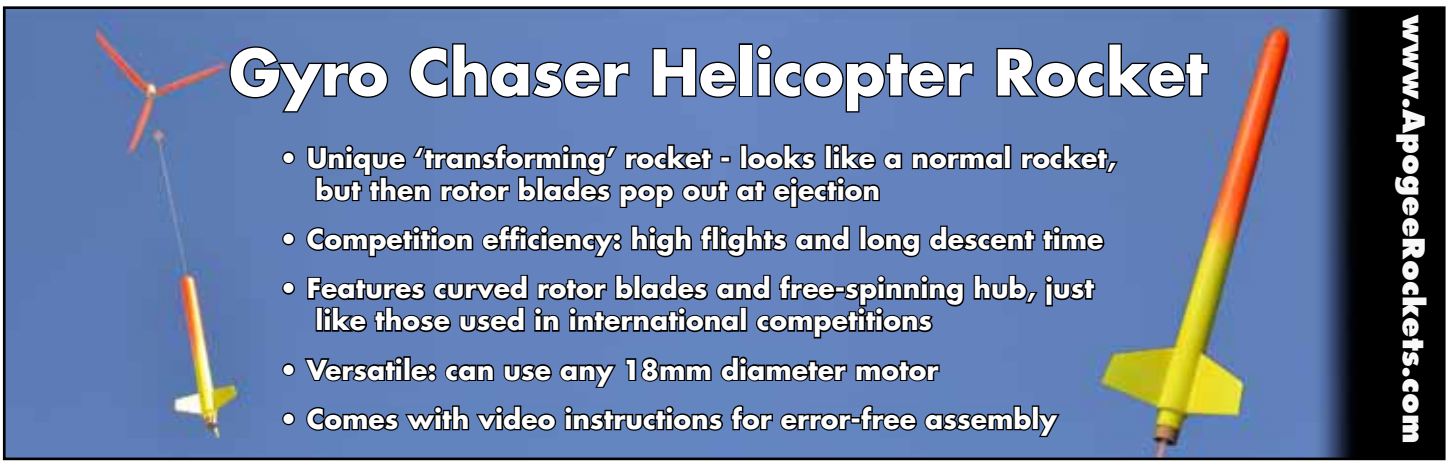

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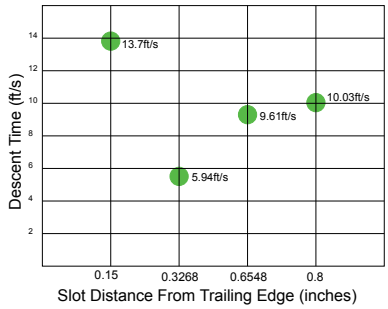
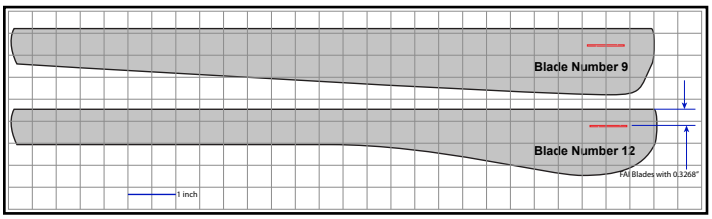


Graph 2: Results for the different slot locations.

Then, I decided to make two more blade shapes; one of them I moved the widest point to almost the very top of the blade. The other blade I created I also made the fat part closer to the hub but then I made it turn into a long skinny part to try to create more lift on the blade. Both of these blades slot points were at 0.3268" (see Drawing 3).

Step 15: I made these blades the EXACT same way I



Drawing 3: The Two New Blade Shapes

made the other blades; Cut them, curved them, put skyLoft on, then I was ready to drop these blades.

Step 16: It was time to test the new blade shapes. As before, I got the masses of just the blades. Then I put the hub, blades, and little wood pieces on the scale. I added clay until it was equal to 20 grams. Then I made all the blades balanced. Finally it was time to do the drop tests. My Dad climbed up on the roof, while I sat on the ground and timed each drop.

Step 17: It was time to evaluate all my data.

Step 18: Based on the drop tests, I concluded that

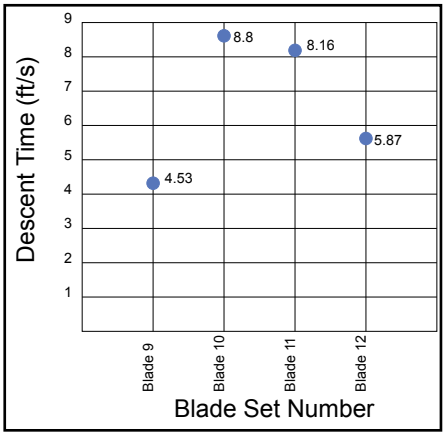
Blade #	Weight	Height	Total Weight	1	2	3	4	Average	Speed	Notes
9	4.1g	23.66ft	20g	2.49s	3.12s	5.36s	4.95s	5.2175s	4.53ft/s	Long time to start rotating then okay
10	4.4g	23.66ft	20g	2.57s	2.87s	2.94s	2.37s	2.6875ss	8.8ft/s	Drops like a rock
11	4.9g	23.66ft	20g	3.66s	2.52s	2.90s	2.52s	2.9s	8.16ft/s	Really long time to start spinning
12	5.2g	23.66ft	20g	5.02s	3.67s	3.91s	3.51s	4.0275s	5.87ft/s	Took a long time to spin up

Data Table 3: Results from round two of drop tests.

Blade shape #9 (shown in Drawing 3) worked the best, and I will be using it on my FAI models.

The results obtained

The most efficient working helicopter blades that I created were blade set #9. This blade I had moved the fat point to almost the very top of the blade. I also found out that you have to have a balance between the skinny part of the blade and the fat part of the blade. Blade set number 12 didn't work as well because the skinny part of the blade was too long. But that blade shape still worked better than all the others except #9. In 3rd place is blade #6 which is a slot blade whose slot is at .3268" from the leading edge.



Graph 3: The Second Round of Drop Test.

The conclusions drawn

To make the most efficient helicopter blade you

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Finding The Best Gyrocopter Blade Shape

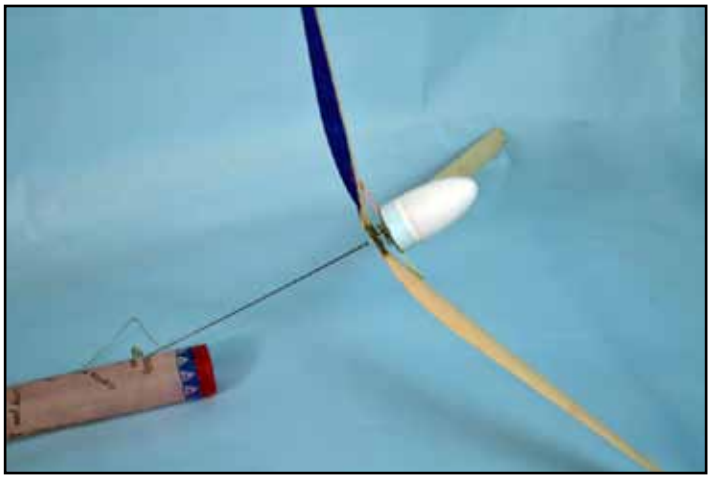

Photo 7: A finished gyrocopter rocket.

need to make the blade have a fat point. The fat point needs to be as close to the top as possible. Then the blade needs to have a skinny point which creates lift, but if you have too much of the blade become skinny too fast it makes the blade less effective. The best slot placement is a little bit less then half way between the blade. On my helicopter blade the best placement was .3268". If the slot is too close to the leading edge it spins really fast but also drops really fast. But if the slot is too close to the trailing edge it doesn't spin very well and also drops fast. So the best blade you could make is one with the fat point at the top and gets skinny but not to fast, the slot is a little less then half way, and I would recommend at least sanding these, probably air-foiling them. I didn't sand them for my test because I ran out of time.

Further work that would clarify or extend the results obtained

I would try to figure out the exact equation of the fat point to the skinny point and the exact placement of the slot so I could make the most effective blade. I would also test them by doing flight tests.

Also, I will be testing this out in Bulgaria to see if I can win.

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