A Different Paradigm for Propeller and Rubber Motor Selection by Sam Brauer FAC

About 5 years ago, I wrote an article that was based on my experience with using some plastic propellers for rubber powered free flight models (mostly scale). I hadn't been flying outdoor FF for all that long competitively (if you can call it that) so it was largely based on my experience flying indoors. But these days- especially with COVID, I've been flying outdoors more, so perhaps its time to update this guide.

Flying outdoors has some different requirements than indoors- you often want a bit more oomph to climb out since altitude buys you less turbulence (hopefully) and some time in the glide. However, I've also seen some folks have a real rocket climb with their airplanes- gets impressively small in a hurry. Downside to this approach is that you need good eyesight and legs for retrieval. I don't mind walking, but I'm not very good at tracking where my airplanes land so I prefer keeping them a little closer. There's another downside as well. Often the amount of rubber you need to produce that rocket climb- well, it leads to quite the sled ride when the power runs out. From flying indoors, I tend to prefer using minimal power- i.e. enough to get the airplane to climb to the desired altitude of 20 to 50 feet, but not much more.This isn't a hard and fast rule- some of my airplanes climb out so that I can have quite the chase. (I still tend not to use D/Ts- seems to be "cheating" in our crowd.)

There are two benefits of using less motor:

- 1) lighter weight which leads to less drag and longer duration in the glide
- 2) smaller prop also leads to less drag and a more "floaty" glide.

Depending on the day, the lower power approach can work fine and I've gotten a few kanones occasionally. One meet at Pinkham field, my Jug took the marbles flying with 15% rubber against some well known fliers- and it won every round in WWII with three very consistent flights in the 50 second range. Never got very high, but didn't come down quickly either.

When I began flying mass launch events with rubber restrictions, that made me start keeping track of the weight of my motors. And while my day job may be a scientist (haven't been in a lab in decades though), I do this stuff for fun and I don't want it to feel like work. I don't use notebooks and track data religiously- I just look for some relationships that make figuring things out a little easier.

I came up with a rule of thumb about motor cross section and weight. I discovered that you can bump up the cross section of a single strand of the rubber by about 1/16" per 10 grams of all up airplane weight. (I'm sure that others have come up with a similar relationship- I just don't remember reading it anywhere.) So a 20 gram airplane needs a loop of about an 1/8", a 30 gram airplane is going to need around 3/16" and 40 grams needs a loop of $\frac{1}{4}"$. It's not a hard and fast rule, but it gets you in the ball park- and you don't need a very good scale either. Bear in mind that these loops are about 2x prop to peg – I rarely go more than 2.5x as I don't like

the motor flopping around- it's wasting energy. Odds are that this is around 20-25% rubber or so. While the torque that a motor generates is proportional to its cross section, there's an additional relationship with length. Simply put, as the motor gets longer, it produces less power. Tom Arnold (a good egg) came up with a good rule of thumb here- shorten the motor by 10% for a useful increase in power. If you don't have a rubber stripper- this length trick is a good way to fine tune the power of a motor.

Once you've got a motor you think should work for the airplane- it's time to figure out a prop. (Don't tell the FF purists that this is how the electric guys set up airplanes too...) What I've found over the years is that certain props work with certain motors. Too big a prop and you get a powered glide. Too small a prop and you're giving up duration. A lot of folks shoot for the biggest prop that the airplane can handle. Well, that works for them, but not for me. In FF, there are lots of ways to skin a cat. I'm sharing what works for me, but YMMV and there's more than one way to a kanone.

We're looking for the Goldilocks prop- not too big and not too small. Too big and your airplane has to carry extra weight in prop and rubber. Too small and the prop burns through the turns in a hurry and you lose duration. Here are the relationships you have to think about:

- 1) Larger prop with the same P/D ratio will fly the airplane at lower rpm.
- 2) A rubber motor with thicker cross section takes fewer turns/inch.

This is what makes figuring the correct prop out so challenging- there can be a number of combinations which will come up with a reasonable result. How to determine the Goldilocks prop? Well, I have no crystal ball- I simply fly the airplane. I like buying cheap prop hooks, that way, when I change props, it doesn't give me a pain in my wallet. When I get a prop I'm happy with, I'll go to a better prop hook.

Here's the paradigm:

- 1) Figure outa motor that should fly the airplane reasonably. Start with the constraints listed above: rubber weight of 20-25% of the empty airplane weight with a 2x hook to peg length.
- 2) Use the table below and find out which props should work with that size motor.
- 3) Pick a lower pitch prop for a draggy airplane, a higher pitch prop for a cleaner ship.
- 4) Fly the airplane. Use a stop watch and get an idea of how long it's flying for.
- 5) Try a different prop. Use the same motor, same number of turns. Time the airplane. A better prop= more duration. Lousier prop= less duration.

If you start having lots of torque effects-(the airplane rolls hard on launch or begins to tip stall) think about going to a narrow blade prop like a North Pacific prop. Or

you can trim the prop at the tips. You can also think about reducing the blade area by trimming the trailing edge although this isn't generally a great solution.

If the airplane descends and doesn't climb- you now have the option of bumping up the rubber or changing props. Increasing your rubber cross section will add weightis that really what you need to do? You might try clipping the tips of the prop to increase your rpm instead.

You have to be careful you don't get into chasing your tail when you bump up the prop size. The tail chase is that you need more power, which adds weight, so you need more power and the airplane needs to fly faster to carry the weight, so you need more power again.

One of the advantages of limited motor weights is that you avoid this tail chase- your motor weight is fixed. Sometimes what you learn is that when you go back to flying without restrictions- you don't necessarily want to add lots more motor.

Tweaks on props:

A lot of commercial plastic props don't have enough pitch. The exception are the Guillow's props, believe it or else. The simplest way to fix this problem is to cut back the diameter of the prop which increases the pitch/diameter (P/D) ratio. For draggy airplanes, P/D ratios of 1.0 to 1.1 seem to do OK, while for slicker airplanes, a P/D ratio of ~1.3 works for me. But blade shape plays an important role too, so sometimes I'll use a lower pitch prop than ideal because it has a good blade shape, (Testor's prop is a good example.) The other tweak you can do to a prop is scrape it to get rid of some weight. This is tedious and bad for the environment, but sometimes there's not much choice. The simple way to scrape is to take a sharp blade and hold it perpendicular to the surface. You have to scrape the front of the blade. This is also a good way to lighten a prop.

If I've got an airplane that seems to be pretty happy with an Igra (Czech) prop, but I want to try to get a bit more duration and clipping the tips didn't do the trick- well, going to a Peck prop that's 2" larger in diameter and cutting it back to a similar blade shape as the Czech prop can work. I find the Peck props are the easiest to rework- the plastic cuts easily with scissors and they're generally reasonably light. One downside of the Peck props is the prop clutch often fails. If this is annoying to you- the Chinese props may be a good alternative. However, when you're cutting back the prop and using smaller rubber, often the Peck props hold up fine.

So with all that out of the way- let's update the prop selection guideline as I've got a few more airplanes under my belt.

For small airplanes, i.e. under 5 grams- the North Pacific Skeeter prop can work well, but I haven't used this prop much, because I generally don't build this small. I have no idea of the rubber I was using, other than it was < 1/16".

For P-nuts-(note- all my P-nuts fly on rubber I've stripped- generally it's less than 3/32") I've found that the 5" Kaysun prop works pretty well. Has two disadvantages- all of mine have needed balancing pretty badly and there's no prop clutch and trying to cut one in- well, I'm going to the old aluminum tubing and wire trick for a prop clutch. The advantage of this prop is that it has a lot of pitch-I think more than either the Easy Built prop in this size range or the Peck (silver) prop. Both the Easy Built prop and the Peck prop needs work to do much more than 30 seconds and I've pretty much given up on them in this size range- cut back, these props could only work in a smaller airplane and I'm often going to balsa props then. The North Pacific Sleek Streek prop is really a good go-to prop in this size range- the only reason to use the Kaysun prop instead is too much of a torque issue.

For slightly larger airplanes- the choices start expanding.

For 3/32" generally around 5 ½" props- The Igra (Czech) prop remains a good choice but if you start going much larger in rubber than 3/32", consider a different prop such as the Testor (commonly known as the Tern Aero) prop. However, I'm using the Igra props more and more- they're doing very well on airplanes in the 17-20 gram range. On the lighter end of things-there's the North Pacific Sleek Streek prop which I think works for airplanes with not much drag and a relatively low wing loading. For heavier models- consider the Guillow's 4 3/4" prop (found in their Strato Streak). This prop is heavier than the North Pacific (NP) prop, often needs balancing, but has more pitch than anything else in the size range. It's surprisingly efficient- don't toss them out. They can work well in a short nosed dimey. The Easy Built (EB) 6" prop may actually work in this rubber size range too-not sure yet. It's basically double the weight of the NP prop though. My recollection is that it will work on less rubber than the Testor's prop, but I could be wrong.

For 1/8"-these are typically 6" or so props. I still like the Testors prop-on smaller airplanes it can work very well with rubber between 3/32" and 1/8". But if you go to 5/32"- find a different prop.

The Easy Built 6" prop (white/gray). This prop does surprisingly well. I'm not crazy about the blade shape, but it must actually work well. It's also got more pitch than the Peck props. I used to cut down a 7" Peck prop often which was reasonably light, but I haven't done this in a while.

There's an MRC (there's no manufacturers markings on the prop, so I'm guessing) prop- black- with rounded tips that looks very similar to the Testor's prop- I think a lot of people mix the two up. It's got more pitch and I think more camber though than the Testor's prop. Didn't think it worked well at first since it really wants a bit more oomph than the Testor's prop but I'm using a couple and both airplanes are highly competitive. Note that both are pretty slick though. I have one in a Tail Firster embryo and on 1/8" rubber it doesn't climb much- but I can easily break 90 seconds under power. Wouldn't be surprised if it can handle a bit more than 1/8" rubber.

There's also a black prop (unknown mfg- I'm guessing at MPC) that has a similar blade shape to the North Pacific props but is larger and heavier than a Sleek Streek prop. Doesn't do well on 3/32" rubber, but seems to do pretty well on 1/8". Haven't been impressed with the 6" orange Chinese props- I'm getting less enamored with the Chinese props overall anyway. They don't have enough pitch and when you try reworking them, the blade shape suffers.

For 1/8" to 5/32" rubber- here's where I go to the North Pacific 7" prop – unfortunately hard to find. As always, North Pacific props are the lightest in a size range and also have a good pitch distribution. If you've got a porky airplane- don't be afraid to try the Guillow's 5 3/4"" prop. Like it's smaller brethren, it's heavy, often out of balance, but has a lot of pitch. Can go up to 3/16" rubber on this prop (and in a pinch $\frac{1}{4}"$), although you won't get good duration. I've also had good luck cutting back a Peck 8" prop. The Chinese 6" prop can work too.

For 5/32" to 3/16" rubber- I like the Czech 7 3/4" prop. They're a bit heavy and don't really have enough pitch, so I often clip the tips some. Be careful though-it's easy to overdo this trick. I've also gone up to $\frac{1}{4}"$ rubber with these props.I've liked the 7" Chinese props in biplanes with this level of power. I have a Pfalz that would get close to a minute without climbing too hard on this prop and I regularly fly a BE 2e on one as well- it's been the best prop on that airplane so far. Not so great on a slicker airplane andit's really for the 3/16" or so rubber- not 5/32".A cut back 8" Peck prop can work well here too, especially in a light, draggy ship- I have one in an Albatross that does quite nicely indoors on rubber ~ 5/32"-certainly less than 3/16".

For 3/16" rubber- the Easy Built 8" prop seems to do quite well so far in a lightly built Corsair that weighs in at 50 grams with 10% rubber. It's got a 3/16" cross section on 10%, but when I go to a longer motor (10% motors are often close to 1.0-1.2x prop hook to peg length)- it'll go to $\frac{1}{4}"$. Shows that there's really some "fudge room" in those weight/rubber calculations- a slicker airplane needs less power. In a smaller airplane, although with a higher wing loading, the Peck 9 $\frac{1}{2}"$ prop cut back to 7 $\frac{3}{4}"$ can really shine. I have one in a Lockheed Orion that just wasn't so happy on the Czech 7 $\frac{3}{4}"$ prop.

The other option that works well is the Czech P-30 prop cut down some but this is for closer to $\frac{1}{4}$ " rubber. I have one at 8 $\frac{1}{4}$ " that's doing quite well in a Laird biplane as well as my Jug. I've gotten less enamored of the 9" Chinese props- they needed a lot of rubber and didn't seem to deliver too much- lots of torque effects too.

When you go over ¼" rubber- well, I don't have many scale ships that size yet.

Manufacturer	Size (inches)	Weight (grams)	Rubber size range	Notes
			(inches)	
North Pacific	4 1/4	0.76	< 1/16	AKASkeeter

				prop,
Easy Built	43/4	1.77	<3/32	Not enough pitch to be all that useful.
Kaysun	43/4	1.55	<3/32	Needs balancing, prop clutch, but higher pitch than similar props and light
North Pacific	5 1/2	1.45	3/32	AKA Sleek Streek prop- light and efficient, but not so great in some heavier, draggy airplanes.
Guillows	4 3/4	1.94	3/32	Heavy, but high pitch
Igra	5 3/4	2.97	3/32+	AKA Czech prop, multiple colors, if you get to 1/8" rubber, go to a different prop. Haven't seen any improvement in modifying this prop.
Easy Built	6	3.15	3/32 to 1/8	Can be a good in a slick airplane.
MPC?	6	2.79	3/32+ to 1/8th	Looks similar to the North Pacific props, but heavier, 1/8 th might be a bit much, but 3/32 is too little.
Testors	6	2.75	3/32+ to 1/8	AKA Tern Aero prop. Can

				work with
				rubber a bit
				less than 1/8 th ,
				but generally
				with 1/8 th , can
				be a very
				competitive
				combination.
MRC?	6	2.83	1/8 to 1/8+	Can work on
				1/8 th , but
				might want a
				bit more. Very
				similar to the
				Testors prop,
				but needs
				more rubber.
Guillows	5 3/4	3.96	5/32	Might work on
				something a
				little less than
				5/32. Highly
				pitched. Not
				good in a
				draggy
				airplane.
North Pacific	6 15/16	2.64	5/32	AKA Star Flyer
				prop, hard to
				find. Good
				pitch
				distribution.
Chinese	7 1/16	4.01	5/32+ to	Can work in a
			3/16	draggy
				airplane.
Igra	7 3/4	5.56	3/16 to 1/4	Often needs to
				be cut back to
				7 1/4
Peck	91/2 cut back	N/A (it's in a	3/16 to 1/4	Higher pitch
	to 7 3/4	noseblock)		than Igra prop
		starts at 6.88		
Easy Built	8	5.35	3/16 to 1/4	Not much
				experience yet,
		5 04 (but promising.
Igra	$9\frac{1}{2}$ cut back to	7.31 (not	⊦¼ to a bit	Works in a 65
	81/4	trimmed)	more	gram airplane.

This table shows the props discussed above. I've tried to order the table so that descending the props listed goes to increasing power requirements. Note that the weights for a given propeller can vary a lot depending on moisture, fillers used etc. These are just the weights of the props in my drawer. I've tried to list the props that get modified often, but for most of the smaller props, well, it's easier to just change the prop out than to try to tweak it, especially because the tweaks often don't seem to help.

Here's a photo of the props in the table:

The props are ordered clockwise with the Skeeter prop being in the bottom right corner. I've shown the Peck prop that was the starting point for the cut down prop in the center noseblock (from an EB Lockheed Orion), while the Czech prop in the top right corner had the tips clipped for the prop with the cylindrical noseblock from a Laird Super Solution.

I hope that some of you find this table helpful. Periodically we get the plaintive question of "how do I figure out what prop/rubber to use in this airplane?" This article will hopefully allow you to figure out your own best combinations. Like Tom Hallman says- "Change your prop, change your airplane."

Thermals,

Sam