F2D News - December 2012

Mark Rudner
rudner@mit.edu

This month's column is about props. We've all got 'em. Green ones, blue ones, red ones, purple ones, fat ones, skinny ones, scimitar-looking curly ones. But how much thought do you give to that blade you're strapping on to your engine every Sunday? Winter's here, so let's take some time to investigate.

I've had a personal fascination with props for a long time. Let's start with a trip down memory lane. The journey begins back in the days of fast combat, with my time growing up with the Southern California Combat Team. Since those times are long-gone, and they're not coming back, I can share a bit of previously classified information. Surely there are others who will want to disagree, but I think it's safe to say that, especially in the days before the Nelson .36, the Southern California Combat Team had a very strong tradition of maintaining some of the fastest engines in the country. Our Foxes looked like Foxes, but on the inside they weren't really Foxes. Aussie cranks, Wisniewski AAC liners, double bubble heads, the whole shabangabang. That part is well known. Less openly discussed, however, was the issue of props. Various APC props, Top-Flite, Zinger and Rev-Up wood props, and later the beautiful Mejzlik props, were available on the market. We didn't use any of them, at least not in any kind of recognizable form.

The basis for everything that I knew about making props at that time came from two great teachers: my dad and Pete Athans. First, we always used wood. Why? It's much lighter than the other options. Recently I did an interesting comparison (for my experiments with electric F2D), and found that one of my wood props was a full 10 grams lighter than an APC of a similar size (8 grams versus 18 grams). Not only does a heavy prop add weight to the model, but the rotational inertia from spinning a heavier prop at high RPM gives further resistance to turning. If you want to go fast and turn fast, use a light, awesome prop.

What was our starting point? Typically we would start with a Rev-Up 8.5" × 6.5" (pylon or wide blade) or 8.5" × 6" (wide blade, good especially at high altitude in Tucson). Then the cutting and grinding would begin. A typical final size would be something like 7.75" × 6.5". However, there's much more to a prop than just its diameter and pitch. The blades of those props were exceedingly thick, especially out near the tips. On top of this, the blade profile was a bit more circular than "airfoil"-like. One of the key points that Pete taught me was to get all that meat off of the tips. We would thin them way down, toothpick-thin at the tips. There are a few good reasons for doing this. First, those big clubby tips are a lot of drag on the engine. Reshaping the prop with a thinner, sleeker profile let the RPMs come up. Also, it's much safer: with heavy tips, there's a lot of centrifugal force on the hub, which can result in a thrown blade if one is not careful or if there are defects in the wood. My dad also taught me about smoothing out the flat areas around the hub on the back side of the prop. This part of the prop isn't working too much, but nonetheless it's good to give the prop nice clean lines. Most likely, if it doesn't look fast, it won't go fast (the converse of the Skunk Works motto...).

Back in the height of my fast combat flying days, I would spend between 45 minutes and an hour and a half on every prop. It sounds a little crazy, perhaps, but boy did they run. It also became a point of pride for me – I really enjoyed shaping them to as close to perfection as I could.

With so many choices of great fiberglass props available for F2D these days, it seems like there isn't much incentive to play with props beyond testing various models and finding which work best in various conditions. For those who are curious, however, you might start to wonder *why* the green prop runs better than the red one, since at arm's length away they look indistinguishable to an un-sharp eye. It's a good question, and the best way to take a step toward satisfying this curiosity is to start measuring.

Unlike the old days when props came in sizes, now they come in colors and/or initials (NN, AK, C1, TS, etc.). This is not informative, to say the least. Diameter is an easy parameter to measure with any ruler with sufficiently fine markings. If we may dare to go metric for the course of this article, you'll find that all of the props are in the range of 160 mm, give or take about 5 mm. What about pitch? Pitch is incredibly difficult to "eyeball," and so requires some specialized equipment to measure accurately. Prather used to sell a pitch gauge (I have one back in the states), but to be honest the scale is rather coarse so I'm not super impressed with it. Anyway, for my experiments with electric F2D, I recently decided to go back to my fast combat roots and carve some totally new wood props. I had some old Rev-Up "blanks," but they needed to be repitched (it turns out they were systematically under-pitched compared to the advertised values).

Without a pitch gauge in my office here in Copenhagen, I had to improvise. Out of necessity, the "Poor Man's Pitch Gauge" was thus born (see photos). How much does it cost? The cost is one sheet of paper and a few lines worth of toner (or ink, depending on your printer). I've uploaded the pdf file to the website, available on the Resources page or directly at `http://f2dnews.homestead.com/PitchGauge.pdf`, so that you can simply print it, follow along, and use it. When you print it, be sure to have the print scale set to 100%, so that the grid lines will have a spacing of 5 mm (check it with a ruler after printing). For those following along on the web, photos are available on the Resources page of the website.

How does it work? After printing, the key step is to carefully make a sharp 90 degree fold along the solid horizontal line that makes the base of the part that looks like a protractor. I used a metal straight-edge to assist in this process. The accuracy to which your crease exactly follows along the black line will determine the accuracy of the degree markings. If you mess up, just print another. Next, I set the paper on the lid of my pitbox, with the protractor part hanging down (and flat against the sidewall of the box). A flat table with a wide side could work just as well.

The grid lines help to align the prop: to measure the pitch at a certain radius, set the prop (front side facing up) so that the corresponding horizontal line passes right through the center of its hole. Be sure to orient the blade parallel to the vertical lines, so that it sticks straight out over the end of the box (or table), see Figure 2. To measure the angle of the back surface of the blade, hold a straight edge flat against the side of the box. I used the blade of long utility knife for this. Bring the straight edge up gently to the blade, tilting it as you approach so that it ends up squarely following along the face of the blade as it touches (Figure 3). Now you need to shift the prop and straight edge laterally together until the straight edge passes right through the origin of the protractor. Once you find this placement, the straight edge will follow right along one of the angle marker lines. Record this number and move to the next station (farther out or closer in to the hub). It may sound a bit complicated (it's not easy to explain purely in words), but if you play around with it for a bit I'm sure you can get the hang of it.

As we all know, the angle of the blade is much higher near the root than at the tip, since the tip covers much more distance over one revolution than the parts near the root. The poor man's pitch gauge will give you an angle at each radius along the blade. To convert this number to a pitch in centimeters or inches, use the formula Pitch $= 2\pi R \tan\theta$, where R is the radius (corresponding to the horizontal grid line where the prop is centered) and θ is the angle measured. Interestingly, you will find that the pitch is not constant along the blade. Even more interestingly, you might find different results for the two blades on a single prop. Going even further, you can check many props of a given type, from a given batch. Depending on the source, you may find wide variations from prop to prop, or very tight tolerances. Personally, I'm very impressed when I see prop after prop with the same numbers coming up. At the same time, it's quite frustrating to find that certain batches of props have wide variations. If I test one of them and it runs great, how can I expect the next one to run when I pull it out of the box during a match?

One last point about props that I wanted to mention before signing off is material. You can spend all day measuring blades and even tailoring them to some theoretical ideas about what might be fastest on your model. However, what matters most is the blade shape while the engine is *running in the air*, not sitting statically on your bench. The aerodynamic forces on a prop are quite high under load, and in fact cause the blades to twist. Depending on the blade shape, the pitch may increase or decrease as it gets loaded up. The amount to which the blade deflects depends on how stiff the material is (e.g. if it's glass or carbon). Is it really happening? Yes. In the 1980s, my dad did a series of experiments with homemade fiberglass props for Nelson 0.15s for F2D. After finding the best performer of the bunch, he made a mold and copied it directly into carbon. Because the carbon props from the same mold were too stiff to twist significantly under load, they ran terribly. After going back to fiber glass, it was fat city all over again.

Anyways, just wanted to throw a little interesting food for thought out there before the holidays. If you get stuck or confused trying to use the pitch gauge, just drop me a line and I'll try to help out. That's all I've got for now. Happy new year. See you in 2013!