Propellor Loading

By Jack Sallade – jack@flyrc.info www.flyrc.info

I'm often amazed at the lengths some folks go to in order to get the last once of thrust or mph of speed out of a particular airplane without once considering one of the most simple and effective changes that can be made; a simple propeller swap. A lot of folks either walk into the hobby shop and ask for a good prop for their wizbang .46 or even specifically for a 10x6 Dutch Boy Stir Stick because that was what was on the airplane when they bought it. There may be nothing wrong with that particular combination. If the manufacturer picked that propeller there is good reason to believe that it will continue to perform adequately if you replace it with an equivalent model. Is adequate what you want?

Of course there are many factors in deciding what the right prop is, but the easy way to start is to figure out what IS NOT! When considering the diameter and pitch of a propeller choice, a good starting point is to look at the range of propellers that the manufacturer recommends. As long as we stay with something that puts about the same drag or load on the engine as the recommended prop we should at least avoid trouble. Anything that doesn't fit into this range is definitely the WRONG prop and should be avoided or at least tested very carefully to avoid damage to the motor, the pilot or both. The manufacturer chose the recommended prop range such that the engine would stay somewhere close to its peak in both horsepower and torque. If we over prop the motor, it will be unable to turn the propeller up to adequate speed and will probably overheat. Likewise, to little load and the motor will over-rev and will again overheat or even possibly come apart internally – yikes! Let's look at a way to identify a range of props that avoids these issues and gives us some latitude to choose something that gives us what we want, be that speed or torque or a good compromise of the two.

First of all, it seems to be a fairly good consensus that the proper formula to calculate a loading factor is to take the diameter to the 4^{th} power (diameter x diameter x diameter x diameter) and multiply by the pitch. The resultant "load factor" as I call it, is dimensionless.... i.e. there is no associated unit of measurement like inches or pounds. However, as a tool for comparison between props on a particular engine, I've found it to be very useful. As an example lets apply this method to the OS-46AX. The manufacturer recommends the following propellers:

10x7, 10x10, 12x4, 12x5, 13x4, 13x5

If you do the math these loading factors calculate out between 70,000 and 142,805. Here's the result for these props.

10x7 – 70,000
10x10 – 100,000
12x4 – 82,944
12x5 – 103,680
13x4 – 114,244
13x5 – 142,805

As a rule of thumb, for more speed you want a high pitch numbered prop that offers a lesser amount of loading within the range for that engine. In our example a 10x8 looks like a possible good choice for high end speed. The calculated load factor is only 80,000 (near the low end) and that 8 pitch should give us some speed. This is because less load factor means the engine can turn more RPMs and more RPMs of a higher pitch prop generally means more speed! The takeoff run may be a bit longer but the high-end should improve over a more generic mid-range choice like an 11x6. You could also try the 10x10 recommended by OS or perhaps a 10x9. These props load the engine a bit more however and may not turn enough RPMs to get the speed desired. Field testing would be critical to make a final decision. If lots of low end torque is desired for a bit of hovering or long steady climbs, perhaps the 13x4 would be a good pick. It won't produce the highest RPMs but will almost certainly result in a good amount of low end thrust. Of course, for a good overall compromise you could pick the 11x6 or 11x7 somewhere near the midrange of the calculated load and with only a moderate pitch and be pretty safe. One thing to note; these comparisons don't take into account the actual airfoil of the propellers being compared. There are definitely better and worse airfoils out there and other factors play into your choice as well, such as how often you use your propeller to scrape the ground (perhaps as a braking method?) during landing and the cost associated with that maneuver! Ground clearance may prohibit certain choices as well.

In order to NOT have to recalculate these numbers all the time, I have developed a spreadsheet that I use to pick propellers where I've calculated out load factors for every prop from a 7x3 to a 7x7, 8x4 to 8x8, 9x4-9x9, etc… up to 22x20 or so and then sorted them by the calculated load factor. I have inserted a few special sizes that were called for particularly and I have not checked to see that you can actually purchase a prop in any of these sizes so some of these sizes may be theoretical only! I have separate columns for each engine that I have data for and have any interest in. Here is the excerpt for the section of the chart that covers the 46AX:

10	7	70000	x
10.5	6	72930	
11	5	73205	
10	8	80000	
12	4	82944	x
11	6	87846	
10	9	90000	
10	10	100000	x
11	7	102487	
12	5	103680	
13	4	114244	x
11	8	117128	x
12	6	124416	
11	9	131769	
13	5	142805	x

The manufacturer recommended sizes are marked with an x. As you can see, there are a number of propeller sizes not mentioned by the manufacturer that should be usable with this motor. One of my favorites for this motor when I had it on my Morris Hobbies Knife is the 12x5. This is a great combination for an airplane that needs almost no speed but is a lot more fun with the quicker throttle response and increased torque I got when I switched from the 10x7 and 11x5 that I had run before. One special note is that the most common propeller I see folks using on their new .46 size motors at the field is a 10x6. Note that this is NOT within the range recommended by the manufacturer and is probably a poor choice for this motor. Yep, I know the tach says you're turning it at 16,000 RPM, but that high pitched scream you hear may not be what you really want, just what your used to! This prop's load factor calculates to 60000 which is not enough load for this engine. I suspect the continued popularity of this choice is partly due to the fact that all of our engines have increased in performance the last decade or so due to better designs, manufacturing and metallurgy. Modern .46s put out the power of some older .60 class motors and we need to pay attention to the manual! Running your new engine with to small a prop makes it noisier, less efficient and creates more heat with less useful power output. The fact that a lot of folks get away with it is a testament to the quality of the average hobby engine and the quality lubricants that the fuel manufacturer sneak into the mix. All you're really getting out of this combination is a really noisy airplane and a shortened engine life span!

In closing I want to point out that changing propellers may necessitate some small balance and tuning changes on your airplane so don't forget to recheck those critical adjustments. Further, I'm not claiming that this information is the final word in choosing propellers, just something that has provided me with guidelines that have generally given me the results I expected. It has enabled me to get a little extra of whatever I wanted from many of my airplanes without having to spend a lot of time doing actual in flight testing and purchasing a whole bunch of props I didn't need or couldn't use. Not that I mind that to much! Experimenting like this is part of what I enjoy about the hobby. I'd be happy to share my spreadsheet with anyone who wants it. I modify it from time to time but try to keep an updated copy on my website www.flyrc.info under the articles section. Or if you'll email me at jack@flyrc.info I'd be happy to share the current iteration. Try a new prop and see if you can't get a little more of what you've been looking for!