What Airmaster Propeller Hub and Blade Is Best for My Rotax Powered Aircraft?

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Airmaster Propellers has hubs designed for the many blades available. Which is the best blade and hub combination, depends on the aircraft, engine, type of flying, preferred number of blades and of course the all-important subjective looks.

The criteria for choosing the right propeller are dependent on safety, performance, diameter limits, weight, cost, and of course durability.

At Airmaster, the first concern is safety. The hubs of our constant speed mechanism are machined from the best materials available and machined to exact tolerances to provide years of service for the particular application. The hubs are manufactured to meet the engines maximum RPM and in some cases the power pulse stresses of a particular engine. Airmaster hubs are compatible with many blade manufacturers as the Airmaster hubs and ferrules are manufactured to meet their blade shank diameters and stress requirements. However, not all blades are suitable for a constant speed application. If a blade manufacturer produces a flexible blade for its ground adjustable hub where the blade twists when the rpm is increased and it is placed under load, they can actually be dangerous in a constant speed hub where the blade could be loaded beyond its structural limit, or begin to flutter and fatigue.

With so many hubs and blades to choose from, how do you choose? Easy, Airmaster's website has a portion dedicated to specific propellers and hubs for specific aircraft. But what if your aircraft or your desired blade is not shown?

Consider what the engine manufacturer recommends first. The Rotax series engines are limited on the moment of inertia of the prop and some direct drive engines may need a prop mass for the necessary fly wheel effect. The early 912S had kickback issues on start. A long heavy blade put ugly stresses on the sprag clutch. This was originally blamed on the prop, however time showed a change in the ignition of the engine was necessary. Today, we know which blades meet the inertia requirements of every engine.

Next consider what the propeller manufacturer recommends for your engine. The prop manufacturers normally do their due diligence and determine a blade shape and length that is best for a particular engine. But one manufacturer may say any length is possible, just reset the pitch, another may be more specific and give a blade type, and a blade length that is very specific for an engine series. That is a problem if let's say a Rotax engine is chosen, and the prop manufacturer recommends the same prop for the 80HP, 100HP, and 115HP engines. This is a wide horsepower range, so talk with the blade manufacturer on what is working best.

Example: Sensenich early on developed a two blade ground adjustable and found the optimum prop length for the Rotax 912S/914 was about a 70 inch diameter. However, for those preferring a three blade, the blade section was made shorter and thinner with more sweep at the tip. Their preferred maximum diameter for the 912S and 914, was only 68 inches.

Finally, the kit aircraft manufacturer will have a demonstrator and have much experience with what works and what doesn't. Keep in mind that they do not want to wound the reputation of a prop or engine manufacturer. So you may be served by asking the kit owners through a forum. Keep in mind that many believe their prop choice is best (mine is bigger than yours syndrome, or I spent all this money so it has to be the best) but they may only fly STOL whereas others may only be interested in max cruise speed. Most may be fixed pitch and others may be constant speed using an Airmaster or similar hub. Some may be two blade and others three. "It works really good", is not a clear rational reason for you to use that recommended prop blade. Or: "You gotta go with 70 inches" but he has a two blade and you want a three blade.

Which is better, a two blade or three? Two blade props are a bit more efficient, but at the slow turning RPMs at cruise speed of the Rotax, long two blades tend to be noisier and the power pulses across the thin windshields of some aircraft can be booming. The three blade prop has a higher frequency of pulses at a smaller amplitude which lowers cockpit noise as the power pulses are significantly reduced.

Finally, what do you intend to do? If you fly off of a home strip and use the prop to mow the grass on take-off, a thin wall hollow blade may not be prudent. Do you want extremely short take-offs as in a STOL or do you want maximum cruise speed. Or is maximum efficiency and long range your requirement. How do you choose wisely?

I hope to give you some guide lines on choosing the right Airmaster Propeller blade and hub for your particular aircraft.

Analysis:
The diameter of a fixed pitch and constant speed (CS) is a bit of apples and oranges comparison. Let's look analytically at a simple 4 inch wide blade that tapers to 3 inches, of any airfoil section, and has an optimum twist from root to tip of about 16-20 degrees total. I'll calculate the Horse Power (HP) required for various lengths and speeds using propeller momentum theory and flow theory. You will see there are some general conclusions which will help in choosing your blade type: Chart1 shows some typical prop lengths, their pitch, horsepower and diameter comparisons at static run-up, a climb speed of 70 and a cruise of 100 knots. The chart gives the pitch changes necessary to absorb the power of the engine at these speeds and is not representative of the performance of the airframe, only the prop:

Approximate constant speed prop Pitch change vs power vs airspeed.

Sea level std. day

Diameter	Pitch tip	HP	Tach RPM	Prop RPM	IAS KTS
64	11.5	100	5650	2350	0
68	8.3	100	5650	2350	0
72	5.5	100	5650	2350	0
75	3.5	100	5650	2350	0
64	12.9	95	5500	2260	70
68	9.8	95	5500	2260	70
72	7.6	95	5500	2260	70
75	5.8	95	5500	2260	70
64	18.5	75	5000	2050	100
68	15	75	5000	2050	100
72	13	75	5000	2050	100
75	11.4	75	5000	2050	100

Chart 1

As the chart shows, the shorter the blade the greater the pitch required to absorb take-off power. Note that if the pitch were set at take-off power, the blade must twist from 7 to 8 degrees while accelerating from zero to 100 knots to keep the engine pulling to absorb the engine power or prevent an over speed.

Let us look further at the Rotax 912S and 914 equipped aircraft using a common Whirlwind or Warp Drive blades. The Whirlwind (WW) company produces a 68, 70 and a STOL 75 inch blade and is a good starting example of some lengths to experiment with in a constant speed propeller:

The 75 inch (longer is better crowd) fixed pitch prop on a 914 at full power and ground static of 52-5500 RPM in full turbo will produce excellent initial acceleration and climb. Once the pilot pulls the power out of full turbo, the RPM drops quickly from near redline to about 5200. Then will allow acceleration to about 75 KIAS and 5500 RPM at 35 inches. At cruise altitudes below 5,000 with the power pulled back to about 31 inches the RPM decreases to about 5000. However the aircraft speed does not increase past about 90 KIAS. In essence the fixed pitch prop is very good at keeping the pilot at the design climb and cruise of the 914 with no pitch change mechanism while at low speed and low altitude. However, the blade is so long that the slightest increase in aircraft pitch tends to load the engine very quickly. Lower the nose and it unloads the engine past redline in a heartbeat.

Well it is slow because it is a draggy airframe right! Not necessarily.

The twist and loading of this 75 inch STOL blade are excellent for fixed pitch but the engines don't have the torque to pull them any faster when the blade is moved to courser pitches in flight as in a constant speed hub, hence they have difficulty exceeding about 80-90 KTS in a fixed pitch application. Frankly, in the field, the 75s can't cruise very fast and only need a CS prop to help them from over speeding the engine during take-off, climb out and rapid descents but forget about a descent cruise speed. The 75s most likely will top out at well below 100KIAS at altitude with the CS, although still be able to fly a bit faster than the equivalent 75 inch fixed pitch prop. So if cruise speed is not a concern in relation to take off ground roll, a 75 may be right for you. Just don't go very far from home.

Another blade length to consider is the WW 70 and 68 inch blades. The difference between the 70 and 68 inch WW/WD props is the longer taper and twist change on the last inches of the WW 70" tip. This scimitar taper allows for the fixed pitch prop to possibly pull more at the tip for take-off and unload during climb without over torqueing the engine and bogging it down when the power is reduced for cruise. For a fixed pitch prop, the 70 inch gives a little better performance on a two blade in certain areas, but overall I doubt much over the 68 fixed three blade. The WW 70 inch three blade has a much more distinct sweep and taper at the tip. This is what Cato, Whirlwind and Sensenich are known for, excellent lift distribution across the span and taper of the tip to reduce tip load on the fixed pitch prop. The scimitar shape reduces noise and the three blade is very quiet. The Rotax engine turns slow at cruise so the scimitar shapes design which normally is used to reduce Mach critical tip speed, is not a factor, but it is quieter, reduces mass at the tip and looks neat. So these two prop blade lengths provide acceptable performance to a point. Again, I expect there is no difference between the WW 68 and 70 inch blades in the real world in a constant speed or fixed pitch application.

So which prop blade takes the least power to provide the highest comparative speed to use the engine power available? The charts below tell the story.

Approximate HP required to turn the propeller at 87 knots with a fixed pitch prop set for absorbing 100 HP for takeoff.
This chart determines the amount of power reduction required to prevent over speed with a fixed pitch setting.

Diameter	Fixed pitch	HP req.	Tach RPM	Prop RPM	Speed Kt	
64	11.5	61	5000	2050	87	
68	10	51	5000	2050	87	
72	7.5	32	5000	2050	87	
75	5.5	5	5000	2050	87	last two inches are negative angle.

Any faster and you're windmilling.
Basically you're at max speed.

Chart 2

What this chart shows is for a prop set to a fixed pitch to achieve full take off power of 5650 RPM (150 below redline), after accelerating to 87 KIAS the 64-72 inch propellers will allow for more power absorption which can be used for climb or acceleration. However the 75 is just about windmilling. In actuality, the throttle will be severely reduced in a glide at 87 knots or one will over speed the engine.

You say you set your pitch per the Rotax manual to achieve 5200 static RPM. The theoretical pitch for static conditions of each diameter is shown below. They are very close for propellers such as the Warp Drive which validates the analytical computations.

Typical prop pitch and power to achieve a static 5200 RPM Takeoff
100 HP used as an approximate power.

Diameter	Fixed pitch	HP req.	Tach RPM	Prop RPM	Speed Kt	
64	18	100	5200	2160	0	
68	14.5	100	5200	2160	0	
72	10.8	100	5200	2160	0	Some elements at root negative angle
75	9	100	5200	2160	0	Some elements at root negative angle

Chart 3

Chart 4 below shows that theoretically if one wanted to cruise at 75% power or about 75 HP , for the propeller set to a static run-up pitch setting of 5200, you could absorb the cruise power of the engine at the following speeds on a typical two place type aircraft:

Approximate cruise speed at 75 HP Cruise at 5000 RPM
fixed pitch prop set for 5200 static at takeoff and 100 HP.

Diameter	Fixed pitch	HP req.	Tach RPM	Prop RPM	Speed Kt	
64	18	75	5000	2160	98	
68	14.5	75	5000	2160	100	
72	10.8	75	5000	2160	99	Tip is unloaded
75	9	75	5000	2160	74	Prop is unloading

Chart 4

So if you don't want to compromise the take-off and climb too much and still get acceptable cruise performance from your engine, a fixed pitch of 68 inches just ekes out the 64 and 72 inch props for speed and the 75 is left in the dirt.

If you want to take full advantage of the take-off horsepower of your engine and optimize your cruise potential, a constant speed prop is necessary to take full advantage of your engine and prop blades capabilities. From Chart 1 above, one can see that to use all the horsepower at take-off, climb and still get maximum efficiency for cruise the pitch of the prop must be increased as speed is increased.

What Chart 4 indicates the 64-72 inch blades perform better if I want to go faster using my CS hub but which is the better length? The difference between prop lengths indicates a prop of about 68 inches is well matched to the Rotax 100 to 115 HP using a CS prop for cruise potential but what about climb and acceleration.

Go back to Chart 1 and note that to achieve full take-off power you need a finer pitch to use the full 100 ponies of the Rotax 912S and 115Hp of the 914. By twisting the blade from take-off to climb the prop can absorb an extra 10 to 25 horses, which means a very large increase in rate of climb or acceleration over a fixed pitch prop. 25 horses is roughly 700 fpm rate of extra climb in a loaded airplane. That comes in handy. This is why in the fixed pitch cruise prop, the take-off and climb suffer so much.

All the analytics and charts above are for theoretical propellers, but in the real world how do the prop blade lengths compare on different aircraft is a reasonable question.

On a fairly clean aircraft one can expect a higher cruise speed than shown in our charts above. Typically on a very clean composite type aircraft, we see a 20+ knot increase in speed at altitudes of near 10,000 and about 10 knots for a two place fabric LSA type aircraft at 5500 MSL over a fixed pitch prop set for cruise at 5000 or slightly less statoc take-off RPM.

On the other hand, because most of the small, LSA or experimental aircraft such as the early Rans, Kitfox, Zenith, or Highlander aircraft generally had large stubby noses, as did the composite Europa Classic, the root section of the prop ends up being in disturbed air from the cowl and performance was not optimum.

Highlander

Europa Classic

The air bubble of the stubby cowl retards the incoming air angle, which changes the effective angle of the root section of the prop. This “bubble” actually decreases its effective pitch near the cowl. The slightly longer cruising blades (as in the 68- 70 inch) will help get away from this cowl disturbance better than a 64 inch yielding a potential increase in cruise speed and take-off thrust for a fixed (ground adjustable) pitch prop on the Rotax (hence the old wives tale of longer is better is true in this case, to a point). Most of these planes, as they matured just used a larger spinner (some as large as 13 inches) and a smoother cowl to smooth the air and diminish the losses of the fat nose. Unlike the fixed pitch prop, the constant speed prop will just adjust for the nose bubble as the prop will simply increase its pitch, even in a shorter length prop. Case in point. The WD 67 vs the 64 on the Europa Classic yields virtually no difference in cruise speed or climb rate at all in the 912S Classic tested just as shown in Chart 4. My client complained “But I was told that longer is better!” Why the props performed so closely, was the WD 67 runs at a lower pitch than the 64 and the thrust is effectively the same on a CS prop. In more streamlined aircraft the cowl is a bit cleaner and the nose bubble with the 10 inch spinner is less of a problem for these faster aircraft. Hence the longer prop should be better on a stubby aircraft, but in the case of the clean XS cowl on his Europa, he found in his WD that the two to three inches extra diameter just collected more rock dings with minimal difference in performance.

Long or short prop depends on the aircraft's mission:
As far as those wishing for pure STOL operations, the 75s in my analytical calculations, did well, moving more mass (air) and acted like a rotor on initial take-off. However, a blade like the ground adjustable Kiev's installed in a CS hub were actually flexing during full power and the tips were going negative at cruise. In practice, one field report indicated this and it was causing vibration *in the higher speed ranges (above 85 knots}* due to their flexibility. The customer requested a blade change to the 75 WW and is now trouble free. As a result, I prefer not to use a flexible blade in a constant speed hub. The WD, Sensenich and WW are very stiff, so in the event of a negative angle at the tip in a shallow dive, the blade should be, and is smooth running when compared to the more flexible Kiev.

Personally, if absolute short take-off is your need and cruise speed is not an issue, the WW 75s work great because they behave more like a rotor than a propeller. Therefore, don't expect a higher cruise speed. The WW 75 is the prop I would prefer for a STOL only aircraft where cruise is not important. At least the inertia is low, and the customers who buy because: "It looks better with a longer prop" when equipped on their balloon tired STOL machines and are honest and happily admit, "It takes off really well, but it is slow and that's OK with me". They are satisfied with the limits on their cruise performance so they have what they want.

I still believe that nothing good happens after 68 inches on a Rotax, equipped aircraft with a constant speed prop. Oh sure, the tapered WW 70 should be the same, but look at the thinner sections of the blades and lack of tip angle and one can see that they will work fine on a ground adjustable, and will work in our CS hub over the minute speed ranges of the average Rotax powered aircraft with little or no difference in cruise. Frankly, the thrust difference at take-off is so small between the 75 and the 68 that I would prefer the extra ground clearance and receive the benefits of the added cruise speed. At cruise, the poor Rotax only turns 2050 RPM so all of these prop blades are suffering. Turn the Rotax at 5500 RPM and you get better speed on the shorter blades. With my Airmaster 64 inch WD or WW flying at 5500 vs 5000 I true at 160 knots vs 145 but at a fuel burn penalty. It lowers the gas mileage from 30 to 23. Not worth it unless I must get there on time and fuel is not an issue.

In summary for a cruising airplane:
Are you going to be operating off of rough fields with smaller tires and speed kits? If the grass is a bit high, shorten the blade by an inch to the 68" and get a bit more clearance and fewer rock dings. Climb rate and cruise speed wise the CS hub will pitch a little more, and give the same performance of a 70 or 72 inch in climb and provide excellent cruise. The 68 should use less a bit less power to cruise (which means less fuel) at a modest 100-120 KTS and should and does fly a bit faster at the normal 5000 RPM / 26 inches of manifold pressure.

The Warp Drive 67 inch wide chord is solid carbon fiber, it's heavy, and tough. If you need durability, this is the blade for you. I've mowed the grass with it and seen blades that have been on gravel strips for 10 years and were still serviceable. Expect it will be a bit slower than the WW 68 by about 5 knots due to a more efficient profile.

The Whirlwind and Sensenich blades look sexier, are stiff and well protected on their leading edge from rain and bugs. They provide slightly better performance than the WD and are lighter. They are not going to be as durable due to their lighter construction, but have been excellent at holding up to normal operations off cut grass and paved runways.

Two or three blade:
On a three blade, it is quieter and smoother. Cockpit noise is significantly lower. Top end is about the same, initial acceleration is a bit less. A two blade is a bit more efficient. The two blade generally will accelerate slightly better and on a tricycle gear aircraft the cowl removal may be easier. Rate of climb shows no difference. I personally would not exceed 72 inches on a two blade on a Rotax. My experience with the two blade WD and Sensenich indicates about 70 inches gives excellent performance and service.

Final Thoughts:
Nothing good happens after 68 inches on a constant speed prop on a Rotax engine in my opinion. Sensenich only produces a 68 three blade and can shorten to 65, and WW makes both a 68 and 70 (Mine is bigger than yours?) Both use scimitar tip modifications such as sweeping and flattening the tip twist to unload the tip and reduce noise. WD uses a 66 inch constant chord as their square tip blade of choice on a 914 and a taper blade must be used on the Rotax if a longer blade is desired. This is to keep the inertia within limits of the Rotax 9 series engines.

The Airmaster has features that other constant speed manufacturers cannot provide. It comes as a fully feathering propeller. This is optimum for motor gliders and soaring applications. Each of the hubs and all the blades have this option, so whether you are powered by a Jabiru, Rotax, UL or any other engine, the feathering system is standard.

Europa Motor Glider Soaring.

For the float or seaplane owner, the Airmaster may be purchased with a Beta or reversing mode instead of the feathering mode. This is optimum for the float and seaplane aircraft who would like to control their speed approaching the dock or back off of the beach.

Seamax with AP332 WD 67 Inch tapered.

This built in capability makes the Airmaster a superb choice for your experimental aircraft project. I have a number of clients that have planned their project around using the Airmaster from the start.

So relax and let the constant speed Airmaster prop do the work. Let the prop pull you out of a small strip, climb over the obstacles, then transition to the best speed your airframe will ever achieve. On descent, lower the nose and let the prop help keep you from over speeding your engine in a descent if you forget to pull the power during spirited flying. The Airmaster is as close to a FADEC or automatic system you can get, especially for the normally aspirated engines like the 912S. Just rotate the control knob to TAKEOFF and push the throttle up, when safely airborne at climb speed, click to CLIMB, then when at your cruising altitude, level off and click to CRUISE. No manipulation of the throttle is necessary until descent into the pattern. Choose an Airmaster and fly with confidence that you are getting the most out of your aircraft.

Bud Yerly is the owner of Custom Flight Creations, Inc. and is a dealer for Airmaster Propellers and other aircraft and products. He is an aeronautical engineer, retired fighter pilot and has test flown over 30 different aircraft. He is known for his technical writings on building, testing, trimming, operational, and owner maintenance techniques.