Choosing a Propeller

by Larry Schlasinger

Most pilots of personal GA Aircraft are always in search of improvements and modifications that will provide better and safer performance for their aircraft. These modifications may include, engines with uprated horsepower, flight control and wing modifications to provide more lift and speed and of course better avionics. Many pilots are unaware of the dramatic improvement that a new design propeller may provide. Propeller development has come far in the last few years and now many improvements are available to provide better speed, less weight and more thrust for take-off and climb. New materials also reduce vibration and provide longer life. Choosing this new propeller for your General aviation aircraft can be somewhat confusing and difficult as today there are many alternative propeller models available from a myriad of manufacturers. Even though modern propeller science has become both accurate and precise, there is still a bit of mystery as to why some propellers work so well on a certain airframes and others don't work at all.

The most important function of a propeller is to convert the engine horsepower into usable thrust to provide motion to the aircraft. The fact that an engine produces high horsepower and a propeller spins means very little in terms of the ultimate performance of the package. There are many factors that will limit the ability of any certain model of propeller to function correctly on an engine/aircraft and these factors must be considered in choosing the proper propeller. Weight, ground clearance, size of cowl, number of blades necessary, desired performance goal (speed, climb, durability, and cost, to mention a few) will dictate which propellers may work best.

Basic propeller science will gives a good idea of where to start and comprehensive testing will show the best choices available. The propeller must meet the following criterion:

Sufficient ground clearance in all applications (wheels, floats, skis, etc.)

The FAA and common sense mandate the proper clearance for any propeller installation. For experimental aircraft, the FAA mandate is not applicable, but a prop strike is very costly and dangerous and proper clearance is extremely important.

Blade count and design capable of absorbing all the produced horsepower and converting it to thrust.

This may be difficult when a high power engine is used in an application where a small diameter propeller is required. In many cases, a propeller of 3, 4 or 5 blades will be necessary to provide optimum performance. This is even more critical in turbocharged engines flying at high altitude. As the air gets thinner, the blades (just like the wings) become less efficient. Therefore, the propeller may need additional blades or those optimized for high altitude flight.

Weight proper for the CG and useful load of the aircraft.

There can be a vast difference in weight between different models and manufacturers of propellers. In some cases a heavy propeller will be an advantage (this is rare but a good example is the V tail Bonanza that has a critical aft CG problem. A light propeller in this case will make the problem worse.) In the case of most other aircraft, a heavy propeller becomes a problem with reduced useful load and forward CG.

Vibration characteristics compatible with the engine/airframe combination.

This is an area that is little known among most pilots. Every engine, propeller and airframe combination will produce a different frequency of vibration throughout its rpm range. Very often these vibrations or harmonics will reach a destructive level which cannot be tolerated by the components of the aircraft (engine mount, airframe, instruments) and often these are not the vibrations that are felt by the pilot. Many times the performance will appear to be very smooth, but in reality, the resulting harmonics may be slowly (or quickly) destroying the aircraft. All STC certified propellers will have been vibration tested and approved. Installation of untested and unapproved propellers can be a very risky and costly endeavor. While all major propeller manufacturers have the expensive equipment and qualified personnel required to do this testing, many small companies selling propeller to experimental aircraft owners do not. Without this critical analysis you will have no idea what type of vibration characteristics are produced, so beware of these manufactures and always see that what you buy is tested and safe. Another thing to keep in mind is an application where there is an rpm prohibited range. For example if the range prohibited is 2000-2300 rpm, then keeping the rpm just above or below that range doesn't mean that the destructive vibration is gone, it only means that it's not over the permissible limit, but may still be bad enough to cause long term damage. Keep a long way away from these red lines.

Cost is also a big issue.

If the pilot can't afford the propeller, then everything else becomes irrelevant. Most replacement propellers are priced higher than the original models. Although the pilot normally gains his moneys worth in these retrofits, he must ultimately be able to pay the bill. This becomes especially important in aircraft used in business and air taxi as the bottom line is always one of the most important considerations.

Since this article is directed at the utility or bush plane market, I'll start with a normal checklist in selecting the optimum propeller for this type of application.

The ultimate goal of a back country aircraft is normally to provide the best takeoff and climb with the least amount of weight. Speed is often less important but still a consideration in the overall picture. Generally speaking, the longer the propeller blade, the better the takeoff performance. A long or large diameter propeller provides a wind cone of large diameter which will make more efficient use of all the control surfaces and produces greater lift at slow speed. The drawbacks of a long propeller are, however, manifold. The ground clearance often becomes an issue. The FAA requires a ground clearance of 9" in the level attitude for installation of a propeller on a conventional gear aircraft. This requirement alone often limits the diameter of the propeller. We recently STC'd one of our propellers for the Aviat Husky and while we could use a propeller of 83" with sufficient clearance for this aircraft, on the American Champion Scout we

needed to limit the diameter to 80" due to the shorter gear. In contrast to both of these, the Helio Courier will accept a propeller up to 90" with no problem at all. But these large diameter propellers lead to the next problem, propeller tip speed. The blade of a propeller is nothing more than a wing that rotates instead of moving forward with the direction of the plane. The same rules apply to both. To remain efficient, a propeller (or conventional wing) must remain below the speed of sound to produce lift instead of noise. We've found that maintaining a propeller tip speed of .9 mach or less will give the best and most efficient thrust (lift) for the horsepower produced. Turning an 86" propeller at 2850 rpm, as the Cessna 185 does, provides a greater amount of noise than it does thrust. Since I started my backcountry flying career in a 185, I was probably one of the hardest to convince that, although my 2850 rpm/86" propeller combination sounded great, it provided very little thrust compared to the same takeoff at 2700 or even less. Our static thrust testing has proven this time and time again.

Another disadvantage of a long propeller is reduced cruise speed. This is not always the case, but generally speaking the longer the propeller, the more drag it will produce at cruise and the slower it will be. Modern design blades have reduced this drag a great deal, but the length is still something that should be considered in looking for cruise speed.

Most small aircraft have traditionally been equipped with 2 blade propellers. These were cost efficient and light with adequate performance. In recent years, however, the trend has been to replace these with 3 and even 4 or 5 blade models and in most cases this is a move forward (as long as the engine isn't "over propped". The Husky is a good example of the possibility of over propping. We determined that a 2 blade MT had considerably better performance than a 3 blade MT, when used with the 0-360 Lycoming engine in the Husky). With high rpm engines (2700) a multi-blade propeller can me made in a smaller diameter and still absorb all the horsepower efficiently while remaining in the .9 mach range. These smaller diameter props also become quieter and provide more ground clearance and are lighter in weight. Naturally the biggest drawback of multi blade units is the added weight and cost, compared to the original 2 blade models. Except in the case of composite props, the multi-blade models always weigh more than the 2 blade originals and normally cost more as well.

The first step in selection of a new propeller model is to ascertain the most important quality desired by the pilot. As an example, many of the SuperCub pilots I've worked with are most interested in competing in takeoff contests. This requires the longest/flattest pitch propeller possible (fixed pitch) and one that will reach rated horsepower with no forward movement of the aircraft. The initial acceleration of such a propeller is the greatest possible, but the cruise speed is very limited due to the inability of flying with much throttle as this propeller will exceed the rated rpm easily as the aircraft gains flying speed. The Husky owners I work with seem to have different requirements for their aircraft. They prefer to have a good take-off and climb, but in combination with good cruise speed and a reduction in weight and vibration. This gives

a different choice for their aircraft. Another important aspect is CG requirements, weight and rpm restricted ranges. As I indicated earlier, each individual aircraft has different requirements for these. Many combinations of engine/propellers have destructive harmonics and most pilots will recall an aircraft they've flown that had an rpm prohibited range. This red line is extremely important and not respecting it will lead to engine/airframe damage. The Lycoming 360 series engine is particularly prone to these rpm red ranges and normally they occur right in the range where many pilots wish to fly. Changing the propeller model or material of the propeller will often help reduce or eliminate these ranges. Normally a smaller diameter propeller will also help reduce the red zone (as in the example of the Cessna 185 with the big McCauley 401. With the McCauley 401 on the 185 the 80-82" diameter has no restriction, but the 84-88" does). As well, on the Husky, replacing the metal Hartzel with the composite MT totally removes the red ling between 2000 and 2250. As stated earlier, the weight is always important and often a new heavy weight prop will put the CG out the front limit of a typical utility aircraft. It is extremely important to calculate weight and balance in normal day to day situations before replacing an existing propeller with a heavier one. Naturally going to a lighter propeller is always an advantage if the CG will allow this. Again, a lighter propeller will normally make a positive change in a utility aircraft. Float planes are especially prone to forward CG. Amphibs are even worse and a forward CG condition can be very dangerous as it limits elevator effectiveness and make a nose over much more likely.

Propeller maintenance and durability are also of paramount importance. Many propellers of the past have been laden with a multitude of AD's and frequent inspections. Blade erosion and reparability is also a big issue. How many times have you had the prop shop call and give you the bad news that the blades of your prop are out of limits and new ones will be very expensive? Modern materials have made great strides forward in this field and now some propellers are available in composite materials that are repairable and protected by stainless steel leading edges that are far more durable against water erosion and FOD. Many of these blades are also repairable and able to be returned to new dimensions instead of becoming smaller with each overhaul.

So, after thinking about all these factors, where do I begin my quest to find a new propeller to increase my aircrafts performance? First, begin with an experienced and reputable company that does the testing and certification required for a safe and durable application. McCauley, Hartzel, Sensenich, MT, Avia, and Hamilton Standard are all companies that have the equipment and resources to make a product to the standards of modern aviation. Determine the goal of your modification and see which manufacturer has what you want & need. MT & Hartzel make excellent composite blades which are the lightest and strongest of all, the other companies (as well as Hartzel) use aluminum, which is an excellent material for propeller blades. All the companies use aluminum for the hubs. Sensenich uses wood for many of their models (fixed pitch), which provides the lightest of all materials and excellent durability. Some owners of fixed pitch aircraft can move up to constant speed or ground adjustable

model props. These will greatly increase the versatility of the aircraft by giving the best of both takeoff and cruise while adding little if any weight. MT is currently developing a ground adjustable composite for the SuperCub that will allow anything from maximum takeoff performance to maximum cruise, depending on the wish of the pilot. The materials MT and Hartzel use also have vibration dampening qualities that can tame the worst of the Lycoming 360's. All companies mentioned will gladly assist an aircraft owner in selecting the correct propeller for his aircraft and may also help in the process of STC'ing or field approving new models to aircraft with out the appropriate STC. We at MT receive many requests for this service and are always glad to help if we have a propeller that will add performance or reduce weight to a particular application.

Is a new propeller really worth the investment?

For an example, with the Husky our goal was to improve the take-off and climb performance, reduce the nose heaviness and remove the rpm restricted range of 2000rpm to 2250 rpm. We worked with several MT designs and when we were finished the results of the MTV-15-B/210-58 two blade were even better than we had hoped. We were able to remove 19 pounds from the end of the crankshaft which resulted in moving the CG back significantly. This provided much more elevator control on landing with reduced approach speed and better maneuverability. The composite material of the MT also removed the rpm restricted range as we had expected. The take-off performance increase was dramatic with most pilots reporting a reduction of takeoff distance of 50% on wheels and 30% on floats. The rate of climb was increased about 20% and most pilots report an increase in cruise speed of 5-7%. All this by using a modern propeller with lightweight materials and a new blade design.

In conclusion, there are many possibilities to increase your performance with the installation of a new propeller. Use the resources you have in Manufacturers, the EAA, pilot organizations and those with experience, but in all cases keep an open mind. Don't always take the old wives tales for gospel and look for real facts in claims of better performance.