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Builders normally direct a lot of attention toward selecting the engine for their amateur-built airplanes, but what about the propeller? Is it an afterthought, or should selecting a propeller receive an equal amount of attention? Selecting the proper prop is an important decision—just as important as the engine. Obviously, without a propeller an engine can't perform its intended purpose (unless it's a jet, of course).

Many different types of propellers have generated thrust throughout the years, from fabric-covered wooden frames to solid wood, metal, and composite materials. The Wright brothers reasoned that a propeller is a wing that rotates and that prop blades with an airfoil generate more thrust than flat blades that screw themselves through the air.

As builders and scientists studied the aerodynamics and construction of propellers, wood gave way to metal, and blades with a fixed pitch gave way to props with two blade positions and then to the true controllable propeller where pilots could control the blades' pitch angle throughout their range of positions. Propeller design continues today with the use and development of advanced composites.

Propellers must withstand extreme stress, especially at the hub. As they rotate, centrifugal force increases in proportion to the revolutions per minute, and the blades are subjected to additional tension from centrifugal force and flexing or bending that results from the thrust they produce. A propeller must be rigid to preclude any type of flutter that might develop as the blade tips twist back and forth through normal operation. Because of these factors, safety is of utmost concern when selecting the propeller for your aircraft.

Federal Aviation Regulation Parts 35 and 23 respectively define the certification requirements for propellers and what propellers may be used on an aircraft. Homebuilt aircraft are not subject to these requirements, but they are good guidelines because all airplanes are subject to the same stresses of flight regardless of who builds them. With this in mind, make sure that your propeller complies with these regulations.

FAR Part 35 lists the following requirements that must be met before a propeller can be type certificated for use on a production airplane:

- Must have installation, operation, and maintenance manuals
- Must be constructed from approved materials
- Must have all operating limits defined
- Must be able to withstand a 41-percent over speed (twice the rated centrifugal force) without failing
- Fatigue tests of the hub and blades must be conducted
- Must pass an endurance test while installed on an engine
- Functional testing requires operations of more than 1,500 pitch change cycles
- Durability testing must be conducted for 1,000 hours of operation

Special conditions may be assigned. For composite blades, bird strike and lightning strike tests are generally required before the propeller is certificated.

As you can see, the FAA wants to be sure a propeller is safe. Failure of a propeller or its component parts in flight usually results in catastrophe. If a prop blade, or part of a blade, separates in flight, the resulting vibration from the unbalanced disk can shake the engine off its mount. The selection, operation, and maintenance of an airplane propeller are serious matters.

To select the proper propeller for your airplane you should understand its nomenclature, know what's available for your airplane, and, most importantly, know what the aircraft designer recommends.

Propeller Terms

A typical propeller consists of two or more *blades* attached to a propeller *hub*, which is where the prop is mounted on the engine's crankshaft. Like wings, propeller blades have an

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actual with a *leading edge* and a *trailing edge*. The blades themselves have a *shank*, *tip*, *face*, and *back* (Figures 1 and 2).

A propeller's *pitch* is often used interchangeably with *blade angle*, but the two are not the same, even though an increase or decrease in one directly affects the other. Pitch is the distance a propeller will move forward in one revolution.

Blade angle is the actual angle, measured in degrees, between the chord of the blade and the plane of rotation (Figure 2). The chord of the propeller blade is determined in the same manner as the chord of a wing.

Angle of attack is the same as that on a wing. It is the angle at which the air or relative wind hits the propeller blade. For our purposes, thrust is the result of the propeller shape along with the angle of attack of each blade. The propeller's blade angle determines how big a bite of air it will take with each revolution. As you can see, the blade angle is a method used to adjust the angle of attack of the propeller. In effect, the thrust a prop creates is a direct result of the propeller shape, the angle of attack of its blades, and the engine horsepower.

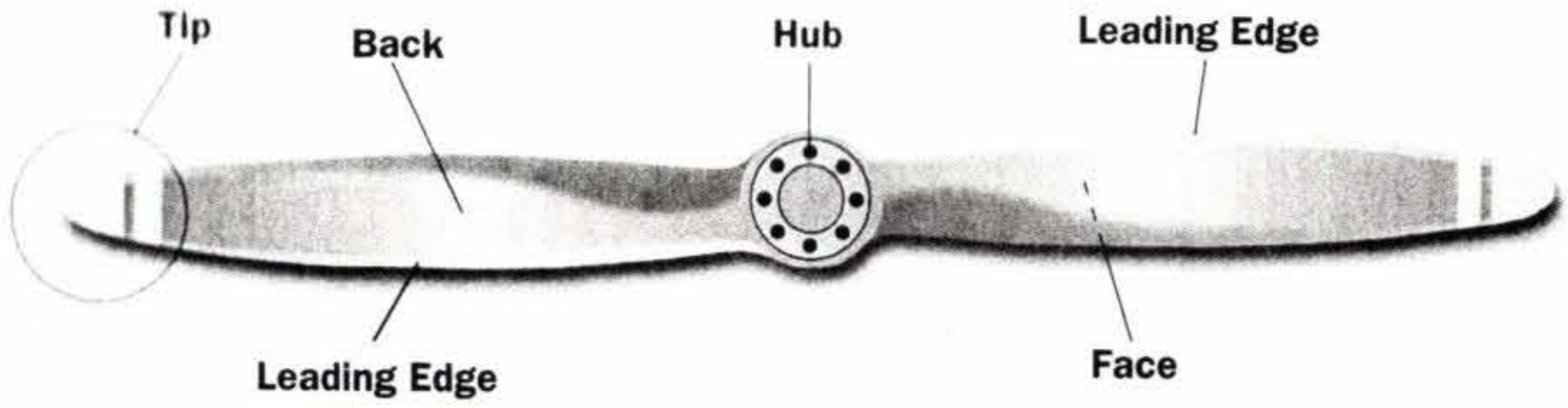

Figure 1

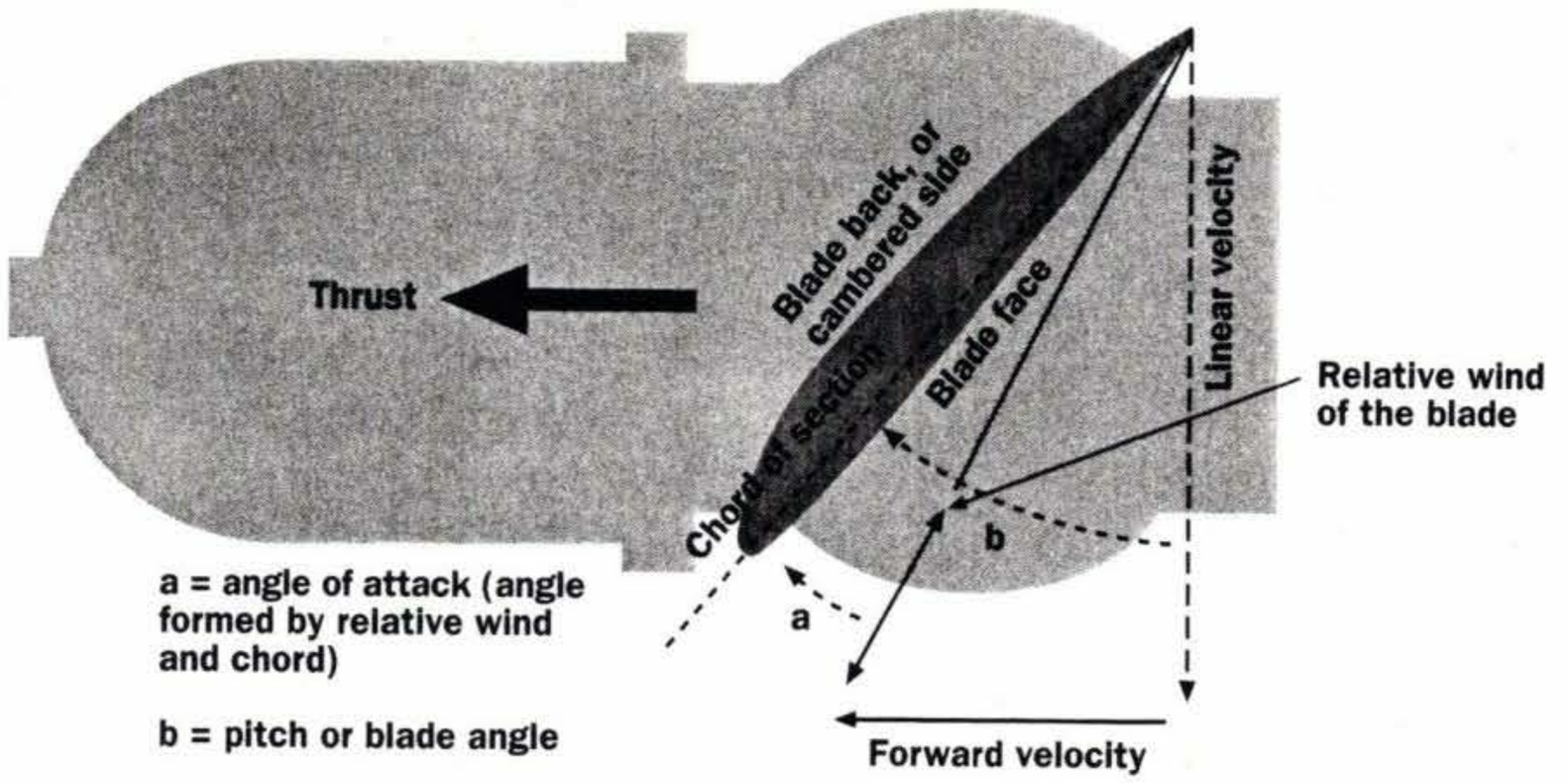

Figure 2

Fixed-Pitch Propellers

Fixed-pitch propellers are just that; the blade angle is built into the prop, and pilots cannot change it. The blades achieve their best efficiency at one rotation and forward speed, and their maximum efficiency may be designed to be at takeoff, climb, or cruise. Because fixed-pitch props produce maximum efficiency in just one phase of flight, the other phases have compromised efficiency and performance. For example, a prop designed for good climb performance gives cruise performance below that of a cruise prop.

Popular in light aircraft of all designs, fixed-pitch propellers are inexpensive, lightweight, and relatively maintenance-free. They are made of wood, metal, or composite material. Wood props are largely birch, but some may be mahogany, cherry, black walnut, or oak. Planks approximately 3/4-inch thick are glued together into a blank that is then shaped to the desired blade angle. Fabric covers the outer portions of each blade, and a metal sheath protects the leading edge.

Metal fixed-pitch propellers are usually made of an aluminum alloy, and their single pitch is forged into them at manufacture. Composite propellers are gaining popularity on homebuilts, and they are constructed using materials such as Kevlar or carbon fiber, often laid up on a wooden core.

No matter what a fixed-pitch prop is made of, it still doesn't change the fact that it's more effective in one realm of flight than the others. Which type you select depends on your flying needs. If you fly from short runways, you might select a climb prop to better avoid the trees at the runways' end. If you're a cross-country traveler who flies to and from long runways, a cruise prop might be best for you. To meet both needs, some builders buy a climb and cruise prop and install the one they need before making a flight that demands the respective prop's respective performance.

Ground-Adjustable Propeller

One way around having two fixed-pitch props is to get a ground-adjustable propeller, which has a hub that allows you to select different blade angles *on the ground only*. You cannot change the angle in flight. This type of prop is available for several experimental aircraft, and it's most often seen on antique and classic aircraft. Although it's adjustable, in essence it's still a fixed-pitch prop because you must select the blade angle before you start the engine.

Controllable-Pitch Propeller

A controllable-pitch propeller allows pilots to change the blade angle while the engine is running to attain the best propeller efficiency for the phase of flight. Popular on aircraft manufactured during the 1940s, it's also known as an in-flight adjustable-pitch propeller, and one installation uses a cockpit toggle switch to control the pitch electrically.

provide the best performance and safest operation for the design. Listen to them. Do not experiment with propellers.

Next you need to decide between a fixed-pitch propeller and a constant-speed prop. If you decide on fixed pitch, you need to choose what it's made of—wood, metal, or composite.

Hartzell Propellers has developed a very handy guide to assist the custom aircraft builder in selecting a propeller. You can download it as a PDF file from its website at *www.hartzellprop.com*. I want to elaborate on certain data provided within that document. Following this discussion are other factors that affect which prop you should purchase.

Vibrational Approval

Hartzell makes a strong case for ensuring that the propeller you select has specific approval for your engine. You can find this information in the Type Certificate Data Sheets for production aircraft, engines, and propellers. Even though experimental aircraft aren't listed, the information found there can serve as a reference for a similar type experimental airplane. Your local airframe and powerplant mechanic with an inspection authorization (A&P-IA) or an FAA-approved repair facility will have access to this information. You can check your installation against a similar type of production airplane that has the same engine and comparable performance.

Vibration approval is one of the most important factors the type certificate addresses. Hartzell says, "This approval is the most important safety consideration in selecting a propeller for an aircraft."

When a propeller is in operation, the forces acting on it cause the blades to vibrate, and the prop's design must compensate for this vibration. Excessive vibration causes flexing that work hardens a metal propeller. The result could be a propeller blade actually breaking off in flight.

Most combinations of engines, props, and airframes eliminate these

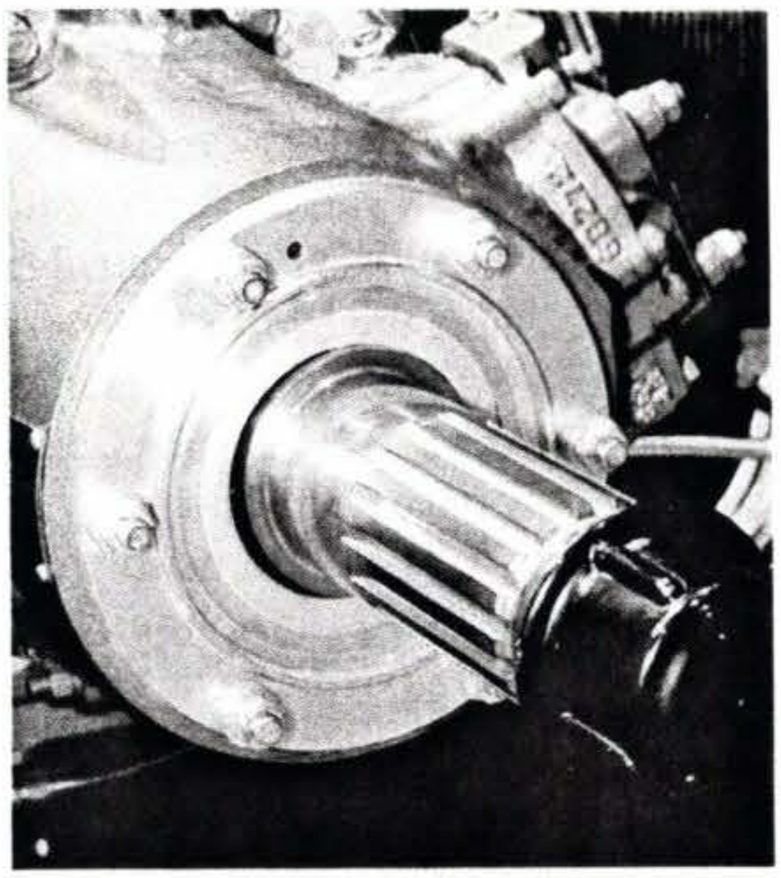

Figure 4

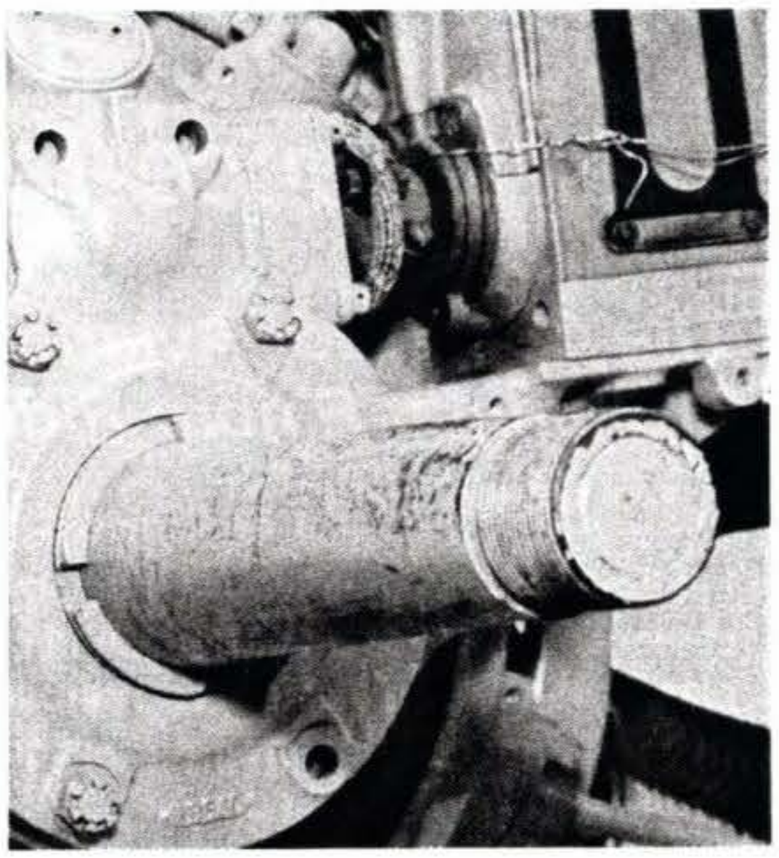

Figure 5

vibrational stresses. But the blade design, along with the engine operating conditions such as rpm and manifold pressure, can affect the vibrational forces. Indexing of the propeller on the crankshaft, hub design, and crankshaft counterweights can also affect vibration. All of these factors combine into a situation that induces extreme vibration at certain power settings.

A smooth-running engine doesn't mean vibration is not present. It's possible to have a smooth-running engine/prop combination where the propeller is being subjected to extreme vibration that will, in time, destroy it. Conversely, an engine/prop combination that is not smooth may not be indicative of a vibrational problem. For this reason it is extremely important that you note the vibration approval for an engine/propeller combination. Often, certain rpm ranges need to be avoided to prevent this vibration. Called a "critical range," the range of rpm to avoid should be indicated on the tachometer with a red arc.

Prop Diameter

It's possible to have the correct prop for your airplane that's unusable because it's too large. Ground clearance is a real consideration, and FAR Part 23 provides some guidance. For production aircraft with tricycle gear, the prop's ground clearance must be no less than 7 inches when the airplane is in its most nose-low attitude. The minimum clearance for a tailwheel aircraft is 9 inches from the edge of the propeller to the ground when the airplane is in its takeoff attitude. You should adhere to these guidelines with your experimental airplane.

Weight & Balance

When building an airplane, you must consider how everything you put on the airframe will affect the weight and balance, and that goes for the propeller, too. Obviously, the propeller is at the farthest point forward from the airplane's center of gravity (CG), and the prop's weight definitely influences the CG's location. Generally, metal props weigh more than those made of wood or composite.

Used vs. New

Often you can find used props at a bargain, but you should be wary of a used prop. Before you fly with it, have an FAA-approved propeller overhaul facility inspect it and overhaul it if necessary. Even if the prop looks good on the outside, it may be suffering from internal corrosion or other unseen damage. This is particularly true with a constant-speed propeller. Damage or corrosion may be present in the hub that will not be apparent without disassembly. So, if you elect to buy a used propeller, do yourself a favor and have it overhauled.

If you buy a yellow-tagged prop, the tag means an overhaul facility has inspected the prop and deemed it airworthy and ready for installation. If the prop has a green tag, the prop isn't airworthy, but it's repairable.

Be wary of damaged propellers that can be repaired. Before you purchase such a prop, have an overhaul or repair facility tell you that it can return the prop to airworthy status. Doing any major work on a propeller is out of the realm of capability for the average homebuilder. *Leave the straightening, shaping, and balancing of a prop to the professionals.*

Again, experimental aircraft are not legally required to use props that have been overhauled or carry a yellow tag, but common sense and safety dictate that the standards are the same for experimental and production airplanes.

Non-Certificated Props

Many props are manufactured for use on experimental aircraft, and they do not have type certificates for use on production aircraft. Most of them are made by reputable companies and are certainly safe for use on your experimental airplane, but you must still match the propeller with the engine and airframe. Use the prop that is designed for your airplane. Some experimental aircraft designs require the use of non-certificated props because there are no production props they can use. Find out as much as you can about the manufacturer and their reputation prior to placing the prop on your airplane.

Another point regarding the use of a non-certificated propeller has to do with test-flying your homebuilt. If you're using a non-certificated propeller—even on a certificated engine—your total test-flying hours will be increased from 25 to 40.

When selecting a prop for your airplane, always follow the designer's recommendations. Picking the wrong prop can reduce your flying safety, and so can experimenting with or modifying propellers. Propeller manufacturers have charts that list the various applications for their products, and they will be more than happy to help you decide which propeller will work best for your project.

In December, we'll continue our discussion of props by presenting proper installation techniques, inspection procedures, and maintenance items.

EAA SportAir Workshop Schedule

October 21-22 Lansing, Michigan
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