INFORMATION FOR AIRCRAFT BUILDERS

TECHNICAL ISSUES INVOLVED IN

PROPELLER SYSTEM SELECTION

FOR YOUR KITPLANE

BUILT ON HONOR
HARTZELL
HARTZELL PROPELLER INC.
PIQUA, OHIO U.S.A.

INTRODUCTION

There comes a time in every aircraft construction project when the builder must decide on the propeller to be installed. There are many factors to be taken into account when choosing a propeller. These include performance, weight, cost, noise, diameter limits, and durability. Selection of a proper propeller is critical as there have been a number of serious accidents due to improper application or modification of propellers.

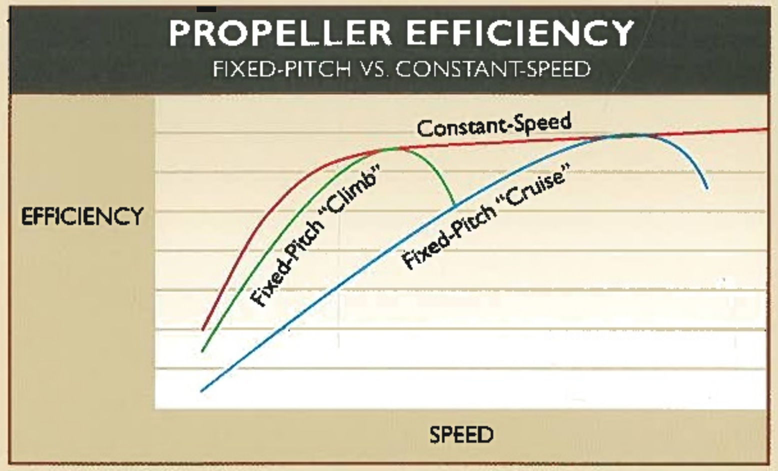
This guide discusses some of the primary considerations to be made in selecting a Hartzell constant-speed propeller. Much of this discussion will apply to other certified propellers as well. This information is provided to help aircraft builders make a safe propeller choice that will enhance the enjoyment of their aircraft.

It will be helpful to begin with a brief description of a Hartzell "compact" series constant-speed propeller. The most visible parts of the propeller are the blades. Propeller blades are complex shapes using a series of airfoils which are constructed of forged aluminum alloy or molded Kevlar™ advanced composite material. The blades are retained by, and transfer load through, a hub. The propeller hub is also constructed of forged aluminum alloy. Contained within the hub is the pitch-change mechanism. The pitch-change mechanism converts governed engine oil pressure into rotational motion to change the pitch angle of the blades. A spinner is used to cover the propeller hub and conform to the contour of the engine cowling. Spinners can be made from spun aluminum or various composite materials.

PERFORMANCE

Constant-Speed Vs. Fixed-Pitch.

Constant-speed propellers offer higher efficiency over a wider air speed range compared to fixed-pitch propellers. With a fixed-pitch propeller, builders have to choose between a "climb" pitch and a "cruise" pitch. Choosing one results in a propeller system that compromises the other. The pilot has only a limited range of engine speed variation available to control the thrust of an aircraft equipped with a fixed-pitch prop. The ability to vary blade angle in a constant-speed propeller allows the engine to develop full power at any air speed. This also enables the pilot to select the desired engine speed in order to optimize both cruise and climb performance of the airplane for maximum efficiency.



Optimized For The Airplane Flight Envelope.

From a performance standpoint, not all constant-speed propellers are created equal. While volumes could and have been written on propeller performance, that discussion is beyond the scope of this guide. In the simplest sense, props for "fast" airplanes are designed to different criteria than relatively "slower" airplanes. This allows the propeller to deliver optimal performance throughout the individual aircraft's flight envelope. Using a prop design that does not match the actual aircraft's flight envelope will compromise overall performance. Hartzell has created propellers especially for many kit aircraft (a complete list can be found on the back of this guide). If not, choose one specified for an aircraft that closely matches the performance characteristics of the plane you are building.

THE VALUE OF CERTIFICATION

Propeller Systems Endure Tremendous Stress.

Metal propeller blades typically experience centrifugal forces of 30,000 to 50,000 pounds each. This is in addition to the aerodynamic loading of the propeller pulling an aircraft through the air, as well as the forced inputs of the engine cylinders firing. All this adds up to tremendous stresses literally trying to rip the blades from the hub and the propeller from the aircraft. Propeller failures involving blade separations are catastrophic, potentially life-threatening events. Blade separations can induce enough vibration to shake engines off mounts, resulting in loss of control of the aircraft.

To ensure adequate strength and to prevent fatigue problems, all manufacturers of certified propellers complete the tests and documentation required to obtain certification. Although you may be thinking "my airplane is experimental; why should I care about certification?"... remember that even though your airworthiness certificate says "experimental," the laws of physics are still in effect. The certification process is your best assurance that the propeller has been adequately engineered to resist failure.

Propeller certification is done in two stages: "Basic" approval per Federal Aviation Regulation (FAR) Part 35, and, "Specific" approval for use on a particular aircraft per FAR Part 23.

The Basic Approval Process.

Basic approval confirms that the propeller meets certain strength and durability criteria. The chart below lists the FAR 35 requirements that must be met in order for a propeller to be type certified:

- 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% overspeed (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 operation of over 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 certified.

"Anytime you're talking about maximum performance you're talking about a constant-speed prop. The constant-speed Hartzell significantly increases the take-off and climb performance of the RVs – and provides optimum cruise as well. You can't get both in a fixed-pitch prop."

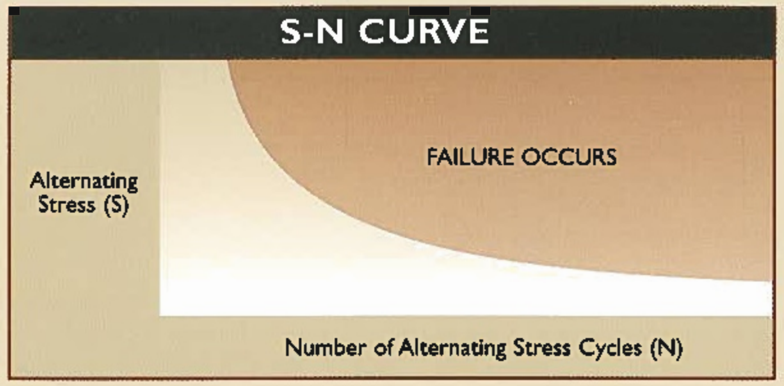
Dick Van Grunsven, President, Van's Aircraft, Inc.

Specific Approval Is Critical To Safety.

Specific approval assures compatibility between the propeller, engine, and airframe. The most significant aspect of specific approval is the vibration approval. *This approval is the most important safety consideration in selecting a propeller for an aircraft.*

Propellers, like all structures, have certain natural frequencies at which they will vibrate excessively with very little coaxing. The example of a tuning fork comes to mind. The sound produced by a tuning fork is it resonating at the fork's natural frequency. If a propeller is installed on an engine which excites (shakes) it at or near a natural frequency, like the tuning fork, it resonates. When operating in or near a resonance condition, stresses in the propeller are very high.

Most of us have flexed a paper clip back and forth until it has broken. A propeller blade or hub can behave like the paper clip on a larger scale. The lower the amount of bending stress, the more cycles it takes to break the part and the longer it will last. If the stresses are low enough, the propeller will last almost indefinitely.



In a resonance condition, however, high stresses can occur at frequencies of up to 10 or 12 cycles per crankshaft revolution. This can put a large number of cycles on a propeller in a short time. A little arithmetic shows that 2500 rpm x 10 cycles per revolution of the crankshaft x 60 minutes per hour = 1.5 million cycles per hour. In 667 hours of flying, this works out to 1 billion cycles. If the stresses at this condition are high enough, it may not be long before something sudden and unpleasant happens.

Vibration approval of the airplane/engine/propeller combination involves flight testing a strain-gauged propeller and measuring vibratory stresses in various areas of the propeller while the airplane is flown throughout its flight envelope.

Generally, the propeller is also tested at several different diameters to allow field repair for blade erosion and minor tip damage. The stress levels measured in flight are compared to the strength of the propeller at the measured locations. Occasionally, a resonant condition will be found to exist at a specific engine operating condition. Usually, a change in the blade design will correct this. When redesign is impractical, however, these propellers require placards which warn the pilot not to operate at the resonant condition.

Many factors can change the natural frequency or vibrational characteristics of the propeller and have major effects on the longevity and safety of the installation. In addition to blade design criteria (such as thickness, chord dimensions and diameter) and engine operating conditions (such as rpm and manifold pressure), other variables that can affect vibration include hub extension length, crankshaft counterweight configuration, and sometimes the indexing of the propeller on the crankshaft.

A builder may assume that simply because the propeller installation is "smooth" (lack of instrument panel, cockpit, and control stick vibration), it is safe from destructive propeller vibration. This is definitely not true. It is possible to fly along in a perfectly smooth cockpit while the propeller is gradually destroying itself. On the other hand, a particular installation could be very annoying to fly, but could actually be quite safe (at least until the instruments vibrate out of the panel and land in your lap). The reason a good installation is not felt in the seat of your pants is because the frequencies which occur in the propeller are typically much higher than the airframe structural frequencies which are sometimes felt by pilots.

It is also worth pointing out that an accurate tachometer is required to avoid inadvertent operation of the propeller in a placarded region or beyond its maximum certified speed. Mechanical tachometers are notoriously inaccurate and should be checked and calibrated periodically to prevent this from occurring.

A secondary part of the specific approval of the propeller and an important criteria for achieving acceptable performance for the installation are the blade angle limits. Proper low blade angle allows the engine to develop maximum power for takeoff, while the high angle needs to be set high enough to prevent the engine from over-speeding at high air speeds. The low angle is typically set to achieve an engine speed of 50 rpm below red line when the airplane is at full power and not moving. Hartzell Owner's Manual 115 will guide you in setting this properly.

"High performance aircraft such as the Lancair IV need propeller airfoils specifically designed for high-speed, high altitude performance. We tested extensively on the IV and the Hartzell's performance could not be beaten. That's why it's recommended."

Lance A. Neibauer, President, Lancair

For Information Refer To Type Certificate Data Sheets.

As part of the certification process, all type certified aircraft, engines, and propellers have a Type Certificate Data Sheet (TCDS) developed for that product. TCDS's contain a wealth of helpful information regarding the proper selection and setup of a propeller. Your local IA mechanic will have access to these and, of course, they are always available directly from the FAA or on the internet at www.faa.gov/avr/air/airhome.htm.

For certified airplanes, the aircraft TCDS's contain the propeller blade angle limits for that airplane. They can serve as a reference for a similar home-built airplane. It's a good idea to check your installation against a similar production airplane (one having the same engine, propeller and similar cruise and climb speed) for blade angle settings. The figure at right shows a typical example, the first page of the Cirrus SR20 data sheets which lists the approved propeller models and blade angle settings.

Engine data sheets include information relevant to the propeller, such as rated horsepower and rpm limits, compression ratio, and, if applicable, the crankshaft damper configuration.

"Aerobatic flight, especially in a Pitts S1-11B, is addictive. 'The Claw' aerobatic propeller by Hartzell provides fantastic hang time at the top as well as outstanding overall performance. And its Kevlar™ construction is extremely durable, erosion resistant, and has passed bird and lightning strike tests as part of the certification process."

Stuart Horn, President, Aviat Aircraft, Inc.

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

A00009CH
Cirrus Design Corporation
SR20
October 23, 1998

TYPE CERTIFICATE DATA SHEET NO. A00009CH

This data sheet, which is part of Type Certificate No. A00009CH, prescribes conditions and limitations under which the product for the which type certificate was issued meets the airworthiness requirements of the Federal Aviation Regulations.

Type Certificate Holder: Cirrus Design Corporation
4515 Taylor Circle
Duluth, MN 55811

1-Model SR20, (Normal Category), Approved October 23, 1998

Engine — Teledyne Continental IO-360-ES, Type Certificate Data Sheet (TCDS) E1CE

Fuel — 100/100LL minimum grade aviation gasoline

Engine Limits — Maximum Take-off 2700 RPM (200 hp)
Maximum Continuous Power 2700 RPM (200 hp)

Prop Info

Propeller and Propeller limits — 1. Hartzell Propeller Inc. P/N BHC-J2YF-1BF/F7694, TCDS P37EA
Maximum Diameter 76 inches
Minimum Diameter: 73 inches
Number of Blades: 2
Low Pitch: 14.6°+/-0.1°
High Pitch: 35.0°+/-1.0°
Not to be operated above 24 inches of manifold pressure between 1900 and 2200 RPM.
Spinner: Hartzell P/N A-229SP

2. Hartzell Propeller Inc. P/N PHC-J3YF-1MF/F7392-1
Propeller limits TCDS P36EA
Maximum Diameter: 74 inches
Minimum Diameter: 72 inches
Number of Blades: 3
Low Pitch: 14.1°+/-0.1°
High Pitch: 35.0°+/-1.0°
No operating limitations to 2800 RPM
Spinner: Hartzell P/N A-2295-1P

Airspeed Limits

VNE	Never Exceed Speed	200 KIAS
VNO	Maximum Structural Cruising Speed	165 KIAS
VO	(2900 lbs) Operating Maneuvering Speed	135 KIAS
VO	(2600 lbs) Operating Maneuvering Speed	126 KIAS
VO	(2200 lbs) Operating Maneuvering Speed	116 KIAS
VFE	Maximum Flap Extension Speed	100 KIAS
VPD	Maximum Parachute Deployment Speed	135 KIAS

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"Backcountry, cross-country, on floats, or on a trailer, the GlaStar® defines versatility. And a constant-speed Hartzell propeller makes it even more versatile. Unlike fixed-pitch props which force you to choose between a 'climb' or 'cruise' design, a constant-speed prop enables you to optimize both."

Bob Gavinsky, President, Stoddard-Hamilton Aircraft, Inc.

A real "gold mine" of information can be found in the propeller type certificate data sheets. These sheets include not only the basic approval information, such as diameter, horsepower and rpm limits, but they also contain "Note 9" vibration approvals. Below is an example showing a portion of a prop TCDS.

As stated earlier, vibration approval is the most important aspect in selecting a safe propeller for your aircraft. An additional benefit of selecting an approved engine/propeller combination is that this will usually allow you to obtain a 25 hour test period for your airplane rather than the typical 40 hours required for uncertified engine/propeller combinations. The installations listed under Note 9 contain vibration approvals for the entire diameter range.

DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

P-920
Revision 21
HARTZELL
HC-C2Y
BHC-C2Y
CHC-C2Y
DHC-C2Y
April 25, 1996

TYPE CERTIFICATE DATA SHEET NO. P920

Propellers of models described herein conforming with this data sheet, (which is part of Type Certificate No. P-920) and other approved data on file with the Federal Aviation Administration, meet the minimum standards for use in certificated aircraft in accordance with pertinent aircraft data sheets and applicable portions of the Federal Aviation Regulations provided they are installed, operated, and maintained as prescribed by the approved manufacturer's manuals and other approved instructions.

Type Certificate Holder	Hartzell Propeller, Inc. Piqua, Ohio 45356
Type	Constant speed; hydraulic (See NOTES 3 and 4)
Engine shaft	SAE #2 flange, special flange 4" B.C.
Hub material	Aluminum alloy
Blade material	Aluminum alloy
Number of blades	Two
Hub models	HC-C2YF-1, -2, -4, BHC-C2YF-1, -2, -4, CHC-C2YF-1, -2, -4; DHC-C2YF-1, -2, -4; HC-C2YK-1, -2, -4; CHC-C2YK-1, -2, -4; HC-C2YL-1, 2, -4; HC-C2YR-1, -2, -4; CHC-C2YR-1, -2, -4 (See NOTES 1 and 4)

Blades (See NOTES 2 & 5)	Maximum Continuous HP	Maximum Continuous RPM	Takeoff HP	Takeoff RPM	Diameter Limits	*Hub and Blades Approx. Wt. (See NOTES 3 and 7)
Non-Counterweighted Blades - Hub Models: All-1						
7068-0 to 7068-10	300	2700	300	2700	70" - 60" (-0 to -10)	55.5 lb.
7280 +1/2 to 7280-7	250	2700	250	2700	72-1/2" - 65" (+1/2 to -7)	51 lb.
7663-0 to 7663-8	210	2800	210	2800	76" - 68"	46 lb
7666-0 to 7666-8	180 or 250	2900 / 2700	180 or 250	2900 / 2700	76" - 68" (-0 to -8)	51 lb
7691-0 to 7691-8	250	2700	250	2700	76" - 68" (-0 to -8)	51 lb.
7692-0 to 7692-8	180 or 250	2900 / 2700	180 or 250	2900 / 2700	76" - 68" (-0 to -8)	46 lb.
8052-0 to 8052-8	310	2600	310	2600	80" - 72" (-0 to -8)	50.5 lb.
8459-0 to 8459-18	260	2800	260	2800	84" - 66" (-0 to -8)	46 lb.

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Any placard limitations are also listed. This approval covers all normal category single-engine aircraft in a tractor configuration.

Such broad approval is possible because the airframe does not interact with the propeller in this configuration and the engine/propeller combination is the only critical issue from a propeller vibration standpoint. Use of the same "factory airplane" shock mounts and a similar engine mount structure is strongly recommended. Also note that twins and pusher installations are not covered by this approval as these aircraft installations can affect the propeller stresses differently than singles. Aerobatic aircraft are also not included because of the extremes of their flight envelope. These excluded configurations require testing in order to achieve specific approval for that aircraft type.

P-920 6

NOTE 7. Accessories. (See NOTE 10)

(a) Propeller Anti-icing
   (1) Fluid feed shoes or icex boots installed in accordance with Hartzell Special Instructions No. 59A.
   (2) Hartzell fluid feed equipment on propeller models for which the equipment is available.

(b) Propeller Deicing
   (1) Goodyear Ice Guards (electrical propeller deicer) when installed in accordance with instructions outlined in Goodyear Report No. AP-147 dated October 23, 1961.
   (2) Goodrich De-icing Kit 77-xxx, 67-xxx, or 65-xxx when installed in accordance with Goodrich Report No. 59-728 ( ).

(c) Propeller Spinner
   (1) Approved with Hartzell spinners (weight of spinner extra).

(d) Propeller Damper C-1576
   (1) Approved for Hartzell Propeller Model HC-C2Y

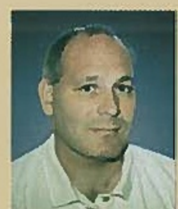
NOTE 8. Shank Fairings. Not applicable.

Note 9 → NOTE 9. Special Limits

Table of Propeller-Engine Combinations
Approved Vibrationwise for Use on Normal Category Single-Reciprocating Engine Tractor Aircraft

The maximum and minimum propeller diameters that can be used from a vibrationwise standpoint are shown below. No reduction below the minimum diameter listed is permissible, since this figure includes the diameter reduction allowable for repair purposes.

Hub Model	Blade Model	Engine Model	Max. Dia (Inches)	Min. Dia. (Inches)	Placards
HC-C2YR	F7068-( )	Lycoming IO-360-B1A, -B1B, -B1C -B1D, -B1E, -B1F, -E1A, -F1A O-360-A1A, -A1AD, -A1C, -A1D, -A1F -A1G, -A1H, -A1LD	68	67	"Stabilized operation is prohibited above 25" manifold pressure between 2300-2350 RPM and below 15" manifold pressure above 2600 RPM"
BHC-C2YF	7663	Continental O-300-E	72	70	None
HC-C2YK	7663	Continental IO-346-B	76	76	None
BHC-C2YF	7663	Continental IO-346-A, -B, -C, -D, -E	76	72	None
BHC-C2YF	F7663( )	Continental IO-360-H, -HB	76	72	None
HC-C2YL	7663	Lycoming O-290-D2A	72	70	None
HC-C2YL	7663	Lycoming O-320-A3A, -A3B, -A3C, -B3A, -B3B, -B3C, -C3A, -C3B, -C3C, -D1A, -D1B, -D1C, -E1A, -E1B, -E1C, -E1F	72	70	None
HC-2CYL	7663	Lycoming IO-320A1A, -A2A, -B1A, -B1B, -B1C, -B1D, -B2A, -C1A, -D1A, -D1B, -E1A	72	70	None
HC-C2YL	7663	Lycoming IO-320-E1A	72	70	None
HC-C2YK HC-C2YR	7666 F766	Lycoming O-360-A1A, -A1AD, -A1C, -A1D, -A1F, -A1G, -A1LD, -B1A, -B1B, -C1A, -C1C, -C1F, -D1A	76	72	"Avoid continuous operation between 2000 and 2250 r.p.m."
HC-C2Y(KR)	F7666A-2Q	Lycoming O-360-A1A, -A1C, -AID, A1F, -A1G, -B1A, -B1B, -C1A, -C1C, -C1F, -D1A	74	74	"Avoid continuous operation between 2000 and 2250 r.p.m."
HC-C2YK CHC-C2YK	7666 C7666	Lycoming IO-360-A1A, -A1B, -A1C, -B1A, -B1C, -C1A, -C1B, -C1C, -D1A	72	74	"Avoid continuous operation between 2000 and 2250 r.p.m."



"Utility planes require reliable performance for their rugged applications. Since Hartzell props are certificated they have been subjected to rigorous fatigue and stress testing not required of experimental props. So you can be assured the constant-speed Hartzell prop will provide the performance needed for primitive short-field work and the durability to take the abuse that comes with it."

Darryl Murphy, President, Murphy Aircraft Mfg. Ltd

USE OF PROPELLERS ON NON-CERTIFICATED ENGINES

With a very few exceptions, we do not endorse the use of Hartzell propellers on non-certified engines due to the lack of demonstrated engine/propeller vibrational compatibility. In a few cases, Hartzell has performed the necessary testing to verify the vibration characteristics of automotive engine/propeller combinations, and have approved the use of a particular propeller with specifically configured engines. Unfortunately, due to the wide variety of engine conversions available and the testing expense involved, it is not practical to test all of them. If you are considering using a non-certificated engine that has not had a propeller vibration survey performed, a wooden fixed-pitched propeller is the safest choice.

USED PROPELLERS

Often builders want to economize by purchasing a used propeller for their project. Some builders are even fortunate enough to buy a "firewall forward" package from a damaged factory-built airplane or one which is being upgraded to another engine. When purchasing the propeller alone, the builder should verify vibrational compatibility with the engine. In both cases, it is also important that the proper design matches the flight characteristics of the airplane to ensure optimal performance.

If you do choose a used propeller either by itself or as part of a "firewall forward" unit, it should definitely be overhauled. Even if it looks fine at first glance, it could have internal corrosion or may have suffered other abuse in the past. In the overhaul process, the propeller is completely disassembled, corrosion is identified and removed, parts are checked for wear and damage, blades are measured to ensure sufficient material is present and airfoils are restored, and seals and corrosion preventive coatings are replaced. The identification and removal of stress risers, which can cause fatigue, are also a significant part of the process. When the prop is reassembled and balanced, it should also be set up to the proper blade angle limits using data discussed earlier. Additionally, you will get a shiny new paint job to go with your shiny new airplane and, of course, peace of mind.

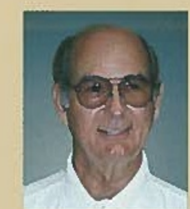
AN EXAMPLE

Armed with all of this background information, consider the following example to examine some important considerations in propeller selection. Let's say a builder we know happens to have a flying buddy with a factory-built airplane. The propeller on his buddy's airplane has eroded below minimum-approved diameter limits for the airplane and, therefore, must be replaced. The builder asks his buddy for the eroded prop since he needs to cut down the diameter anyway in order to get more ground clearance. He also plans to run his engine over the maximum recommended rpm, install high-compression pistons to get more power and does not want extra noise due to excessive tip speed. So, out comes the hacksaw, off go a few inches from each tip, and it's ready for a quick balance check. While he's at it, he decides he has always wanted to have a sleek extended nose bowl for his engine cowling. He goes to a friend with a machine shop and a nice long spacer is created to fit between the engine and propeller to match the extended nose bowl.

The great day arrives and our builder makes his first flight. Back on the ground, he is ecstatic, and, rightfully so. He has completed his project and it performs and handles well. But what's wrong with this picture? Unfortunately, plenty! All of the decisions he has made regarding his propeller can have a profound effect on the longevity of the airplane and its builder.

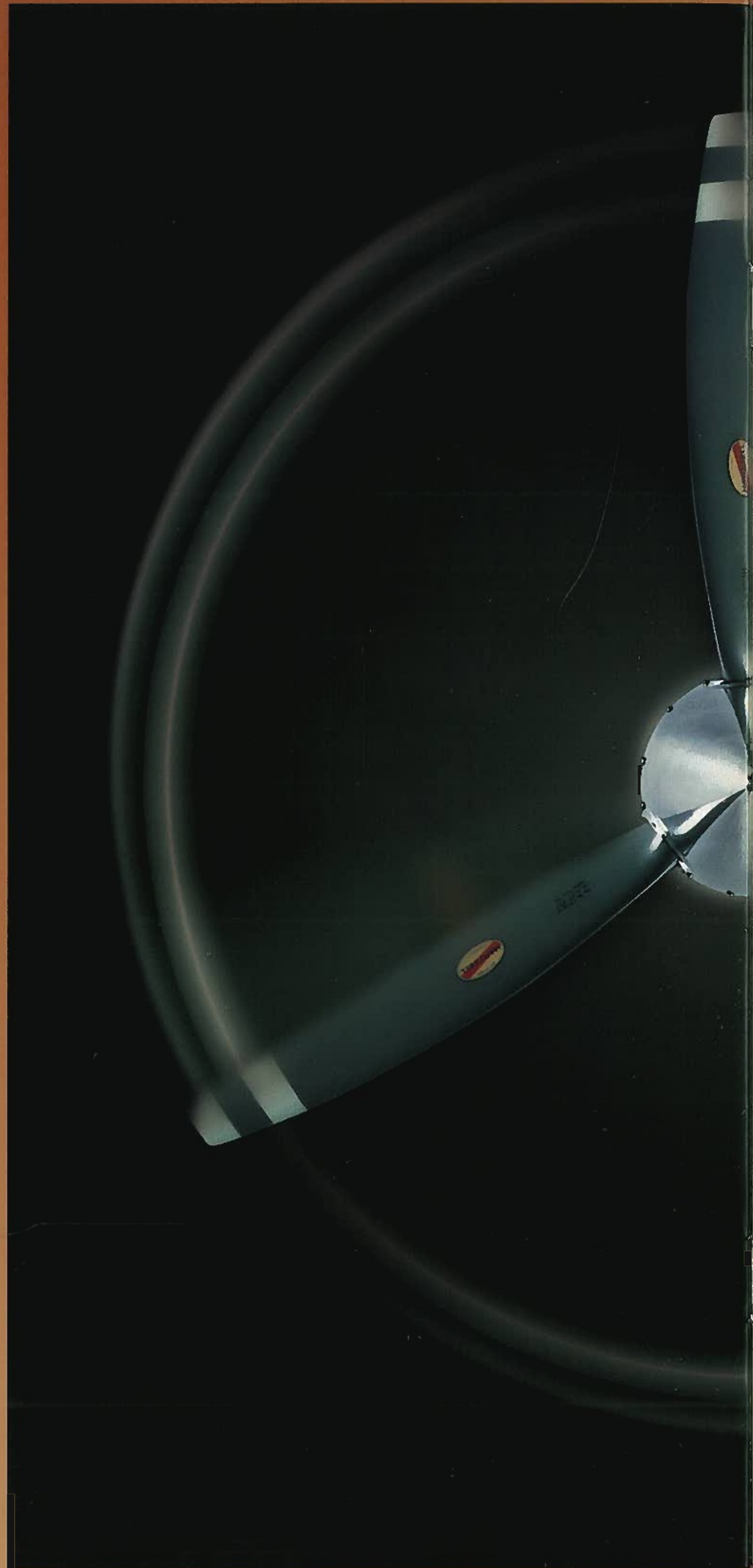
Our builder friend could have several problems. Aside from neglecting to check that the propeller, at its reduced diameter, was vibrationally compatible with his engine, the changes in operating rpm; compression ratio; and inclusion of a custom spacer make this a very high-risk installation. Cutting down the diameter below approved limits, increasing the compression ratio, or adding the spacer will increase stresses in the propeller. It also changes the locations and rpm at which they occur. Even if he had used an approved propeller at its proper diameter for the engine, over-speeding may have exposed him to new resonance conditions which may exist past the maximum rated rpm.

While this was a hypothetical situation, there are some real life examples of improper propeller application as well. For instance, on August 17, 1997 a propeller blade failure resulted in the fatal crash of a Pitts S1S. Metallurgical analysis revealed that the blade failed at mid-span due to fatigue. The NTSB report listed the probable cause as: "the operation of the propeller beyond design rpm limitations and the resultant gyroscopic loads from aerobatics. Contributing to the accident was the lack of a required instrument panel rpm restriction for the propeller mandated by an airworthiness directive."



"The Stewart S-51D combines two American icons of performance – the P-51 Mustang and the big block Chevrolet V-8. The new Hartzell 4-blade prop was designed and tested especially for the S-51, it's 70% the size of the original Mustang's – but the performance isn't scaled down."

Jim Stewart, President, Stewart 51 Inc.



IN CONCLUSION

Hartzell has worked with the popular kit manufacturers listed on the back cover to develop suitable propellers to be installed with the engines recommended for the kit. If you are building a kit for which a Hartzell propeller is available from the kit manufacturer, obtaining the propeller from that manufacturer is the best option. Many kit manufacturers also offer builders special pricing on Hartzell propellers. So, not only is this choice less risky, it may also be less expensive.

The creativity and originality exhibited by aircraft builders are some of the things that make "home building" so enjoyable. Modifying or mis-applying a propeller, however, is a poor place to express your individuality. Why not take advantage of the available information that someone else has spent the time and money to acquire? Operating your propeller within its approved diameter and rpm range when installed on the proper engine will go a long way towards ensuring a safe, dependable aircraft. All it takes is a little awareness and research.

HARTZELL PROPELLERS ARE AVAILABLE THROUGH THESE KIT MANUFACTURERS.

- AkroTech Aviation
- Aviat Aircraft
- Express Aircraft
- Griffon Aerospace
- Lancair
- Murphy Aircraft
- Mustang Aeronautics
- Osprey Aircraft
- Performance Aircraft
- Sequoia Aircraft
- S.N.A.
- Steen Aero Lab
- Stewart 51 Inc.
- Stoddard-Hamilton
- Stolp Starduster
- SX-300 Builders Group
- TRI-R Technologies
- Van's Aircraft
- ...and others

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HARTZELL

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