RAISBECK
ENGINEERING

TECHNICAL NOTES ON THE SWEPT TURBOFAN PROPELLER

"The biggest benefit of propeller blade sweep for the King Air type of airplane is that it allows for a larger propeller diameter propeller without increasing the sound level in the airplane and on the ground. This in turn provides for more takeoff and climb thrust." – James Raisbeck

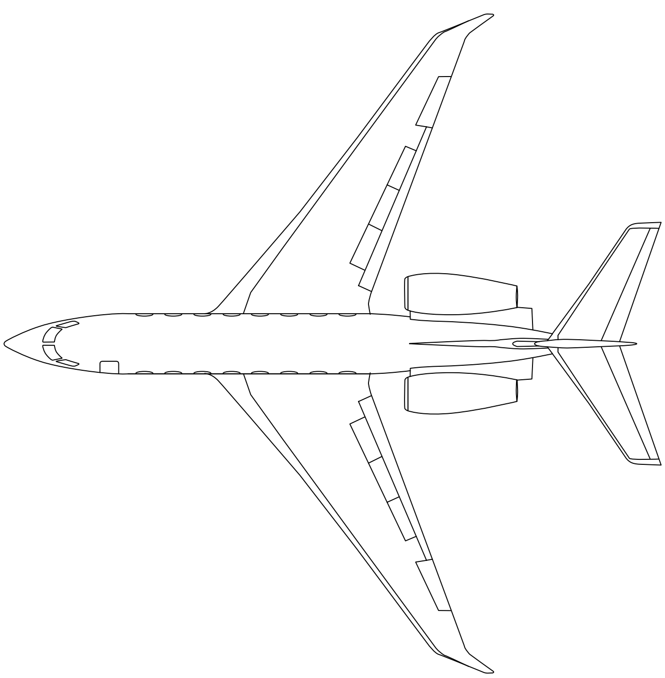
Why Sweep the Propeller blades?

The newer King Air 200s can cruise as fast as .52 Mach (M_{MO}) at 28,000 feet. At a propeller RPM of 1800, the propeller tip Mach number is over .9 at cruise.

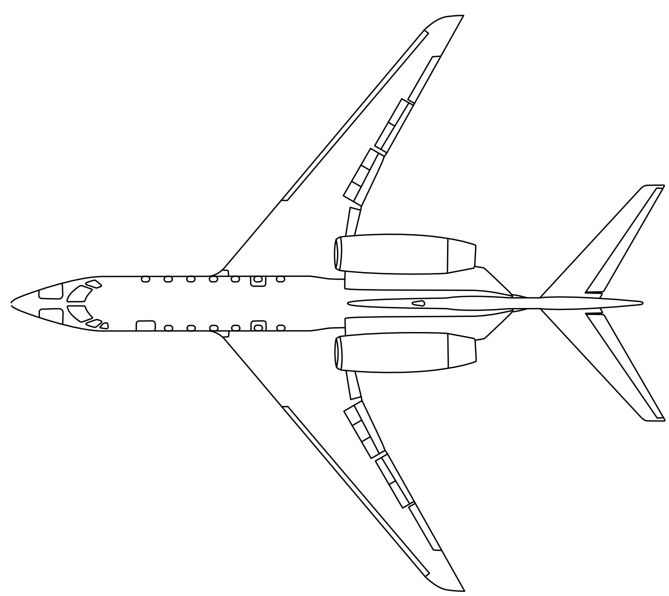
This same high-Mach phenomenon is also very much present during takeoff at low forward airspeeds but higher prop RPM. As an example, at 120 Knots during initial climb at 2000 RPM, the propeller tip Mach is an astonishingly high .8.

These takeoff, climb and cruise conditions are encountered on almost every King Air 200 flight, and they push the propeller blades significantly into the transonic drag rise for airfoils and unswept wings.

As a comparative example, commercial airliners and business jets typically fly around Mach .79 to .82, and some of them are pushing .90 (747) and even as high as .92 (Gulfstream 650 and Cessna Citation Ten). The wing sweep on these airplanes varies from 30 to 40 degrees. All one has to do is look at the top view of any of these aircraft to see how dramatic the sweep is (see figures below).



Gulfstream 650



Cessna Citation X

Typical commercial airplane quarter-chord sweep angles are the Douglas DC-8 at 32 degrees and the Boeing 757 with 25 degrees. Boeing's biggest sweep ever built into a Boeing commercial airplane is the 747 with 37 ½ degrees of quarter cord sweep which cruises over Mach .9 when pushed.

With a jet airplane, its entire wing is at the same Mach number. However, with a propeller blade, the farther out on its diameter, the higher the Mach number. Adding additional diameter to a propeller adds to its tip Mach number, which in turn adds unwanted additional transonic drag and noise. This of course detracts from the other desirable performance increases resulting from such an increase in diameter.

Now, air over an airfoil doesn't know if that airfoil is part of a wing going straight through the air, or a propeller blade being whirled around in a circle by its propeller hub. The air reacts the same to increasing Mach number.

Merely adding propeller diameter doesn't necessarily add proportionate performance improvement and it can be measurably noisier because of high Mach effects at the outer parts of the blades.

Introducing blade sweep to the blades, can largely overcome these drawbacks. You are never going to get rid of noise, but it does allow you to increase diameter to increase performance without paying the normal penalties.

Brief History of Wing and Blade Sweep

The next question is, if the swept wing has been around since Willy Messerschmitt put it on the ME 163 in 1943, and that work was discovered by George Schiarer from Boeing after the War in 1945 and was first employed in 1947 on the B-47, swept-wing bomber why hasn't anybody designed swept propeller blades until now?

Actually, there have been some successful attempts to design and build true swept-propellers. The European A400M cargo plane has swept wings and swept propellers (below). It is designed to fly at Mach .72 and airspeeds to 421 knots. The propeller has 8 blades and is very costly for general aviation consideration.

Airbus A400M

Lockheed C130J

There are other examples such as the C130J (above), but they are all on very expensive and usually military airplanes. As such, they inherently don't qualify for markets such as the King Air.

But to the layman, it is not intuitively obvious that sweeping the blades of a propeller installed on a King Air that incorporates no wing sweep itself and flies at cruise Mach numbers well below the transonic drag rise, makes any sense.

And since no one has gone there in propeller design for airplanes like the King Air, no market has ever been developed. Market is what drives research, technology and their results—new products which satisfy a new market need.

The team of Hartzell Propeller and Raisbeck Engineering have combined for the last three decades to push back the dual boundaries of technology and market. The latest of these efforts is the Raisbeck Swept Turbofan Propeller System (STPS).

Application of Wing Sweep to the King Air Propeller

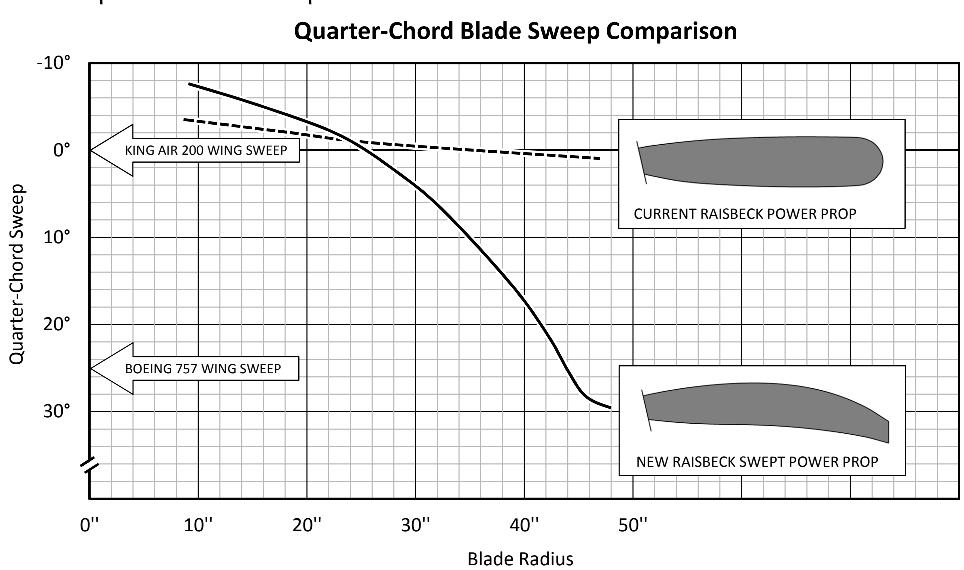
Surveying a number of recent general aviation airplane propellers, they at first appear to have swept blades. But they don't. Several examples exist with the Hartzell Scimitar propeller (below).

Hartzell Unswept Scimitar Propeller

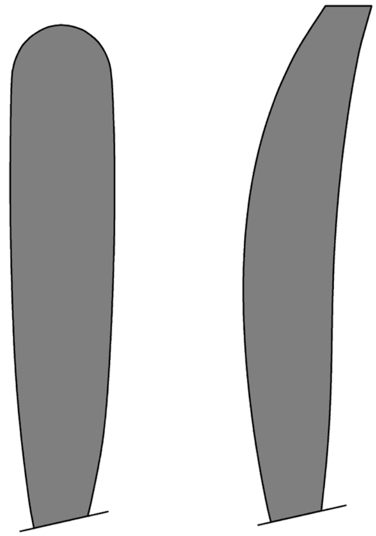
One of the latest of these is the Composite Scimitar Propeller for the King Air 250.

The blades on these propellers have cut-back leading edges, but the trailing edges remain unswept. Quarter chord sweep (the sweep of the 25% chord) is what the air responds to and calibrates well with drag rise at higher Mach.

The graph below compares the quarter-chord sweeps of the blades on our current Raisbeck Turbofan Power Prop with our new Swept Turbofan Propeller.



When viewed side by side (see below), the visual effect of the blade sweep stands out in a crowd.



Current Raisbeck Power Prop ***New Raisbeck Swept Power Prop***

Development and FAA certification Flight Testing

First conforming propellers with the new blades were delivered to Raisbeck's flight-test facilities In June 2012, following 2½ years of CFD analyses and resulting studies and trade-offs. Configuration had been frozen in February 2012, and Hartzell had then begun manufacture of the pre-production blades.

During development flight testing, three different propellers were evaluated on a fully instrumented King Air B200; the current Hartzell OEM propeller for the B200GT (93″ diameter); the current Raisbeck Turbofan Power Prop (94″ diameter); and the new Swept Turbofan Power Prop (96″ diameter). Incremental increases in performance between these three were documented, and fell roughly as expected, with performance following increased diameter in each case.

With performance well documented in-house, Raisbeck's engineers went forward with full FAA certification. FAA flight testing was completed in August, and all submittals were made except the new Airplane Flight Manual Supplements containing the performance. These were submitted two months later and accepted shortly thereafter.

The propeller itself was separately Type-certificated by Hartzell to add to their Type Certification Data Sheet, a necessary step toward Raisbeck certification. Details of the certified performance comparisons are available on a separate document, attached.

Manufacturing Considerations

The large sweep on the new propeller in turn required new aluminum forgings for quantity production. New forgings cost money; they are provided to Hartzell by Alcoa in this case. Long lead times for new forgings are typical. However, the trade-off is the per-unit manufacturing cost of the resulting aluminum blades as compared with the only other alternative—composite construction.

Raisbeck Swept Turbofan Propellers installed on a King Air B200

Typically the recurring cost and resulting pricing of composite propellers are two times or more of an aluminum blade. In all probability, this new technology for business and general aviation applications will find a home on more airplane models, both OEM and retrofit.

The blades used for flight testing and FAA certification were machined from large aluminum ingots. Three complete propellers were required; two for performance, stability and control, governor pressure, takeoff, landing and taxi characteristics; the third Swept Propeller was fully instrumented and put on one side only, to document stress, strain, loads, vibration, and dynamic response.

The overall advantage of a composite propeller is the weight savings over aluminum. The drawback is cost. In the case of the Swept Turbofan Props, there is no increase in weight over the current Raisbeck props; new and thinner airfoils more than compensated for the increase diameter.

With all this in mind, the Raisbeck/Hartzell team opted for aluminum construction. The benefactor of this choice is the customer—affordable new technology.

Pricing and Availability

The Swept Turbofans are priced $8,900 per shipset above the current Raisbeck prices for the Power Props. The 2013 price for the Swept Turbofan Power Props alone is $83,400 per shipset, and in combination with the EPIC Performance System is $149,850. The Swept Propeller model number is HC-D4N-3A/D9515K, complete with prop deice, spinner, and all necessary hardware.

The current Power Prop, in production since 1984, will continue to be offered for those who want commonality of their current Raisbeck-equipped fleet, and those wishing to save money.

Deliveries begin March 1st to customers of record. Detailed information has been sent to all 118 dealers and installation centers worldwide.

What's Next?

The engineers and marketers at Raisbeck are looking at where the new technology should be applied next, and on what model aircraft. In keeping with Raisbeck Engineering's long-standing policy of proving out new technology and certifying it before offering it for sale or, in most cases even talking about it, any discussion of what tomorrow brings will have to wait until tomorrow.

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