Performance Evaluation of the Hartzell HC-F2YR-1ANX1/NM7504-5X1 on the Lancair 360

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Recently I had the opportunity evaluate a new Hartzell composite propeller HC-F2YR-1ANX1/NM7504-5X1 (7504) on the Lancair 360. The original propeller was an aluminum Hartzell propeller with HC-F2YR-1F/F7068-2 (7068) blades which were developed for the Lancair 360 during the 90's. This propeller had been on the plane since the first flight in '97. The 7068 blades performed quite well on the 360, but Hartzell was able to extract additional performance using the new composite blades.

The prototype propeller had already been though vibration testing. The intent was to compare performance and check other general operating characteristics. The composite blades improved performance in several areas and result in higher cruise speeds, improved high altitude climb and greater aerodynamic braking in power-off descents.

The composite propeller assembly is roughly 20 lbs lighter than the 7068 (~43lb vs ~63lb). In addition to different blades, Hartzell also developed a new two-piece hub that is interchangeable with the older three-piece hubs – those with the characteristic 'Frankenstein' bolts.

1. Propeller Installation

A new two-piece hub design eliminates the 'Frankenstein' bolts (Figure 1) and makes for a much cleaner hub. The cut-outs in the backplate to clear the Frankenstein bolts are no longer needed. The hubs are interchangeable so the blade centerline is the same distance from the engine flange. To maintain the same spinner to blade clearance gap (3/16") with the 7504 blades, I fabricated a new back plate and spinner assembly. The 7504 blades have a more rounded cross-section where they penetrate the spinner.

Using a regulated nitrogen source, the propeller was cycled through the entire pitch range to confirm clearance between the spinner and the propeller blades (Figure 2).

Figure 1, New Two-Piece Hub (left), Old Three-Piece Hub (right)

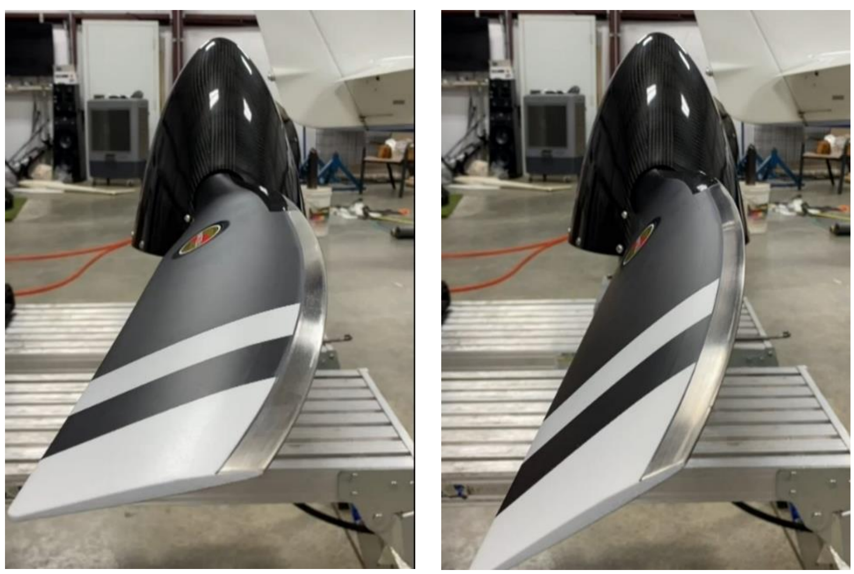

Figure 2, Propeller to Spinner Clearance Verification

2. Propeller Governor Interaction

The governor on the aircraft is the McCauley DC290D1-T17. The governor is able to drive the 7504 blades down to a much lower engine speed than it was with the 7068 blades. The difference is on the order of 2-300 rpm. This low engine speed creates the opportunity for improvements in long range economy cruise. At 17,500' for example, the 7504 blades can be governed down to 1,950 rpm at wide open throttle (WOT).

3. Performance

Cruise Performance

Cruise performance was checked at 17,500', 12,500' and 7,500'. Each test flight began with full fuel tanks. In-flight weight was determined by fuel burn. Each point was flown for 5 to 10 minutes to help detect any contaminating influence from atmospheric disturbances.

Temperatures aloft were quite high, ranging from 23 to 29 deg F above a standard atmosphere.

Engine speeds were swept through the range achievable by both installations. The 7068 propeller has operating limitations which limit engine speed at the 17,500' point due to low manifold pressure. The 7068 also determined the lowest engine speed compared as the minimum governable speed is higher than that of the 7504 propeller.

Data taken at 17,500' was the most consistent (Figure 3) with a one to two knot increase in speed. At 12,500' some slight perturbations in the trends can be observed (Figure 4), but still showed an improvement in the one to two knot range. Unfortunately, atmospheric disturbances caused both curves at 7,500 to exhibit too much scatter to be useful.

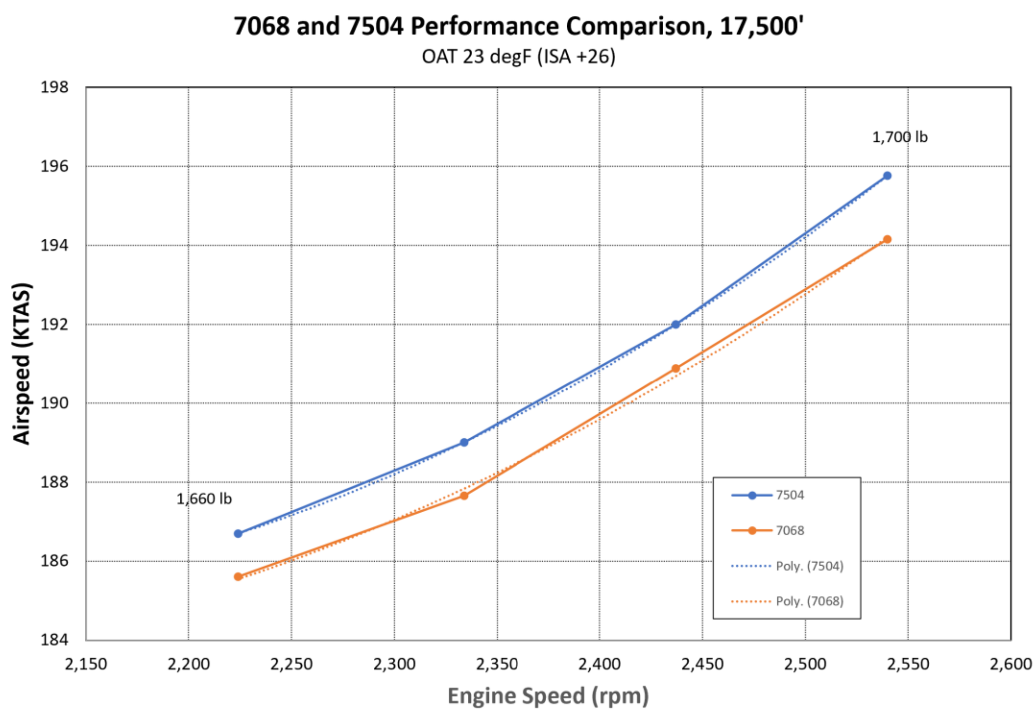

Figure 3, 17,500' Cruise Performance

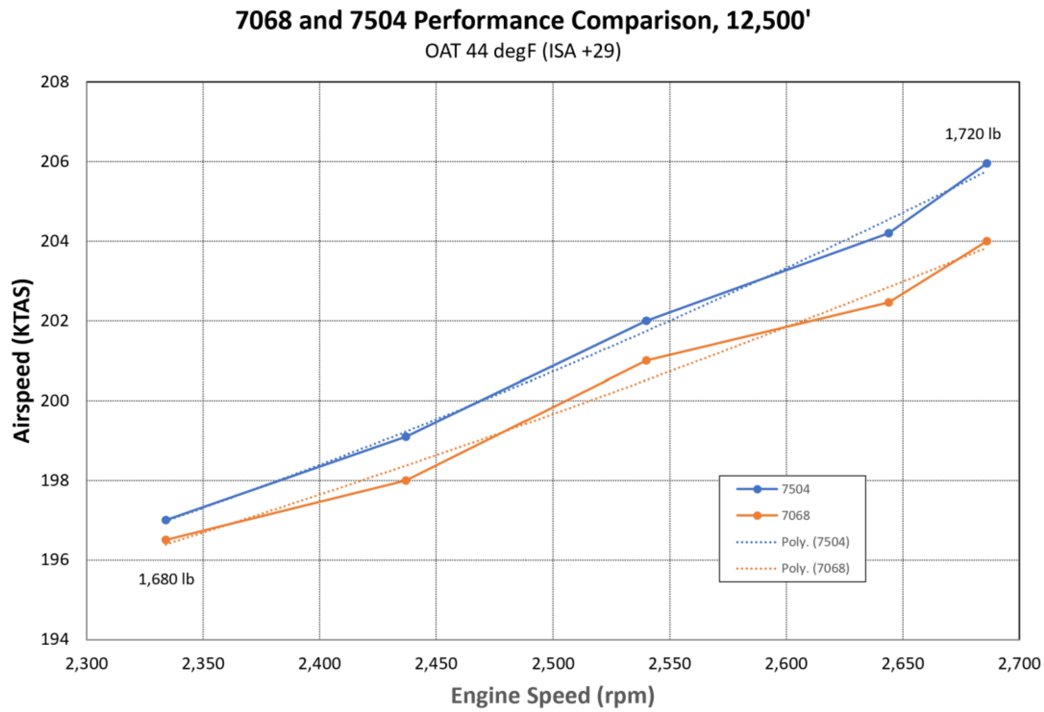

Figure 4, 12,500' Cruise Performance

Climb Performance

The difference in climb performance between the two propellers is indistinguishable (up to 16,000') given the fidelity of the test method. Climbs were recorded during ascents to 17,500' for cruise performance measurements. The climb profile starts at 140 KIAS shortly after take-off (Figure 5). This speed is gradually reduced throughout the climb, reaching 125 KIAS at 17,500'. The climb was flown by the autopilot as a climb rate. Climb rate was reduced as the airspeed dropped below the desired window. Performance of the two propellers is close enough that a more precise method would be needed to distinguish between the two, such as to controlling to a singular airspeed rather than a band.

The 7504 blades do have a distinct advantage up high as there is no operating limitation on MP/rpm combinations. The 7068 propeller needs to be pulled back below 2,600 rpm once MP drops to 15 in Hg[1] (Figure 6). At high altitude, any loss in power has a significant impact on climb rate, 33% in this case.

[1] For HC-F2YR-1F/F7068-2 propeller on the 180 HP IO-360-B, E & F undamped engines, the following restrictions apply: 1. "Stabilized operation is prohibited above 25" manifold pressure between 2300-2500 RPM". 2. "Stabilized operation is prohibited below 15" manifold pressure above 2600 RPM". See Hartzell Manual 193, Volume 1.

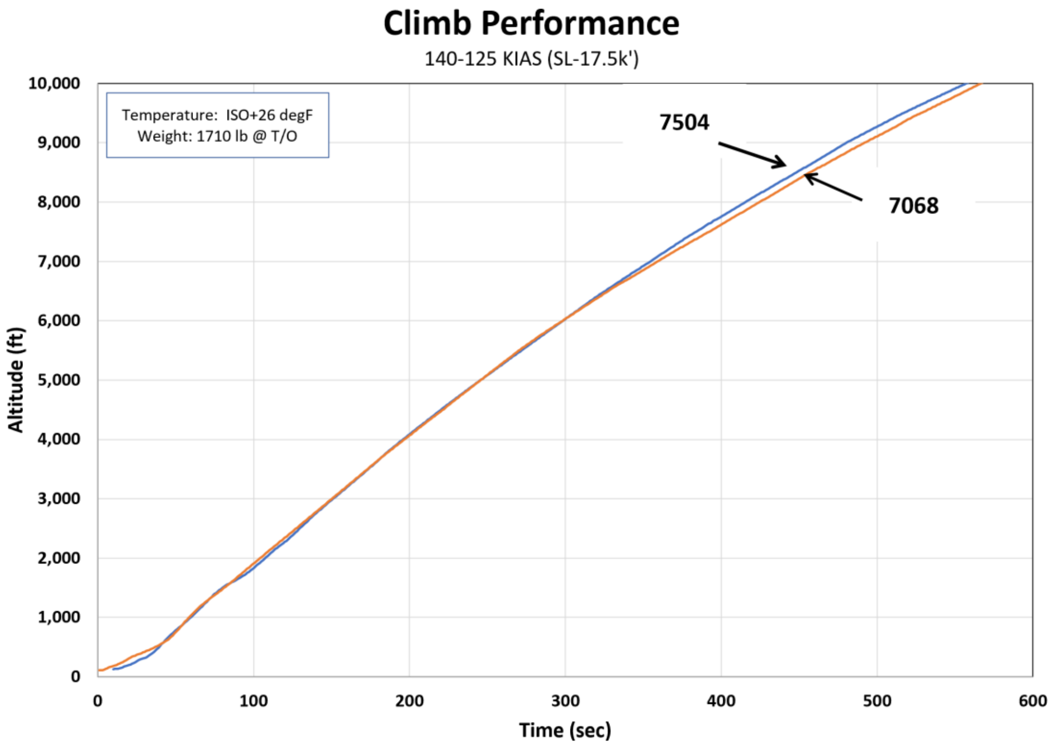

Figure 5, Low Altitude Climb Performance

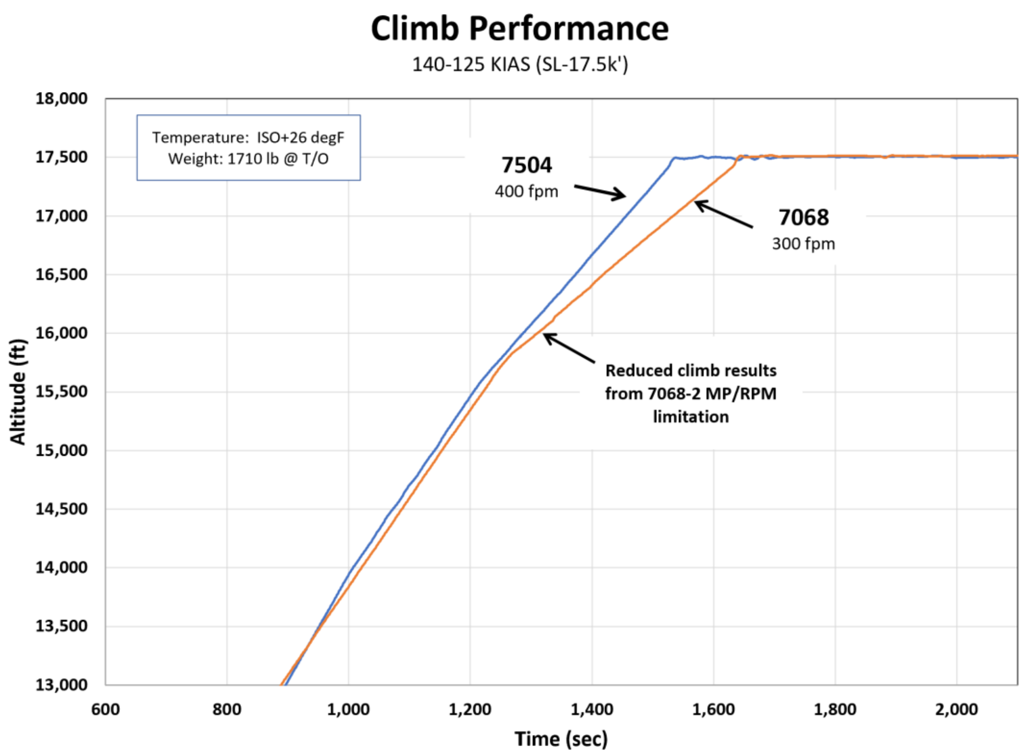

Figure 6, High Altitude Climb Performance

Take-Off Acceleration

Take-off acceleration was measured using a stand-alone 20Hz GPS used in the auto/motorcycle racing circles (VBox). Good side-by-side data with matching conditions for the 7068 is not available, however no qualitative change in acceleration was noted. At sea level, initial acceleration in the Lancair 360 is quite brisk, approaching 0.3 G's. Rotation at sea level is initiated at 65 KIAS (Figure 7, Figure 8), but actual lift off may be as late as 70 or 75 KIAS due to the high rate of acceleration. Rotation speed is increased to about 70 KIAS at higher density altitudes due to the lower acceleration.

Static rpm was adjusted to approximately 2,550 rpm. At sea level, engine speed reaches 2,700 rpm about 150' into the take-off roll. Two take-offs are shown at sea-level and one at high density altitude in figures 7 through 9.

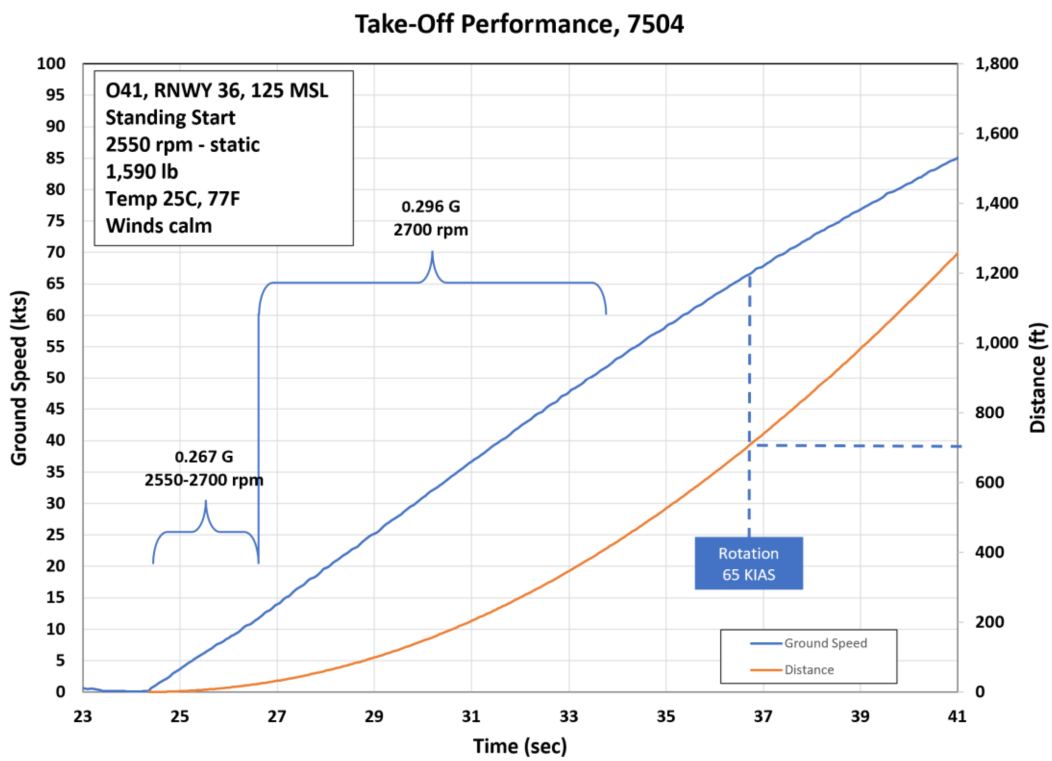

Figure 7, Take-Off at 125'MSL, Density Altitude 1,212'

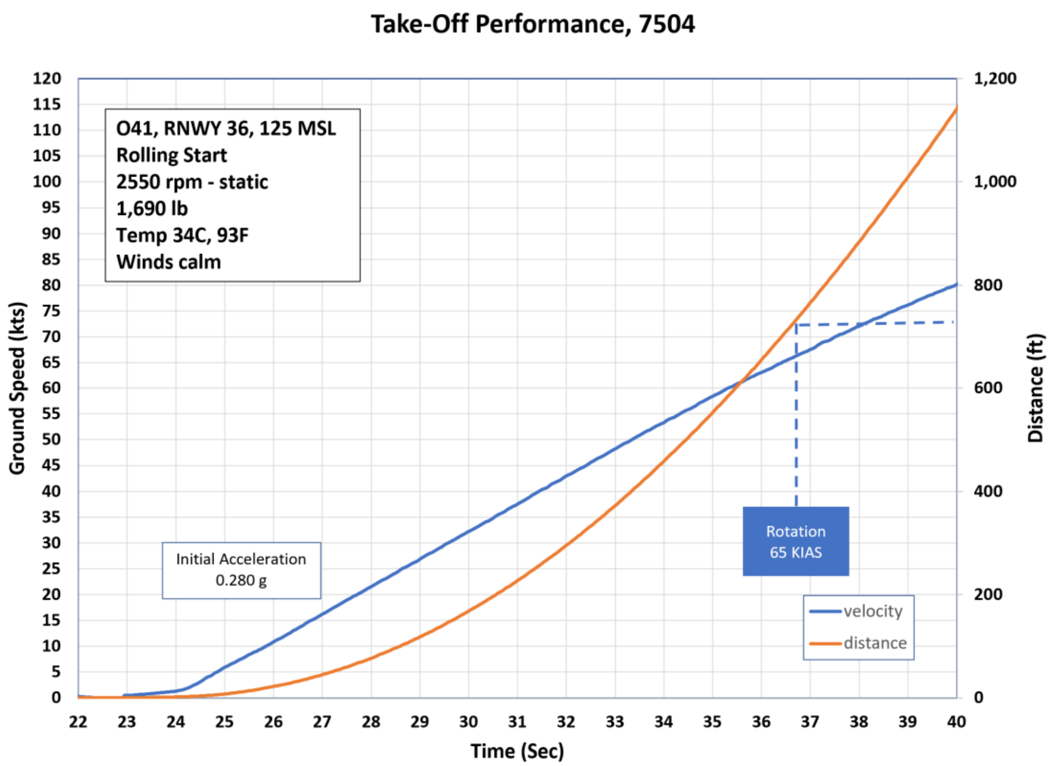

Figure 8, Take-Off at 125'MSL, Density Altitude 2,269'

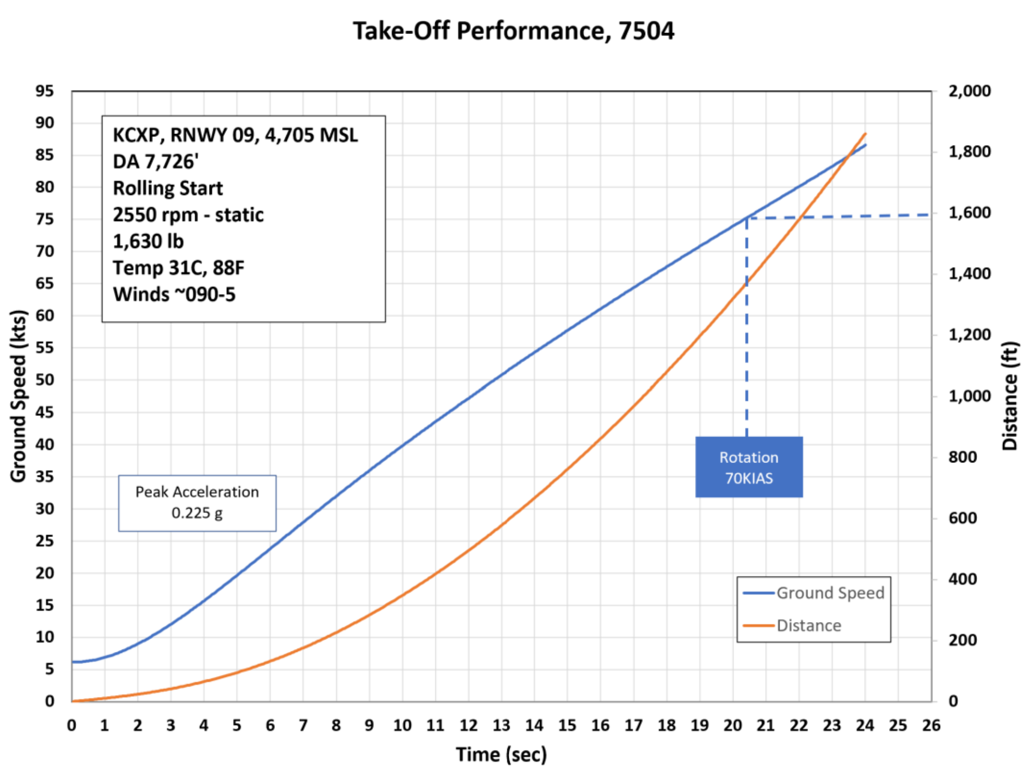

Figure 9, Take-Off at 4,705'MSL, Density Altitude 7,726'

4. Engine Starts and Ground Idle

The lower inertia of the 7504 blades is quite noticeable during engine starts and shut down. The 7504 blades accelerate much more quickly and generate much less of a reaction on the engine, i.e. engine movement is reduced. Despite the much lower inertia, the same low-end idle of 550 rpm was achieved when pulling the throttle all the way back to the idle stop set-screw. No qualitative difference in smoothness/roughness was noted between the 7068 and the 7504 blades at normal or extreme low idle.

5. Propeller Power-Off Drag

Landing Flare

Increased propeller drag was recorded in the flare between round-out and touch down. With the 7068 propeller, typical aircraft deceleration in the flare at sea level is 0.105g. With the 7504 propeller 0.115 to 0.125g was measured. This rate is likely to be a function of the idle pitch stop setting which was changed a few times during testing. The final setting of 2,550 rpm corresponds to 0.125g. A finer pitch setting would likely increase the braking effect further.

Power-Off Glide

Power-off glide was flown at two different weights to check minimum governable engine speed and propeller drag (Figure 10). Power was pulled to idle and the mixture was leaned to prevent back-firing but not pulled to cut-off. Based on prior testing, a roughly 10% increase in sink rate should be expected with a complete mixture cut-off.

During power-off glides in full course pitch, both propellers achieve the same engine speed and sink rate. 550 fpm has historically been the minimum with the 7068 propeller and the 7504 matched these results.

It should be noted that engine speed achieved via the governor is a significant driver in these results regardless of propeller model. If the governor control arm cannot be rotated up against the travel stop, the resulting engine speed will be higher and will adversely affect sink rate.

Maximum Descent Rate – Landing Configuration

The maximum descent rate in the power-off landing configuration was checked, that is, engine idle, landing gear down, and full flaps, fine pitch. These results are a function of the low pitch stop setting as the engine is being back-driven. The static rpm pitch stop was set at 2550 rpm during this test.

The typical approach speed in the Lancair 360 is 80 KIAS (1.3 Vso) and the maximum (full) flaps extended speed is 100 KIAS. At 80 KIAS both the 7068 and the 7504 propellers produce a sink rate of 1,500 fpm. Increasing speed to 100 KIAS produces 2,000 fpm with the 7068 and a slightly higher 2,200 fpm with the 7504 blades.

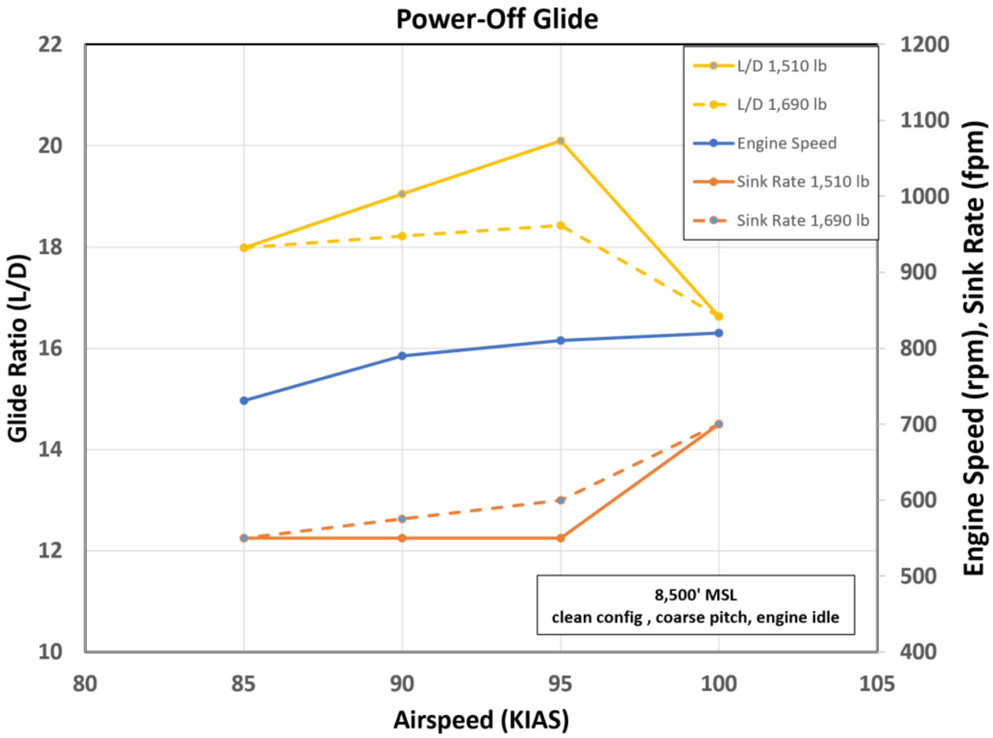

Figure 10, Power-Off Glide

6. Dynamic Balance

Both propellers were dynamically balanced using a DynaVibe propeller balancer. The 7504 propeller was balanced to 0.01 IPS and the 7068 achieved 0.00 IPS (0.01 IPS resolution).

7. Conclusion

The composite 7504 propeller blades demonstrated performance improvements with the Lancair 360. Performance gains were achieved in cruise with a 1 to 2 knots increase in airspeed. The absence of operating limitations improved climb rates at high altitude by 33%. Operational efficiency gains in economy cruise can be achieved by the ability to govern this propeller to much lower engine speeds. Shorter landing distances are realized from slightly higher drag in fine pitch. Steeper 'short approach' descents are also possible. No differences in take-off performance were noted. Engine-out glide performance was also unchanged. The weight reduction of 20 lbs and associated reduction in inertia reduces the engine and airframe reactions during engine start and shut down.