EDUCATION RECREATION EAA HOMEBUILDERS

Climb Test Procedures - In-flight data collection

Sport Aviation - 10/00
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In September's "Test Pilot" we laid the foundation for climb performance testing. We related climb rate to excess power and showed that the maximum excess power occurs at an airspeed (VX) that is neither the maximum power-available nor the minimum power-required airspeed. Climb angle, however, depends on excess thrust, and we showed that the maximum excess thrust airspeed (VY) is neither the maximum thrust-available nor the minimum thrust-required airspeed. And we even included a little thrust and power equation manipulation as a convincer.

Now that you know where we want to go with climb performance testing, it's time to discuss the flight test procedures that give the data you'll need to create your airplane's climb charts. Aviation uses several climb testing techniques, but we'll stick with just one for simplicity and because it provides fuel consumption rates representative of your actual climb profiles.

The modified check climb procedure is straightforward. Climb while holding a constant indicated airspeed and measure the time it takes to climb through several altitude blocks, i.e., from 1,250 to 1,750 feet and from 3,250 to 3,750 feet, etc. Continue the climb through the highest altitude for which you want to know your plane's climb performance.

Repeat the test using different airspeeds. From the data you gather, you can determine which airspeed produces the best climb rate and what that rate is for each altitude block. From here it's just a matter of data reduction to apply your results to all altitudes.

Climb Test Procedure

Load the airplane (weight and center of gravity) to represent the way you'll load it for normal flying. This may be maximum gross weight, half fuel with only the pilot aboard, or whatever loading you find useful. Record this information.

Take off and, when ready to begin the test, set the altimeter to 29.92. This allows you to record the pressure altitude during the test, which you'll use with outside air temperature (OAT) to determine density altitude. Your finished climb performance charts will be based on density altitude, which allows you to use them anytime, anywhere. If the charts are not based on density altitude, they will give you accurate performance information when the barometric and temperature conditions exactly match the test day.

Fly your airplane a couple of hundred feet below the bottom of the lowest altitude block. Use good judgment here; your lowest block should be at least 1,000 feet above ground level (AGL) over reasonably flat and obstruction-free terrain.

Establish the climb airspeed in level flight and choose an airspeed close to the predicted VY airspeed for your first test. Eventually, you'll fly a range of airspeeds, but prudent flight testing generally starts in the middle of the flight envelope-the climb speed envelope in this case.

After you've stabilized your airplane in this level-flight condition, advance the throttle and raise the nose to maintain the test airspeed until you are stabilized in a climb at full power (or climb power or maximum continuous power and rpm, if appropriate) at the test airspeed. Then trim the airplane.

This careful setup establishes the airplane in a stabilized climb before you record any data. The engine should be stabilized at the selected setting. Your pitch attitude should be stabilized to hold the test airspeed. Trimming usually isn't an essential requirement for data accuracy, but trimming it for hands-free flight generally makes the profile easier to fly.

If you're not stabilized as you climb through the bottom of the first altitude block, reduce power, descend, and set up again. You may want to begin lower to give yourself more time to stabilize the airplane on the test condition before reaching the bottom of the first block.

With the plane stabilized, when you reach the bottom of the first altitude block note the time or start a stopwatch. Hold the airspeed constant through the altitude block and note the time or stop the stopwatch when you reach the top of the block. Record the time (in seconds), altitude block, and any other data you think useful.

Figure 1 is a sample data grid, and it contains a few extra columns because we'll use it next month for our data reduction. Fill in the Test Data columns during your test flight; you complete the Calculated columns during your post-flight data reduction.

Customize your flight test data cards so they are easy to use during your flight. For example, you won't make any calculations during your flight, so you can eliminate Calculated columns from your data card grid. If you do, you'll need another data reduction grid, like **Figure 1**, for your post-flight calculations.

Continue climbing and repeat the procedure for every altitude block through the highest block you're interested in. As you climb through higher altitude blocks you'll probably have to lower your plane's nose to maintain the same indicated airspeed. It's okay to re-trim the airplane between blocks as you set up for the next block.

After you complete your series of tests through the altitude blocks, relax. Make a 180-degree turn and descend. On the way down, fly level at the midpoint of each test block long enough for the OAT to stabilize and record it.

During the climb some OAT gauges are too slow to react to the rapidly changing temperature, particularly if you're flying a high-performance machine with an eye-watering climb rate. If you're confident the OAT gauge will give you accurate temperatures during the climb, there's no need to record them during the descent. Don't forget to reset your altimeter to the proper field barometric pressure before entering the landing pattern.

At this point you'll probably want to land and review your data, which should show longer times for higher altitude blocks and a reasonable temperature lapse rate. You now have one airspeed mapped. Reload the airplane to the same condition it was before this flight and repeat the climb test at a different airspeed. Reload again and fly another different airspeed. Continue the process until you fly a range of airspeeds, from slightly slower than your expected VX to slightly faster than your anticipated cruise-climb airspeed.

By The Numbers

1. Load your airplane for the climb test weight and balance.
2. Take off and set 29.92 in the altimeter.
3. Establish the climb test condition before climbing through the bottom of the first altitude block. Engine, pitch attitude, airspeed, and trim should be stabilized.
4. Record the time it takes to climb through the altitude block.
5. Continue climbing toward the next altitude block; adjust the pitch attitude and re-trim if necessary to maintain the test airspeed.
6. Repeat Steps 4 and 5 for all planned altitude blocks.
7. Descend on a reciprocal heading, pausing in the middle of each test altitude block long enough to record the stabilized OAT, if necessary.
8. Land (Don't forget to reset your altimeter!), review your data for reasonableness, reload your airplane, and repeat the climb test profile using a different airspeed.
9. Repeat the tests for each climb test airspeed.

Data Quality

The old computer adage-garbage in/garbage out-applies here. If you have any doubt about the quality of your data, repeat the test. Here are a few flight test guidelines.

Airspeed control. Some of these results are very sensitive to airspeed variations. Traditional climb flight test parameters limit airspeed excursions to a maximum of 1 knot. This may sound unrealistic, but any pilot can achieve it with some practice and a diligent trim effort.

Smoothness counts. Keeping your airspeed ±1 knot at the expense of large or abrupt flight control deflections contaminates your data. Every time you move a flight control, you change the airplane's drag. The bigger and faster the surface movement, the greater the drag change. Some small adjustments are expected, and it's okay to make these adjustments within the test altitude block, but make them smoothly.

Turbulence. Fly your test early in the morning or just before dusk to avoid the thermal turbulence of midday. In a small airplane, it only takes one bump to invalidate your airspeed or control deflection tolerance. Avoid flying near rapidly changing terrain that may produce thermal variations or updrafts/ downdrafts. You shouldn't be anywhere near clouds.

Wind. A dead-calm day is best, but not very realistic. Fly your climbs perpendicular to the wind to avoid any shear effects or transient airspeed indications.

Pitch attitude reference. As good as some artificial horizons are, their indications are generally too coarse for the fine airspeed control required. Perform the test on a clear day with a distinct horizon and use the horizon to maintain the proper pitch attitude for the climb. A grease pencil mark on the windscreen or side window may help you detect and correct tiny pitch changes before they affect the airspeed.

Straight climb. Perform the entire test on a reasonably constant heading. Substantial turns even between altitude blocks will affect fuel consumption and airplane weight.

Altitude block height. Accurately timing through a 100-foot altitude block will be difficult in an airplane with a 2,000 fpm climb rate. On the other hand, remaining within tolerance through a 1,000-foot block in an airplane with a 300 fpm climb rate can also be difficult. Choose block heights that make sense for your airplane.

Make the block tall enough that a one or two second timing error won't make a substantial difference in the average rate of climb through the block. Make the block short enough so that there isn't an appreciable difference in climb rate from the bottom to the top of the block. It's okay to have taller blocks at lower altitudes where the climb rate is better and to have shorter blocks at the higher altitudes because you'll be calculating average climb rates for each block.

Take a break. It is not necessary to maintain the precise test airspeed between altitude blocks. You record no data here, so relax until you approach the bottom of the next block. Don't let the airspeed stray too far from the target speed, or you'll just have to work that much harder to reestablish the stabilized condition.

Don't trust the VSI. Feel free to record the VSI reading within the test block, but use it for correlation with your timed data only. Most VSIs are just too inaccurate for this test.

Leaning. Lean your engine as you would for normal climbs. Leaning between altitude blocks may be preferable to leaning the mixture while in the test block, which complicates your test and might contaminate your data. Be as repeatable as possible with your leaning schedule; lean the same way for every climb test flight. The same goes for cowl flaps and any other adjustment peculiar to your airplane that can affect climb performance.

Subjective assessment. Even if you've flown the test profile within the limits, you may want to make a qualitative comment about the test. You'll know whether you really nailed the point, right on airspeed, pitch attitude set in granite, perfect timing, or whether you pushed the limits with airspeed going from 1 knot fast to 1 knot slow four times during the block, constantly searching for the exact pitch attitude, etc. Making such a note on your data card can help explain a wayward data point later. You should also be alert for changes in climb rate within each altitude test block. If climb rate decreases noticeably within the block, the block height is too large. Repeat the test using a smaller, more appropriate altitude block height.

But Wait, There's More

You've already done a lot of flying to map your airplane's climb performance, but so far you've tested just one weight, center of gravity, and external configuration. You can perform these tests for a variety of airplane loadings and configurations if you'll find that information useful later on. You can test at the maximum and minimum anticipated weights and then interpolate them for intermediate weights. Or you may include an intermediate weight in your testing.

In theory the center of gravity's location can affect climb performance because it affects the airplane's trim drag. In reality, this influence is generally minimal enough to ignore for most homebuilt airplanes. Open canopies, cowl flaps, and cooling vent scoops affect the airplane's drag. While you can test every conceivable combination, you probably want to spend your flying time differently. Perhaps testing the worst-case combination of weight, center of gravity, and external configuration might be good enough, figuring you'll realize better performance for all other cases. At least this way your planning will be conservative.

Safety is the final, emphatic point. The tests described require a diligent instrument scan and potentially prolonged nose-high pitch attitudes. Both affect your ability to see and avoid. Be careful. Don't perform these tests on a gorgeous Saturday morning near a busy airport. Consider lowering the nose or performing a belly check between altitude blocks. Keep an eye on your engine. Low-speed climbs at full power tax the engine and inhibit cooling. Remember to fly the airplane first-collect data second.

Now that you have all these climb test data, you'll have to turn them into meaningful flight planning information. That's where we'll pick up our climb performance testing next month. We'll convert your raw or test-day data into charts you can use to predict your plane's maximum climb rate and maximum climb rate airspeed. We'll also show how you can use these charts for cruise climb rate and speed so you can begin planning your trip to AirVenture 2001.

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