

Forward Center of Gravity Limit

by David F. Rogers

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All of us who fly know that you must be careful not to load the aircraft so that the center of gravity (CG) is behind the aft CG limit. Furthermore, if the fuel tanks are located forward of the typical CG, for example as in a Bonanza, the CG will move aft as fuel is burned. Consequently, we need to calculate the CG not only for the take-off condition but also for the landing condition - you do don't you? We really should also calculate it for the no fuel condition in case we have to divert from our intended landing site. But, have you ever thought about why a forward center of gravity limit is specified? What will happen if the CG is ahead of the forward CG limit? Is it possible to load the aircraft such that the CG is ahead of the forward CG limit?

The forward CG limit is determined by control forces, control force gradients and available control deflections.

The forward CG limit is usually determined by one of the following considerations:

The stick force shall not exceed a specified value.

If you don't have a trim tab or it doesn't work or is stuck, what force is necessary to trim the aircraft at the desired speed? Here, Part 23 (23.143) of the FARs specifies that for prolonged application the stick force shall not exceed 10 pounds. For short durations, using a yoke, Part 23 specifies that, using one hand, stick force shall not exceed 50 pounds and with two hands 75 pounds.

Now ten pounds does not seem like much. But, for one experiment in the flight test engineering course I had to hold up to 22 pounds for up to three minutes while holding speed within plus or minus one knot and do it for eight different speeds during a single flight. Not only does that take lots of concentration it is also rather fatiguing!

The stick force gradient at trim shall not exceed some specified value.

What's a control force gradient? Assume that the aircraft is trimmed up, then a control force gradient is the force necessary to move the aircraft from that trimmed condition. For example, you are trimmed for the approach and you want to change the speed, what force does it take to change the speed by a certain amount, say one knot? That is the control force gradient. If this value is too large, you can not maneuver the aircraft.

The stick force per g shall not exceed a specified value.

The stick force per g is a measure of the ability to execute a pull up. Again, this is associated with your ability to maneuver the aircraft.

With the aircraft trimmed for the approach, the stick force to land shall not exceed a specified value.

If this force is too large, you will not be able to flair the aircraft to, or nearly to, stall velocity and hence achieve the minimum landing speed. You might also land in a flat attitude or even nose wheel first. Not good.

The elevator angle required to land, i.e., stall, or nearly stall, the aircraft near the ground, shall not exceed the maximum available up elevator. Again you might land in a flat attitude or wheelbarrow. Again, not good.

Can you load an aircraft so that the CG is ahead of the forward limit? Yes. For an E33A model Bonanza, if, with full fuel, empty rear seats and nothing in the baggage compartment, the aircraft is loaded with more than 425 pounds in the front seats, then the CG is ahead of the forward CG limit. Of course, because the Bonanza's fuel tanks are ahead of the typical CG, as fuel is burned the CG moves aft and may very well bring the CG back inside the permissible CG envelop. But, what about take-off or an emergency right after take-off?

Fly knowledgeable.