Zero Elevator Angle

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When the elevator is aligned with the fixed part of the horizontal stabilizer that is called the zero elevator angle. If the elevator is deflected trailing edge up the elevator angle, δ_e is negative. Why negative? Well, because when the elevator is deflected trailing edge up, the angle of attack of the wing increases. Alternatively, one can argue that the aircraft pitches positively about the lateral axis which extends from the center of gravity positive out the right wing.

First, let's mark the zero elevator angle and note the zero trim tab angle. Either have a colleague help you or make up a simple jig to hold the ruddervator or elevator carefully aligned with the fixed part of the horizontal stabilizer. A couple of $1\,{}^1\!/_2$ by 30 to 36 inch plywood boards are useful in getting the alignment right. With the colleague, or jig, holding the ruddervator or elevator in position, sit in the cockpit and mark the position where the column exits the avionics panel (red arrow). The result is shown in the nearby photo (black arrow). I used a black Sharpe marker. Obviously, in the photo, the column is pulled aft of where the mark was made for illustrative purposes. You now have a permanent gauge for the zero elevator setting. This is the correct elevator position for takeoff.

Second, while you are in the cockpit, move the trim wheel until your collegue indicates that the trailing edge of the trim tab aligns with the ruddervator or elevator trailing edge. Make a mental note of the reading, or, from your normal seated position, use the Sharpe to make a small mark on the trim wheel cover that aligns with a known number, say zero, on the trim indicator. This is the zero tab deflection angle. Why is this important?

There are basically two sources of resistance or drag during the takeoff run: rolling friction and aerodynamic drag. Rolling friction is most important during the initial portion, while aerodyanamic drag is most important during the latter stages of the takeoff..

Rolling friction is directly related to weight, tire pressure and the runway surface. The more weight on the wheels, the more rolling friction. Up to a point, the higher the tire pressure the less rolling friction; but there is a trade off with tire strength, hydroplaning and whether the tire will fit in the wheel well—use the POH recommended pressures. Obviously high wet grass has higher rolling friction than smooth concrete or asphalt. Aerodynamic drag is, as always, a combination of parasite and induced drag. Minimizing drag and hence maximizing acceleration requires a trade off between rolling friction and aerodynamic drag. More wing lift reduces rolling friction because it decreases the weight on the wheels. Unfortunately, it also increases induced drag.

Elevator deflection produces both increased parasite and induced drag, as does trim tab deflection. However, trim tab deflections produce much smaller drag increases than elevator deflections. Consequently, zero elevator deflection is desired but the trim tab should be set to give the speed for climb out. Use the POH recommended values for the trim tab. They are different for different loadings, e.g., front seats only occupied or front and rear seats occupied.

At this point you might be wondering how the designer controls the wing lift if the elevator deflection is zero during the take off ground run. To see this, take a good look at the attitude of a Bonanza on the ramp *when the main and nose gear struts are properly inflated.* Taking into account that the wing is set with the root chord at 3° angle of attack with respect to the wing zero lift line, the main and nose wheel struts provide an appropriate wing angle of attack during the take off run. Use the recommeded values from the POH or maintenence manual. If you over-inflate the nose gear strut, then the wing angle of attack will be too large during the ground run. The result is a longer take off ground run because of the increased induced drag. If you don't hold the yoke at the zero elevator deflection angle but allow the down springs to hold the yoke forward, there is more weight on the nose wheel, a reduction in the wing angle of attack which decreases the wing lift and puts more weight on the wheels all of which result in more rolling friction and a longer ground run. Little things make a difference.

If you mark the zero elevator deflection position, set the trim tab according to the book, set the strut inflation according to the book, and use the correct rotation speed for the weight then, little tug on the yoke will have the aircraft flying.

Incidentally, do you know the recommended elevator trim settings for your aircraft? For an E33A if only the front seats are occupied the trim setting is 3° nose up while if the rear seats are also occuppied the elevator trim setting is 0°. Also, do you know the trim speed for these settings? With only the front seats occupied an elevator trim setting of 3° nose up gives a trim speed of approximately 100 KIAS for an E33A with full fuel and just the pilot aboard. One hundred knots is close to the the speed for maximun rate of climb!

What else will marking the zero elevator and zero trim tab give you?

All aircraft have a design point or mission. The Bonanza design mission is high speed cruise. In order to reduce the trim drag that results from a deflected elevator, the designer positions the horizontal stabilizer incidence angle such that no elevator deflection nor any trim tab deflection is required at the design condition, i.e, cruise. Therefore, for typical cruise conditions, say 6–9000 ft. at a true airspeed (TAS) of 160–175 KTAS, the trim tab should read at or close to zero and the elevator should be at or close to the zero elevator mark. On a typical Bonanza the horizontal stabilizer in set on the aircraft at 2° leading edge *down* with respect to the wing zero lift line. For typical cruise conditions the resulting down force on the horizontal tail balances the aircraft about the center of gravity.

It is also a good idea to position the elevator at the zero deflection setting during run-up to reduce the forces on the tail as well as the rest of the airframe. There is some data that suggests that either holding the yoke full aft or allowing the down springs to position the elevator full trailing edge down results in additional stress on the wing main spar.

Another useful exercise is to mark the control position for the speed for a standard instrument approach, say an ILS or GPS LNAV+V or LPV.

Finally, the zero elevator and trim tab marks represent a known flight angle of attack, and hence speed, in the event of instrument failure. Depending on the power available you will be either climbing, in level flight, or descending at that angle of attack.

Note: the elevator deflection angle determines the angle of attack. Speed will vary with weight and density altitude.