On the ’Wing… #124

Adding a “plank” center section to a swept ’wing

Several readers of this column have recently contacted us concerning the addition of a “plank” center section to a swept ’wing. In one case, the modification had already been accomplished, and the builder was lamenting the loss of roll response and wondering why it felt tail heavy in flight. Another correspondent was wondering about the change in location of the neutral point, as he was attempting to determine the new center of gravity. Such questions usually generate another “On the ’Wing…” column, and this time was no exception.

Let’s take the case of the second correspondent first. “How does the addition of a plank center section affect the neutral point?” Simply put, the neutral point moves forward in proportion to the span of the additional constant chord panel. That is, the greater the span of the new panel, the further forward the neutral point will be.

Figure 1 depicts the original swept wing configuration. For simplicity, we chose a swept wing with a chord of ten units and a tip chord of five units. The leading edge is swept back ten units, and the half-span is 20 units. To determine the neutral point, we used a method described by Richard Moran in the March 1994 issue of *RC Soaring Digest*. Using this method, the neutral point is found to be at 6.12 units from the apex of the leading edge. (Remember, the center of gravity (CG) is always placed in front of this point.)

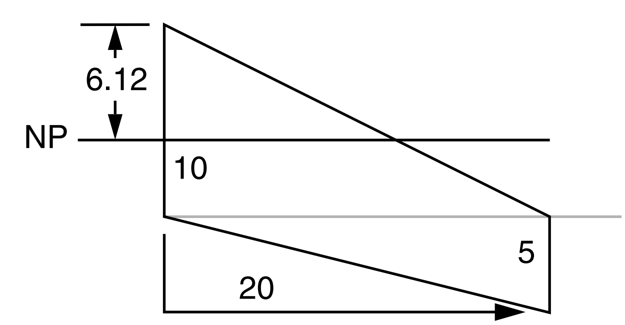


Figure 1

Figure 2 shows the plank center section which will be added to the swept wing planform described above. The semi-span of this segment is denoted by V. Because the chord is constant, the neutral point will be at 25% of the chord, 2.5 units behind the leading edge, no matter the span.

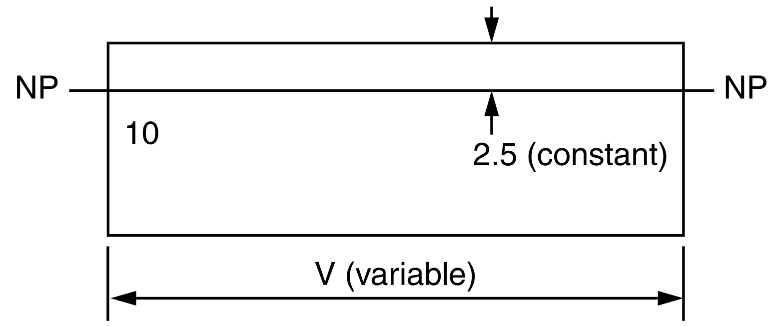


Figure 2

The composite aircraft is shown in Figure 3. Note the original swept portion of the wing remains constant, as does the chord of the center section. To reiterate, the neutral point of the swept section is 6.12 units from the apex of the leading edge; the neutral point of the constant chord center section is 2.5 units from the leading edge.

In computing the neutral point, we find the relationship between the span of the center section and the distance of the neutral point from the leading edge is not directly proportional. Table 1 shows that as the added center section span is increased, the neutral point moves forward, as expected. But a graph depicting the relationship between V and X_{NP}, the two variables, shows a slightly non-linear relationship. See Graph 1.

Why would such a composite planform, once constructed, feel tail heavy during flight? Probably because it IS tail heavy! In the example case shown here, the addition of a center section of 40 units in span (20 units semi-span) dictates

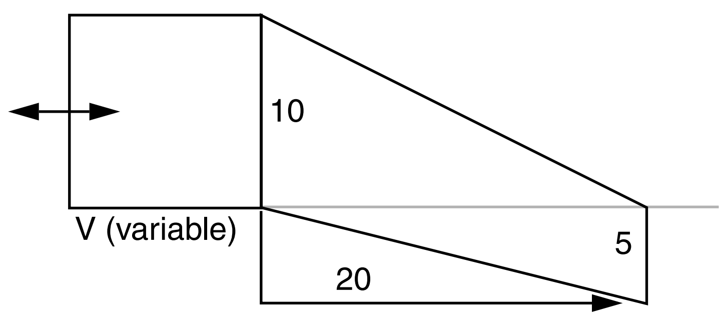
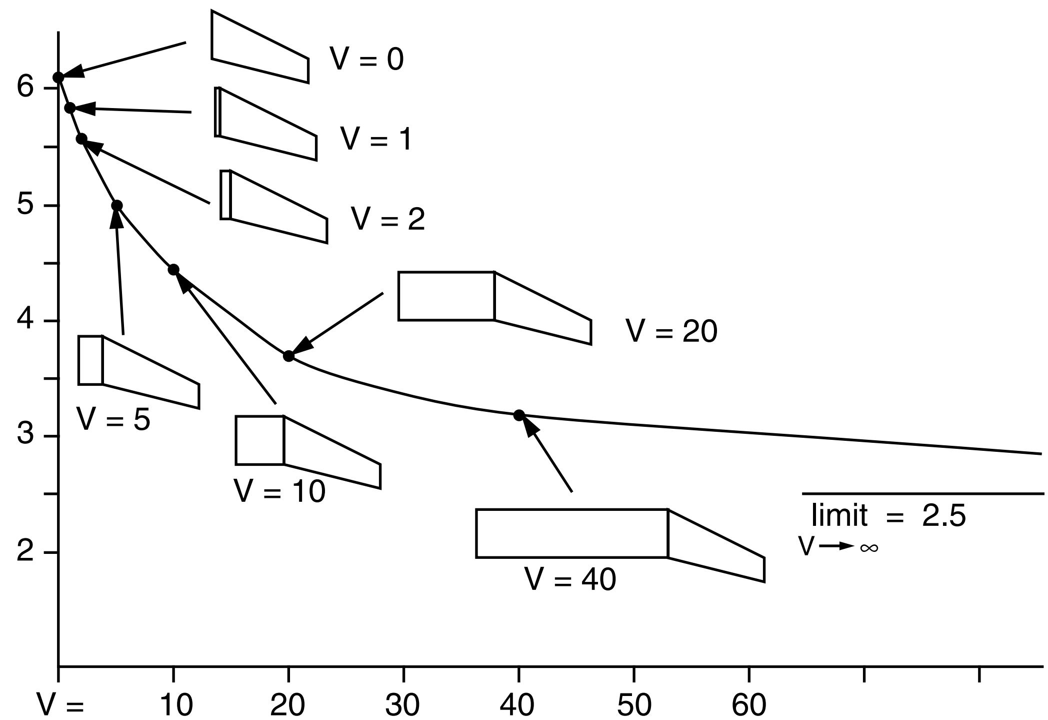


Figure 3

TABLE 1: COMPUTATION OF NEUTRAL POINT FOR DEFINED COMPOSITE AIRCRAFT

V	plank area, A2	A1 + A2	$Z = \frac{A1 + A2}{4}$	$X^2 + VX - Z = 0$	$X_{NP} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	X_{NP}
0	0	150	37.5	$X^2 + 0 - 37.5 = 0$	$X_{NP} = \frac{-0 \pm \sqrt{0-4(-37.5}}{2}$	6.12
1	10	160	40	$X^2 + X - 40 = 0$	$X_{NP} = \frac{-1 \pm \sqrt{1-4(-40)}}{2}$	5.84
2	20	170	42.5	$X^2 + 2X - 42.5 = 0$	$X_{NP} = \frac{-2 \pm \sqrt{4-4(-42.5)}}{2}$	5.59
5	50	200	50	$X^2 + 5X - 50 = 0$	$X_{NP} = \frac{-5 \pm \sqrt{25-4(-50)}}{2}$	5.0
10	100	250	62.5	$X^2 + 10X - 62.5 = 0$	$X_{NP} = \frac{-10 \pm \sqrt{100-4(62.5)}}{2}$	4.35
20	200	350	87.5	$X^2 + 20X - 87.5 = 0$	$X_{NP} = \frac{-20 \pm \sqrt{400-4(-87.5}}{2}$	3.69
40	400	550	137.5	$X^2 + 40X - 137.5 = 0$	$X_{NP} = \frac{-40 \pm \sqrt{1600-4(137.5)}}{2}$	3.18
∞	—	—	—	—	—	2.5

NOTE: V is the semi-span of the added “plank” center section. The area of the swept portion is 150 square units and constant; the area of the added plank section is A2. Z is the wing area which lies in front of the neutral point. The quadratic equation defines Z in terms of a segment of the swept portion and a segment of the plank portion.



Graph 1

that the neutral point will need to be moved forward from 6.12 to 3.69 units aft of the leading edge apex. This is nearly 2.5 units! Since the added section has a constant chord, the volume of the composite aircraft is more than doubled as well. Little wonder so much weight is required to place the CG in front of the neutral point.

Finally, why is the composite aircraft relatively non-responsive in roll? There are three reasons which come immediately to mind:

Inertia - The lengthened span has more inertia than before the modification. This tends to prevent the roll motion from starting, and, once started, from stopping. The inertia for the entire wing will grow at an exponential rate if the mass of the wing is distributed evenly along the span. While this is not true for the given example because of the swept and tapered outer panel, it does provide some idea of what may be expected as the wing span increases.

Sensitivity - Since the elevons are now further outboard, away from the center of gravity, the aircraft is less sensitive to control surface deflections. Aerodynamic control surfaces are in control terminology velocity control devices. That is, the velocity of the surface to which they are attached (in a direction perpendicular to the free stream velocity) is proportional to their deflection. As the distance of the surface from the CG is increased, the control sensitivity is reduced in inverse proportion. Thus “twice as far” equates to half as sensitive.

Roll damping - As soon as the rolling motion begins, the effective angle of attack changes. The change in effective angle of attack is different at various locations along the span. The greatest change takes place at the wing tip, where the rolling velocity is greatest, while at the center line there is no change at all. For the downgoing side, the effective angle of attack increases, increasing lift in the direction which is against the rolling motion. For the upgoing wing, the effective angle of attack decreases. The resulting negative lift is against the rolling motion as well. These changes in effective angle of attack damp the roll. Roll damping increases as the wing span is increased.

These three factors — inertia, sensitivity, and roll damping — create a situation where roll response deteriorates as span increases. Aileron area must be larger or deflection angles made greater in order to maintain control authority in roll.

So, is adding a constant chord center section to a swept wing design a good idea? Probably not. A better alternative is to take the same planform and simply make a bigger ’wing!

References:

Moran, Richard. Beyond the Mean Aerodynamic Chord. *RC Soaring Digest*, March 1994, pp. 44-49

Special thanks to “Pat,” Arthur Kresse, and Gregg MacPherson, members of the Nurflugel-l, an e-mail special interest group based at <http://www.nurflugel.com>, who made suggestions and provided helpful information concerning inertia, sensitivity, and roll damping.