

## Wing Taper Considerations

Tapering a wing planform gives a number of significant aerodynamic and structural advantages, but it can also cause problems if overdone. Consider three  $AR=10$  wings of the same span and area, but different taper ratios  $\lambda = c_{tip}/c_{root}$ . When operated at some overall lift coefficient  $C_L$ , these wings have the  $L'(y)$  and  $c_l(y)$  distributions shown in Figure 1.

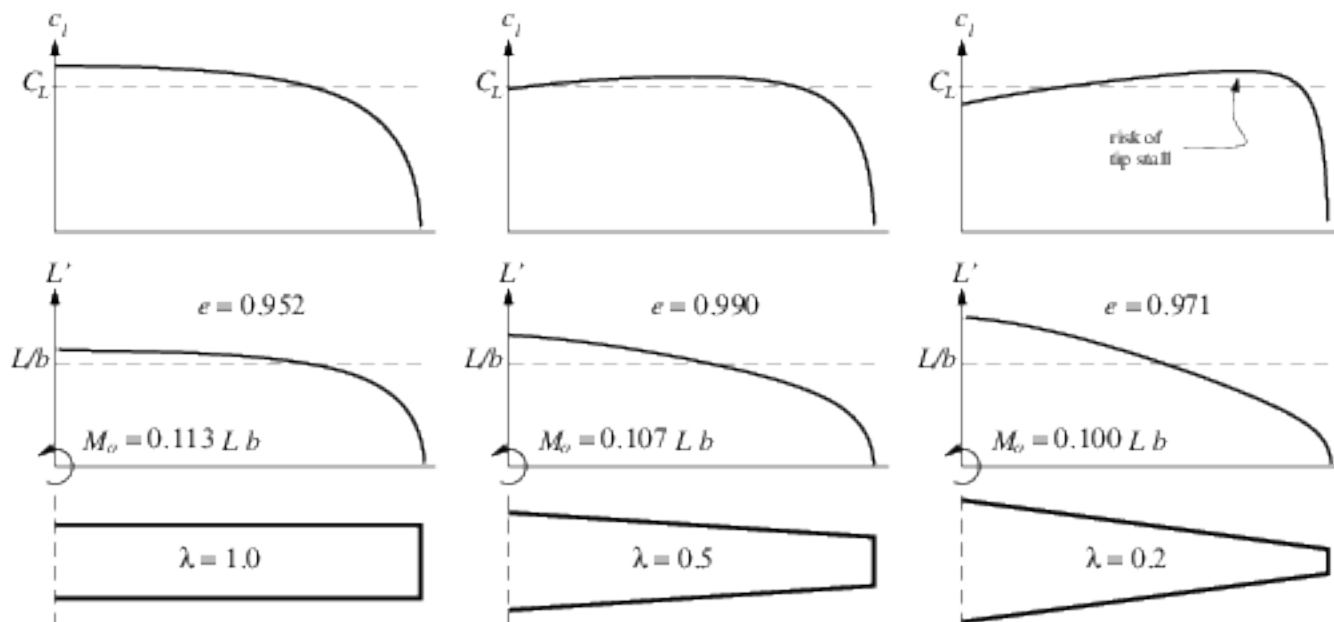


Figure 1: Load distributions, root bending moment, and span efficiency for three taper ratios. All three cases have  $AR=10$ , and no wing twist.

Of the three wings, the most strongly tapered  $\lambda = 0.2$  wing will have by far the smallest tip deflection ratio  $\delta/b$ . This is mostly due to its larger root chord giving a greater local stiffness, although its smaller root bending moment factor of 0.100 also contributes. Such inherent stiffness allows the strongly tapered wing to have a larger span than the others, giving it a potentially lower induced drag.

One drawback of strong taper is that it causes the local  $c_l$  to have a maximum near the tip, giving the possibility of tip stall during flight. When one wingtip stalls before the rest of the wing, the loss of lift at that tip can give a sudden unexpected roll of the aircraft. This is potentially dangerous when it happens near the ground. In contrast, stall on the untapered wing occurs first at the center, which will not cause a roll control upset. Another drawback of strong taper is that it gives small chord Reynolds numbers near the tips. This will reduce the maximum  $c_l$  that the tips can achieve, and aggravate the tip stall problem even more.

Tip stall problems on a strongly tapered wing can be partially alleviated through the use of washout. But if not done correctly, this can distort the  $L'(y)$  load distribution and increase the induced drag (decrease  $e$ ). Washout also causes problems at high speed where the overall  $\alpha$  is decreased. The local  $\alpha + \alpha_{aero}(y)$  at the tips can then become negative, giving a negative local  $c_l(y)$  and large local  $c_d(y)$ .

Picking a suitable wing taper clearly involves tradeoffs. The main tradeoffs are between structural merit and adequate resistance to tip stall. Washout twist is another variable which may or may not be useful to consider.