Design Variable Concepts

4 Mar 06

Lab 4 Lecture Notes — Addendum

Alternative Objectives

Frequently, an engineering design problem will involve competing objectives. For example, an alternative objective to minimize flight power (or maximize duration), is to maximize the maximum-attainable flight speed. The level-flight power relations still apply to this flight condition, but now the power is a known quantity, and equal to the maximum available power onboard.

$$\eta_p \, \eta_m \, P_{\max} \;=\; \frac{1}{2}\rho \, V_{\max}^3 \, S \left[\frac{CDA_0}{S} \;+\; c_d(C_{L_{\min}}; Re_{\max}) \;+\; \frac{C_{L_{\min}}^2}{\pi \, e AR} \right] \tag{1}$$

$$\text{where} \quad C_{L_{\min}} \;=\; \frac{2W/S}{\rho \, V_{\max}^2}$$

This can be solved for $V_{\max}$, or equivalently $C_{L_{\min}}$, by numerical means if necessary. If one can assume that at $V_{\max}$ the induced drag is negligible, and c_d is some constant, then we have

$$V_{\max}(AR, S) \;\simeq\; \left[\frac{2 \, \eta_p \, \eta_m \, P_{\max}}{\rho \, (CDA_0 + S \, c_d)} \right]^{1/3} \tag{2}$$

which is a suitable alternative objective function.

The figure shows the isolines of $V_{\max}$ versus the design variables, calculated using (1). The slight upturn in the isolines for decreasing AR is the Re effect in c_d. The sharp downturn near $AR = 0$ is due to the induced drag term. Isolines computed using the approximation (2) would be level.

Now the stiffness-constrained optimum results in an unreasonably small wing, which means that other more practical constraints are likely to come into play.

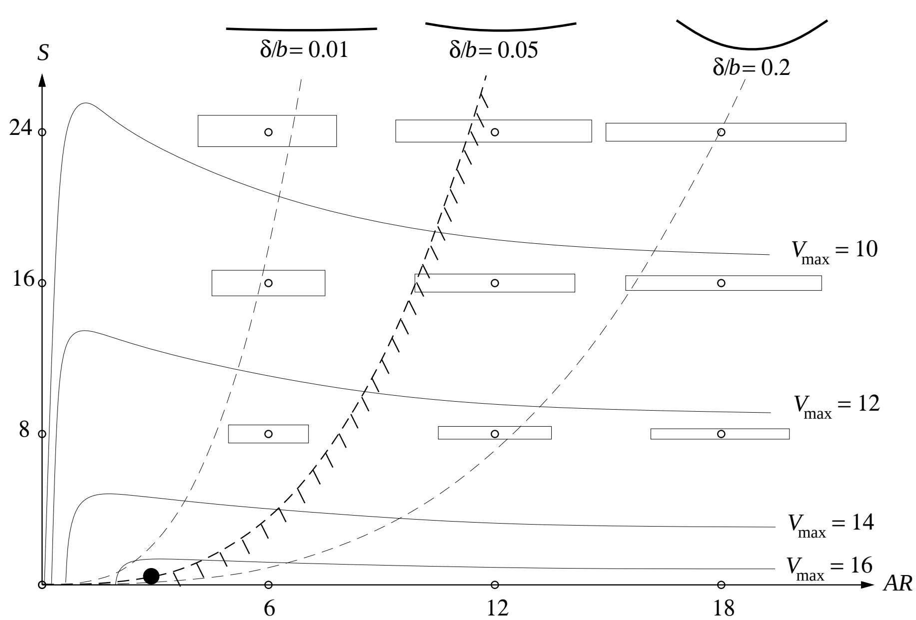

Figure 1: Objective function contours (isolines) in design space of a rectangular wing. Dot shows the stiffness-constrained optimum point.