Design Performance of single engined propeller aircraft

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Based on Bureau of Aeronautics Report 192 Diehl, except as noted. (numbers) are equations from that paper. Single number results are in turquoise, inputs in green. No claims this is accurate, just interesting.

US customary units throughout except as noted.

$Engine\_BHP := 180$

$W := 2400$ MTOW lb

$Wfuel := 362$

$PropRPM := 2700$

$V := 130$

$L\_over\_D\_max := 10$

$S := 160$

$CLmax := 1.33$

$CR := 8.5$ Compression ratio of engine

$$\frac{Engine\_BHP}{V} = 1.38$$

$$\frac{Engine\_BHP}{S} = 1.12$$

$$\frac{W}{S} = 15$$

$$sfc := (.75 - .04 \cdot CR) \cdot 1.25$$

BoA TR234 (11) sfc of engine, corrected for modern fuel?

$$D := \left[\left(\frac{90000}{PropRPM}\right)^2 \cdot \frac{Engine\_BHP}{V}\right]^{.25}$$

$$D \cdot 12 = 75.15$$

(1) prop diameter in inches

$$\eta2max := .94 - \frac{.11}{\left(\frac{\frac{V}{60} \cdot 3 \cdot 1760}{PropRPM \cdot D}\right)}$$

(3) max efficiency of a 2 bladed prop of that diameter

$$\eta2max = 0.78$$

$$Vs := 19.8 \cdot \sqrt{\frac{W}{CLmax \cdot S}}$$

(6) Stalling speed mph at sea level

$$Vs = 66.49$$

$$Vmax := \frac{20.3 \cdot \eta2max^{\frac{1}{3}} \cdot Vs}{\left[\left(\frac{Vs \cdot W}{Engine\_BHP}\right)^{\frac{1}{3}}\right]}$$

(5) max speed at sea level mph

$$Vmax = 129.2$$

$$C := 33000 \cdot \left[\frac{\eta2max \cdot \left(\frac{Vmax}{Vs}\right)^{-.27}}{\left(\frac{W}{Engine\_BHP}\right)} - \left(\frac{2 \cdot Vs + Vmax}{1125 \cdot L\_over\_D\_max}\right)\right]$$

$C = 839.11$ (7) Climb rate at sea level fpm

The following bit is not in the paper, this is an alternative method to find the density of the air at maximum altitude, and then working out the altitude at which that density occurs. Engine power is proportional to density

$\rho0 := 1.225$ kg m-3

$$\rho min := \left[\frac{2\cdot\left(W\cdot\frac{9.81}{2.2}\right)^3\cdot\rho0^2}{\left[(\text{Engine BHP 747})^2\cdot\eta2max^2\cdot L\ over\ D\ max^2\cdot CLmax\cdot\left(S\cdot .305^2\right)\right]}\right]^{\frac{1}{3}}$$

$\rho min = 0.55$ kg m-3

$$Za := \text{ainterp}\left[\begin{pmatrix} .25 \\ .37 \\ .54 \\ .74 \\ 1 \end{pmatrix}, \begin{pmatrix} 40000 \\ 30000 \\ 20000 \\ 10000 \\ 0 \end{pmatrix}, \frac{\rho min}{\rho0}\right]$$

$Za = 2.47\cdot 10^4$

absolute max altitude in feet, this seems very high (admittedly for good reasons)

$$Zs := Za\cdot\left(\frac{C - 100}{C}\right)$$

(9) service ceiling again high

$Zs = 2.18\cdot 10^4$

$$T2A(z) := \begin{array}{l} \text{if } z \geq Za \\ \quad 1000 \\ \text{else} \\ \quad \frac{-Za}{C}\cdot\ln\left(\frac{Za - z}{Za}\right) \end{array}$$

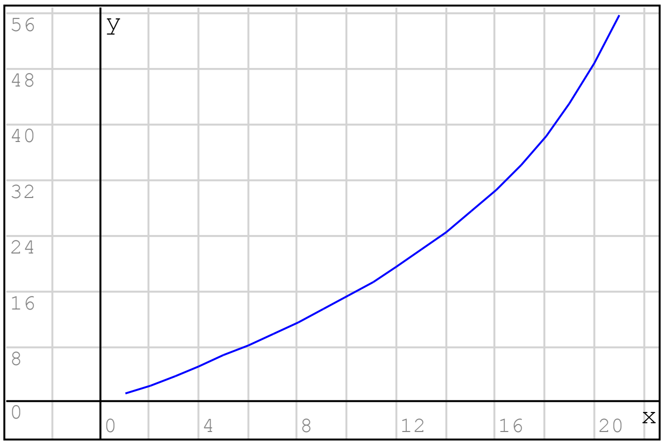
(11) Time in minutes to a given altitude

$T2A(2000) = 2.49$

for $k := 1, k < 22, k := k + 1$

$\quad Time2Alt_{k,1} := k$

$\quad Time2Alt_{k,2} := T2A(Time2Alt_{k,1}\cdot 1000)$



Time2Alt

Plot of time in minutes to reach a given altitude in thousands of feet

$$Vc := \frac{2 \cdot Vs + Vmax}{3}$$ $Vc = 87.4$

BoA TR173 Climbing speed mph

$$Vn(z) := \text{ainterp}\left(\begin{pmatrix} 0 \\ .25 \\ .5 \\ .75 \\ 1 \end{pmatrix}, \begin{pmatrix} 1 \\ .98 \\ .95 \\ .88 \\ .65 \end{pmatrix}, \frac{z}{Za}\right)$$

Fig 15

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for k := 1 , k < 22 , k := k + 1
  | VAlt[k,1] := k
  | VAlt[k,2] := Vn(VAlt[k,1] · 1000) · Vmax
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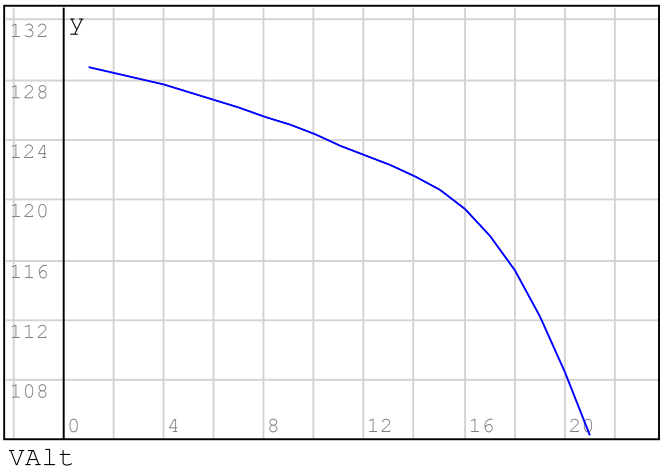

Max speed in mph vs altitude in thousands of feet

$$R := 862 \cdot \left(\frac{\eta2max}{sfc}\right) \cdot L\ over\ D\ max \cdot \log_{10}\left(\frac{W}{W - Wfuel}\right)$$

(12) Breguet range in miles

$R = 928.46$