

By Iteration determine bike speeds (Vg) given power generated (P) by the rider

$V_{g1} := 0 \cdot \text{mph}$ $V_{g2} := 0 \cdot \text{mph}$ $V_{g3} := 0 \cdot \text{mph}$ Initialize velocity for each position

Bike aerodynamic drag coefficient (Cd1) for the Typical Body Position

Given

$$P = \frac{1}{2} \cdot \rho_{\text{air}} \cdot C_{d1} \cdot A \cdot (V_{g1} + V_{\text{wind}})^2 \cdot V_{g1} + C_{RR} \cdot W_T \cdot V_{g1} + F_W \cdot V_{g1}^3 + W_T \cdot V_{g1} \cdot \sin(\text{atan}(\text{RoadGrade}))$$

$$V_{g1} := \text{Find}(V_{g1}) \quad V_{g1} = 17.319 \cdot \text{mph} \quad C_{d1} = 0.621$$

Bike aerodynamic drag coefficient (Cd2) for the Good Body Position

Given

$$P = \frac{1}{2} \cdot \rho_{\text{air}} \cdot C_{d2} \cdot A \cdot (V_{g2} + V_{\text{wind}})^2 \cdot V_{g2} + C_{RR} \cdot W_T \cdot V_{g2} + F_W \cdot V_{g2}^3 + W_T \cdot V_{g2} \cdot \sin(\text{atan}(\text{RoadGrade}))$$

$$V_{g2} := \text{Find}(V_{g2}) \quad V_{g2} = 17.838 \cdot \text{mph} \quad C_{d2} = 0.54$$

Bike aerodynamic drag coefficient (Cd3) for the Excellent Body Position

Given

$$P = \frac{1}{2} \cdot \rho_{\text{air}} \cdot C_{d3} \cdot A \cdot (V_{g3} + V_{\text{wind}})^2 \cdot V_{g3} + C_{RR} \cdot W_T \cdot V_{g3} + F_W \cdot V_{g3}^3 + W_T \cdot V_{g3} \cdot \sin(\text{atan}(\text{RoadGrade}))$$

$$V_{g3} := \text{Find}(V_{g3}) \quad V_{g3} = 18.439 \cdot \text{mph} \quad C_{d3} = 0.46$$

Bike aerodynamic drag coefficients (Cd) and the resulting bike ground velocities (Vg)

$C_d = \begin{bmatrix} 0.621 \\ 0.54 \\ 0.46 \end{bmatrix}$	$V_g = \begin{bmatrix} 17.319 \\ 17.838 \\ 18.439 \end{bmatrix} \text{mph}$	Aero body position Typical Good Excellent	$P = 225 \cdot \text{W}$
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$i := 1 \dots 3$

Air velocity relative to bike

$$V_{a_i} := V_{g_i} + V_{\text{wind}} \quad V_a = \begin{bmatrix} 17.319 \\ 17.838 \\ 18.439 \end{bmatrix} \text{mph}$$

Check Power Results for each aerodynamic drag coefficient and body position

$$P_i := \frac{1}{2} \cdot \rho_{\text{air}} \cdot C_{d_i} \cdot A \cdot (V_{g_i} + V_{\text{wind}})^2 \cdot V_{g_i} + C_{RR} \cdot W_T \cdot V_{g_i} + F_W \cdot (V_{g_i})^3 + W_T \cdot V_{g_i} \cdot \sin(\text{atan}(\text{RoadGrade}))$$

$$P = \begin{bmatrix} 225 \\ 225 \\ 225 \end{bmatrix} \cdot W$$

Power Components

Power required by bike and rider aerodynamic drag

Power required by wheel rolling resistance

$$\frac{1}{2} \cdot \rho_{\text{air}} \cdot C_{d_i} \cdot A \cdot (V_{g_i} + V_{\text{wind}})^2 \cdot V_{g_i} =$$

$$C_{RR} \cdot W_T \cdot V_{g_i} =$$

86.681
82.408
77.442

14.604
15.041
15.548

Power required by wheel rotational aerodynamic drag

$$F_W \cdot (V_{g_i})^3 =$$

2.042
2.231
2.464

Power required for road grade

$$W_T \cdot V_{g_i} \cdot \sin(\text{atan}(\text{RoadGrade})) =$$

121.673
125.319
129.545

Time to ride 40 km

$$S := 40 \cdot \text{km}$$

$$t_{40K} := \frac{S}{V_g}$$

$$t_{40K} = \begin{bmatrix} 86.109 \\ 83.604 \\ 80.877 \end{bmatrix} \cdot \text{min}$$

Aero body position

Typical
Good
Excellent

UNITS

K≡1

ORIGIN≡1

%≡1

Air Density as a Function of Air Temperature, Pressure and Altitude

$TF_0 := 80$ **Input** sea level air temperature during bike ride (degrees F)

$$TC_0 := \frac{TF_0 - 32}{1.8} \quad TC_0 = 26.667 \quad T_0 := TC_0 + 273.15$$

Air temperature in degrees Kelvin, sea level air pressure, gas constant and lapse rate of atmosphere

$$T_0 = 299.817 \cdot K \quad P_0 := 101314 \cdot \frac{\text{newton}}{\text{m}^2} \quad R_{\text{gas}} := 287 \cdot \frac{\text{m}^2}{\text{s}^2 \cdot K} \quad B := 0.00650 \cdot \frac{K}{\text{m}}$$

Air pressure as a function of air temperature, altitude and atmospheric lapse rate (See Fluid Mechanics)

$$P_{\text{air}} := P_0 \cdot \left(1 - \frac{B \cdot Z}{T_0}\right)^{\frac{g}{R_{\text{gas}} \cdot B}} \quad P_{\text{air}} = 101314 \cdot \frac{\text{newton}}{\text{m}^2} \quad P_{\text{air}} = 1 \cdot \text{atm}$$

Air density and temperature as a function of air pressure and altitude (Insert air density into data list)

$$\rho_{\text{air}} := \frac{P_{\text{air}}}{R_{\text{gas}} \cdot T_0} \quad \rho_{\text{air}} = 1.177 \cdot \frac{\text{kg}}{\text{m}^3} \quad P_{\text{air}} = 1 \cdot \text{atm}$$

$$T_{\text{air}} := T_0 - B \cdot Z \quad T_{\text{air}} = 299.817 \cdot K \quad \text{Air temperature in degrees F}$$

$$T_{\text{air}_F} := TF_0 - B \cdot Z \quad T_{\text{air}_F} = 80$$

Bike drag coefficients (Cd) derived from Cervelo wind tunnel drag force measurements

$$V_t := 30 \cdot \text{mph} \quad V_t = 13.411 \cdot \frac{\text{m}}{\text{sec}}$$

Standard frame and wheels (-0.4 lbf for aerowheels and -0.3 lbf for aeroframe)

$$D := \begin{bmatrix} 8.0 \\ 7.0 \\ 6.0 \end{bmatrix} \cdot \text{lbf} \quad Cd := \frac{D}{\frac{1}{2} \cdot \rho_0 \cdot A \cdot (V_t)^2} \quad Cd = \begin{bmatrix} 0.645 \\ 0.565 \\ 0.484 \end{bmatrix} \quad \begin{array}{l} \text{Aero body position} \\ \text{Typical} \\ \text{Good} \\ \text{Excellent} \end{array}$$

Standard frame and aerowheels

$$D := \begin{bmatrix} 7.6 \\ 6.6 \\ 5.6 \end{bmatrix} \cdot \text{lbf} \quad Cd := \frac{D}{\frac{1}{2} \cdot \rho_0 \cdot A \cdot (V_t)^2} \quad Cd = \begin{bmatrix} 0.613 \\ 0.532 \\ 0.452 \end{bmatrix} \quad \begin{array}{l} \text{Aero body position} \\ \text{Typical} \\ \text{Good} \\ \text{Excellent} \end{array}$$

Aeroframe and aerowheels

$$D := \begin{bmatrix} 7.3 \\ 6.3 \\ 5.3 \end{bmatrix} \cdot \text{lbf} \quad Cd := \frac{D}{\frac{1}{2} \cdot \rho_0 \cdot A \cdot (V_t)^2} \quad Cd = \begin{bmatrix} 0.589 \\ 0.508 \\ 0.428 \end{bmatrix} \quad \begin{array}{l} \text{Aero body position} \\ \text{Typical} \\ \text{Good} \\ \text{Excellent} \end{array}$$

REFERENCES

1) **Cervelo Aero Cycling Primer**

2) **Fluid Dynamic Drag by S.F. Hoerner**

See page 3-14, for the drag areas (D/q) of an average man
and Chapter III for the drag of basic shapes like cylinders, plates and airfoils

3) Fluid Mechanics by Frank M. White, Hydrostatic Pressure in Gases