BICYCLE AND RIDER DRAG COEFFICIENTS FOR ALL. By John Lafford

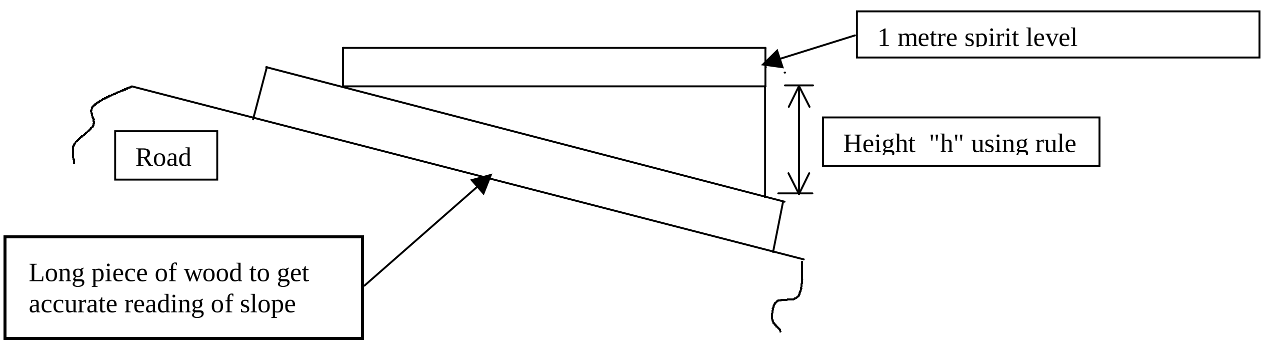
It is possible to find out the drag coefficient of your own bicycle/rider combination without resorting to the use of wind tunnel facilities. This can be done with a Coastdown Test.

I have found that by adapting information contained in an article by Douglas J. Malewicki from Bike Tech dated October 1984, you can calculate your own CdA, (and thus Cd) and also the power you are putting in at any particular speed.

The basic requirement is to determine the force being applied to your bicycle to achieve a given speed. This can be done with a fair degree of accuracy in the following way.

Find yourself a piece of road that is reasonably long and with a constant slope (the steeper the slope, the more accurate the answers will be). The idea is that on a windless day you coast down the slope and find your terminal speed using your cycle computer (velocity V) . Next, take your bathroom scales and, while still wearing all your cycling clothes (including shoes and helmet) and carrying your bicycle, weigh yourself and obtain the Total Weight of Bicycle and Rider (weight W).

You now need to measure the slope. I have found it convenient to use a standard 1 metre long spirit level, a 6" steel rule with millimetre markings and a straight piece of wood 6' to 7' long. Place these on the slope of the road as shown in the sketch and measure the height "h".



Take care to avoid getting run over by other road users when doing this out in the road. To do this I use my car as a 'shield' by parking it in front of where I want to measure.
Now, having got the basic data we can calculate the answers.

The basic equation is a balance of forces :

1. Pf, Propulsive power to the wheels = Prr, Power consumed by rolling resistance + Pa, Power consumed by aerodynamic drag.

In this case the propulsive power to the wheels is due to gravity acting on the bicycle and rider.

Power = force x velocity = slope x weight x velocity

If we use the units of slope as $\frac{\text{"h" mm}}{\text{1000 mm}}$, and measure weight "W"(bicycle plus rider) in pounds, and velocity "V" in mph then,

$$\text{Power Pf} = \frac{\text{"h"}}{1000} \times W \times \frac{V}{375} \quad \text{(horsepower)}$$

In one of my own cases, I had h = 47mm, W = 202 lbs, and V = 37.5mph to give
P = .949 hp (708 Watts).

2. Power consumed by rolling resistance is given as : -

$$Prr = Crr \times \frac{W}{375} \times V \text{ hp}$$

We have W and V above and a typical Crr for tyres on tarmac roads is 0.006. (If your tyres are listed in the Rolling Resistance for Tyres data sheet, then a more precise value can be used here). Substituting in equation 2, I got Prr = 0.121 hp (90 Watts)

3. Power consumed by Aerodynamic Drag,

$$Pa = Cd \times A \times \frac{V^2}{391} \times \frac{V}{375}$$

where A is in square feet and is the frontal area of the rider plus bicycle.

But Pa = Pf - Prr which we have already calculated, so we can rearrange the equation to find $CdA = \frac{(Pf - Prr) \times 391 \times 375}{V^3}$

For me and my bicycle this gives CdA = 2.3 sq.ft.

4. You can obtain the cross-sectional area A, and then your Cd if you want to, but the CdA value is all you need to calculate values of Power against Speed using equation 1 which is the main interest.

$$Pf = Crr \times \frac{W}{375} \times V + CdA \times \frac{V^2}{391} \times \frac{V}{375} \text{ horsepower}$$

These values of horsepower can be converted to Watts by multiplying by 746.

However, if required, you can obtain the cross-sectional area A, of your rider plus bicycle combination and thus the actual drag coefficient Cd. This can be done in several ways but a convenient way is to have someone measure you while you sit on your machine. Do this in inch units and plot the data on a sheet of graph paper and count the number of squares that you cover and convert to square feet (divide by 144). Using this approach my area, A = 3.02 sq.ft. and thus my Cd = 0.76. This is a high number, but gives a lot of scope for improvement. The principle works for all types of cycle and some faired HPV's have a Cd value in the range of 0.055 to .075 which explains why the world hour record for faired HPV's is approx 48 miles (ie. 48mph average).

The Bike Tech article has a graph of Velocity against CdA with curves at constant horsepowers. This is reprinted here. You can plot your own CdA on it and it will show you what horsepower you need to develop to travel at 20, 30, 40mph or whatever, speed instead of doing the calculations in part 4. If you know your 200m sprint speed you can see what your maximum output power is. Similarly, if you know your average speed for a 10 mile time trial you can plot and see what your average power output is. You can also see what you have to do to go faster to achieve a particular speed i.e. reduce your Cd, or A, or get stronger, or all three. From the data collected, I have for interest, plotted horsepower against speed for my bicycle for a level road and no wind. You can also plot graphs for going up and down hills and for cycling in a wind, using the above equations.

Using this data lets you put numbers on quantities you probably did not know before. It also allows you to check on potential improvements by comparing the difference in performance by using alternative equipment. You can try a disk wheel, or a change of helmet and do another coastdown test. Take some more readings and calculate the change in performance. This type of testing is ideally done back-to-back to ensure the basic conditions are the same.

Having found the above procedure interesting and useful, I have now set up the equations using Mathcad software in my computer. This is a great help as Mathcad does an automatic update on the whole set of calculations when any of the variables is amended, tabulating Power against Speed and plotting a graph. This has encouraged me to do a lot more testing using different equipment and bicycles.