How To Be A Lazy Cyclist

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1 Introduction

I am going to model several situations relating to aerodynamics in cycling. My first situation has a cyclist riding along a straight, smooth road, with his hands on the tops of his bars. This is the least aerodynamic position. I am going to calculate the power required to travel in this position at a certain speed. I then repeat this with their hands on the hoods, and on the drops (see figure 1). With these changes the cyclist becomes progressively more aerodynamic. Theoretically, we should see the power required to travel at the given speed decrease for each situation. I will then repeat this for different wind speeds, and prove the hypothesis that as the wind speed increases, the aerodynamics of the cyclist has an increasing affect.

Figure 1: A picture demonstrating the different hand positions (drops, hoods, tops)

2 Calculating Aerodynamic Drag

I need to calculate the Drag (CdA) of the cyclist. This is done by approximating his drag coefficient and frontal area, for an average male cyclist using typical values [1] it can be assumed that :

1. On the tops the CdA will be 0.727,
2. On the hoods, the CdA will be 0.400,
3. On the drops the CdA will be 0.317.

Given air density of 1.225 kg/m^3 and Drag Equation (1) the drag experienced by the cyclist can be calculated:

$$F = CdA\rho\frac{v^2}{2} \tag{1}$$

Where:

Drag = Drag Co-efficient x Frontal Area x Air Density x $\frac{MovingSpeed^2}{2}$

This python code on sage shows how to work out the drag equation for each different position, taking into account the three different CdA's, as well as varying the wind speed.

```
def calc_f (myCdA, myu):
    """
    This function uses the drag equation to calculate the drag for varying values of CdA,
    and wind speed.
    Arguments:
```

```
        myCdA: the drag coefficient for each position
        myu: the varying windspeed
    Output:
        myf: the drag force created
    """
    #physical constants
    p = 1.225  # air resistance
    v = 8  # cyclist's moving speed
    myf = myCdA * p * ((v + myu) ^ 2) / 2  # drag equation
    return myf
```

And the Power Equation (2) to translate the answer into the form required:

$$P = \frac{Fd}{\Delta t} \tag{2}$$

Where:

$$\text{Power} = \frac{\text{Drag Force x Distance}}{\text{time}}$$

(Point to note: Speed = Distance / time)

The code below works out the Power using the F values from above, so now we have the Power required for the cyclist in each position at each wind speed.

```
def calc_power (myCdA, myu):
    """
    This function calculates the power output by the cyclist
    Arguments:
        myCdA: these are the values of CdA for the different positions
        myu: this is the wind speed
    Output:
        mypower: this is the power exerted my the cyclist in order to move at the required
        speed
        """
    myv = 8
    mypower = calc_f(myCdA, myu) * myv  #power equation, P=FD/t
    return mypower
```

The table below shows the calculated values with no wind. As expected, it can be seen that the cyclist has to work much harder to achieve the same speed when he has the greatest frontal area, ie. on the tops.

Position	Drag Co-efficient	Frontal Area $/m^2$	CdA	Drag / N	Power / W	Speed / m/s
Tops	1.15	0.632	0.727	28.5	228.0	8
Hoods	1.00	0.400	0.400	15.7	125.6	8
Drops	0.88	0.360	0.317	12.4	99.2	8

3 Now let's bring wind into the equation...

Now, assume a headwind of 2m/s acting against the cyclist. This will have have an affect on how hard the cyclist has to work to maintain the same speed. Noting that CdA is constant, we can now calculate the new power values:

$$F = CdA\rho\frac{(v+u)^2}{2} \tag{3}$$

where v = cyclists forward speed, and u = windspeed. The following table shows the values calculated for a head wind speed of 2 m/s

Position	CdA	Drag / N	Power / W	Speed / m/s
Tops	0.727	44.5	356.2	8
Hoods	0.400	24.5	196.0	8
Drops	0.317	19.4	155.3	8

This demonstrates that for the cyclist to travel at the same speed, substantially more power is needed.

4 Let's make him work a bit harder!

In this section I will model the windspeed having cubed in order to show that with an even stronger wind speed, the cyclist will require proportionally more power. To show this, the windspeed will become 8 m/s.

The next table shows the results for the new wind speed. Using reference data from a professional cyclist [2] it is clear that it would be impossible for someone to output 912 W for a long period of time, whereas it is not uncommon for a professional cyclist to output 400 W for an hour. This demonstrates how much more efficient it is to be aerodynamic, and how important it is to the cyclist as the wind increases.

Position	CdA	Drag / N	Power / W	Speed / m/s
Tops	0.727	114.0	912.0	8
Hoods	0.400	62.7	501.6	8
Drops	0.317	49.7	397.6	8

5 Bringing Everything Together

Finally, bringing all the previous pieces of code together, we can plot a graph to show how the Power required varies depending on wind speed and which position the cyclist is in.

```
startwind = 0  #setting my range of windspeeds
endwind = 8

f(x) = calc_power(0.727, x)
g(x) = calc_power(0.4, x)
h(x) = calc_power(0.317, x)
p = plot(f, x, startwind, endwind, color = 'green', legend_label = 'CdA=0.727')
p += plot(g, x, startwind, endwind, color = 'purple', legend_label = 'CdA=0.400')
p += plot(h, x, startwind, endwind, color = 'orange', legend_label = 'CdA=0.317', frame = True,
axes_labels = ['Wind Speed', 'Power'], axes = False)
p
```

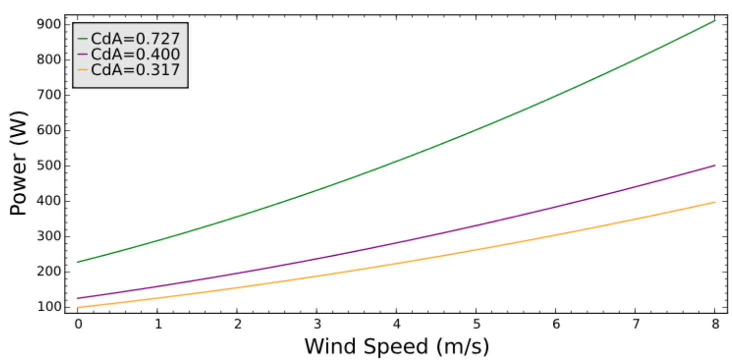

Figure 2: A graph to show how Power required varies with wind speed for different values of CdA

As expected the graph in Figure 2 shows that it is more efficient to be in a more aerodynamic position, as the frontal area to the wind is much smaller. It also shows us that it gets gradually more efficient to be riding in the drops.

In conclusion, if you want to train hard, make yourself as big as possible, if you want to race hard, try to make yourself disappear...

References

[1] Cycling Aerodynamics. `http://www.cyclingpowerlab.com/CyclingAerodynamics.aspx`. Accessed: 2015-12-04.

[2] Ed Clancy my five shortcuts to faster cycling. `http://www.telegraph.co.uk/men/active/recreational-cycling/10880429/Ed-Clancy-my-five-shortcuts-to-faster-cycling.html`. Accessed: 2015-12-04.