

Some observations on power output on a rowing machine at the Y

My indoor cardio exercise of choice is rowing machines. On one of these machines, you sit in a tucked position, then pull back on a bar which is attached to a chain, which is in turn attached to a flywheel which you then accelerate by applying a force to the bar, much as you would in a rowing scull. You then reset to the original position, and repeat.

I played with a Concept II rowing machine at the Y on Sunday, and rowed at a variety of paces to see what my power output was. Here is a quick summary of my experiences.

(Rowing machines typically show you the time it would take you to cover 500m at your current pace, much like runners talk about their pace in terms of how long it takes to cover 1 mile; I've converted these into velocities in m/s)

A pace of 3.3m/s was about as slow as I could stand (this corresponds to a 2:30 500m). I was pulling very gently on the bar. This used about 110W, or about 110J/s.

A pace of 3.9m/s is my 'comfortable for a long row' pace (2:08/500m). This used about 170W.

A pace of 4.2m/s (2:00/500m) is my 'working hard' pace, which I can keep up for, say, 8-10 minutes. It uses 200W.

A pace of 4.75m/s is my 'sprint' pace (1:45/500m). I can keep this up for only a minute or two. It uses 300W.

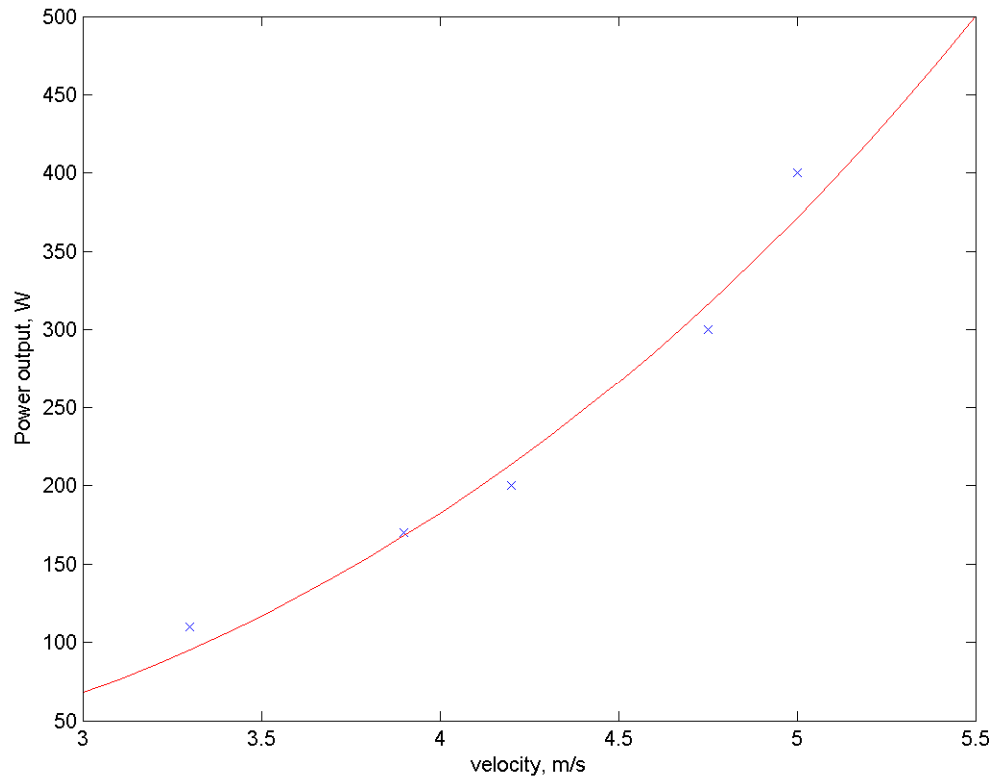
A pace of 5m/s (1:40/500m) was very nearly impossible to pull at. I managed this for about 45s before having to back off. This bordered on painful. It corresponds to 400W, which is short of the power output that Lance Armstrong can maintain for a half hour during a race (500W). Armstrong can manage short sprints with power ratings of up to 1000W, which is pretty hard to imagine.

For the 4.2m/s pace (2:00/ 500meters), I noted that I was pulling at a rate of about 25 strokes per minute. A single stroke consists of a force being applied along a straight line of about 1.8m length. Since there is no negative force imposed on the return stroke, I applied a force over about $1.8\text{m} \times 25 = 45\text{m}$ each minute. In one minute, at this pace, I used $60\text{s} \times 200\text{W} = 12000\text{J}$ of energy. Since I did the work over 45m, the average force I imposed was around 270N.

Obviously, I'm not out in a boat, but these machines are tuned to behave roughly like a boat. Either way, let's calculate the perceived drag force two different ways, making some wild guesses for numbers. Since $P = Fv$, $D = P/V = (200\text{W}) / (4.2\text{m/s}) = 47.6\text{N} \sim 50\text{N}$. I could also make some guesses as to what the drag force on a scull might be. The cross-sectional area is probably pretty small, say about 30cm wide by about 10cm deep, so $A = 0.03\text{m}^2$. The drag coefficient is probably pretty small, say $C = 0.2$. The density of water is 1000kg/m^3 . Then

$$D = \frac{1}{2}CA\rho v^2 = \frac{1}{2}(0.2)(0.03m^2)(1000kgm^{-3})(4.2ms^{-1})^2 = 53N .$$

Not so far off our guess using $P=Fv$. This disregards the drag of the scull and rower through the air, which I'm guessing is small compared to the drag of the water on the system.



Here's a graph of my power output as a function of my velocity; the red curve is the best fit assuming a $P \sim v^3$ relationship.