PHYSICS IN DAILY LIFE: MUDDY CYCLISTS

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When watching the *Tour de France* or the *Giro d'Italia* on a not-so-sunny day, we are confronted with a simple physics problem. Why is it that cyclists on a wet road tend to get their back decorated with a vertical stripe of mud? Of course, it is due to the water from the road picked up by the tire. Centrifugal forces throw it off the tire somewhere in the upper part of its trajectory, and the forward speed launches it towards the poor cyclist's back. But why does the water leave the tire somewhere around the highest point? A superficial analysis of the wheel's motion may give us a clue. Any point along the rim traces out a cycloid, and its speed varies from zero to twice the speed of the bike. So isn't the answer simply: it is because the speed of the tire rim is highest at its highest point, and so is the centrifugal force?

Reasonable as this may sound, it is entirely beside the point. Sure, it is the centrifugal force that counts. But that is the same everywhere along the wheel rim, given a certain speed. The fact that there is a linear motion superimposed on the wheel's rotation is irrelevant.

It is even quite the opposite, which we realize if we take gravity into account. Gravity tends to make the drops fall off much earlier, much closer to the road, whereas it tends to make the water stick to the tire near the top. We must conclude that the cyclist's back gets wet not *because of*, but *despite* the fact that the relevant tire part is near its highest position.

This raises the question: at exactly what speed does the cyclist get spattered with mud? We should realize that the drops leaving the tire precisely at its top position are rather innocent. They will leave horizontally, pass under the saddle and never make it to the cyclist's back. The real culprits are those drops that come off earlier, somewhere around 45 degrees before they reach the top, or even around 60 degrees before the top.

Now things get a bit complicated, since parameters like the exact position of the rider relative to the wheel come into play. Moreover, it is not sufficient to have centrifugal and gravitational forces balance. The water drops coming off the tire rim need some extra speed to be launched upward, in order to reach the cyclist's back.

A calculation for a standard cyclist and ignoring the drag on the droplets, done by Fokke Tuinstra from Delft University of Technology, shows that the drops which most likely make it to the rider's back will, indeed, leave the tire reasonably early, at around 60° before the top. They will hit the rider's back as soon as his speed exceeds some 12 km/h. If he rides a standard-size bicycle, that is. The reason is the crucial role of the wheel diameter. Given a certain speed v of the cyclist, the balance between centrifugal force and gravitation, $v^2/R = g$, shows that smaller wheels make things worse. So if you happen to be on your way to an important meeting wearing your business suit on a folding bike, you better make sure that the bike has an effective mudguard over its back wheel. ■

Article available http://www.europhysicsnews.org or http://dx.doi.org/10.1051/epn/2010404