Science and Bicycles 1: Tires and Pressure

Posted on October 18, 2010

Most cyclists are interested in improving their bike's **performance**, because rolling along at considerable speed while expending relatively little effort is one of the great appeals of cycling. Before you can improve your bike's performance, you need to know what makes your bike faster, and that is where **science** comes in. Science is a **fascinating** process. Here is how we determined that higher tire pressures (beyond a certain point) don't make your bike faster.

Science usually starts with a hypothesis. In 2005, the German magazine *TOUR* published performance tests of racing tires, and found that at 50 km/h (31 mph), the differences between racing tires were relatively small. Looking at the data, I realized that at more moderate speeds, the differences in rolling resistance could be quite significant. We designed a roll-down test. Our preliminary results showed that some tires rolled much faster than others. We refined our test protocol, and started testing dozens of tires (see *BQ* Vol 5 No 1 for more details and complete results).

Science also is hard work: Mark Vande Kamp rode up and down the same hill about 300 times over the course of several months, always in the early morning, when the chances of zero wind are greatest. And several times, we got up at 4 a.m., set everything up, only to have a slight wind rise despite a forecast of perfect conditions… All we could do is go back home. (And because our test track was next to a BMX practice track, we had to sweep the pavement – all 245 m of our test hill – the evening before to create a clean surface for testing.)

We also tried to find out how much performance improved with **higher tire pressures**. We knew that higher pressures are less comfortable, so we wanted to find out just how much speed you give up for that added comfort. To our surprise, the answer was: “None.” We found that higher pressures beyond a certain point did not make the bike roll faster. This was counter to our and almost everybody else’s expectations… To rule out that these results were just noise in the data, we did more tests of different tires at various pressures. The results were consistent with our previous tests. Statistical analysis showed us that the results were highly significant, that means, they are unlikely just noise in the data.

Suspension Losses

The next step was to develop a hypothesis that explained what we had observed: **Suspension losses** are caused by friction in the the **rider’s body tissues** as they are vibrating. Higher pressures cause more vibrations, and hence higher suspension losses. This appears to cancel any gains at higher pressures from reduced **flexing of the tire** (hysteretic losses), as the tire deforms less at the contact patch as the wheel rotates.

This hypothesis also allowed us to explain why the drum test results were different – by neglecting the suspension losses, they measured only one half of the equation.

To test this hypothesis, we had to establish that suspension losses really were a significant factor, rather than some theoretical construct. (OK, the U.S. army already had established this for vibrating tank seats, but we had to show that it happens on a bicycle, too.) We did this by testing power output at constant speed on a smooth and on a very rough surface, side by side (see photo below). The differences were huge. On the rough surface (rumble strip), our rider had to put out 290 Watts more than on the smooth surface (right next to the rumble strip). That means that 290 Watts were lost through vibrations of the bike and rider’s body.

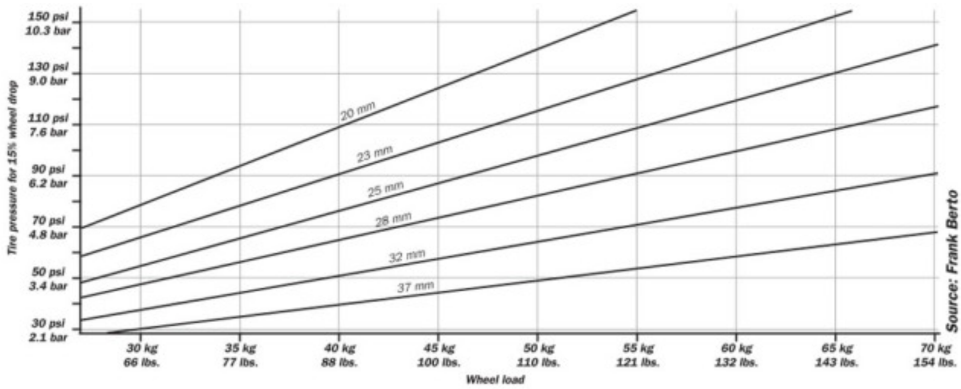
The Army studies had shown that energy absorption in human bodies was directly correlated to discomfort. After having ridden up and down our test hill 300 times, Mark wasn't keen on riding 11 miles on rumble strips. That task instead fell upon me. I was able to confirm the Army's results on the discomfort of absorbing hundreds of Watts as your body vibrates. Did I mention that science is hard work?

As a side effect, the suspension loss tests confirmed once again that higher pressures don't make the bike faster even on very smooth pavement. And this time, we tested with a power meter instead of a roll-down test. So we had confirmed the results with two different methodologies. (This is much more powerful than just reproducing our initial results, which simply means running the same tests again, and finding the same results. We have done that as well, multiple times.)

After all this testing, we now can say with great certainty that increasing your tire pressure (beyond a certain point) does not make your bike faster on road surfaces that range from very rough to very smooth. In fact, on very rough road surfaces, higher pressures are a lot slower than lower pressures, because the suspension losses are so great. On most surfaces, tire pressure (beyond a certain point) simply doesn't make a difference in speed.

Optimized Tire Pressure

Our initial tests even established at what point the performance no longer increases with higher tire pressures. For most tires and on "average" roads, this point appears to be a little higher than the 15% tire drop measured by Frank Berto. Note that the **loads are given per wheel**, not for the entire bike. For most bikes, you can assume between 40% and 45% on the front wheel, and 55% to 60% on the rear.



Tire inflation for 15% wheel drop in relation to wheel load and actual tire width.[4] Example: Rider and bike weight: 100 kg. Weight distribution: 45%/55%. Wheel loads: 45 kg/55 kg. Tire pressures for 20 mm tires: 125 psi/155 psi. Tire pressures for 37 mm tires: 45 psi/53 psi. For heavy riders/bikes, narrow tires require very high inflation pressures, and wide tires are a better choice.

This means that Berto's values are a good starting point for experimenting with tire pressures. If you want to optimize **performance**, you may want to go **a little higher**. If you are mostly concerned about **comfort**, you might prefer a tad **lower pressure**.

As always in science, there remain open questions. Is this cut-off point the same for different tires? Or do stiff tires benefit from higher pressures more than those with supple sidewalls? After all, a stiffer sidewall takes more energy to flex, so reducing that flex by all means may be helpful, even if it makes the bike vibrate more. Or is it the opposite, that stiff tires vibrate so much that running them at lower pressures is better, even if it increases the losses due to tire flex? Rest assured, we are working on this…

- **Further reading:**
- *Bicycle Quarterly* Vol. 5, No. 1: Our first big tire test with performance numbers for many tires, different pressures, details on our testing methods…
- *Bicycle Quarterly* Vol. 5, No. 3: More tires tested, statistical analysis of our tire test data showing which tires were significantly different.
- *Bicycle Quarterly* Vol. 8, No. 1: Suspension losses measured, more tires tested on rough and smooth surfaces at different pressures.

About Jan Heine, Editor, Bicycle Quarterly
I love cycling and bicycles, especially those that take us off the beaten path. I edit Bicycle Quarterly magazine, and occasionally write for other publications. One of our companies, Bicycle Quarterly Press publishes cycling books, while Compass Bicycles Ltd. makes and distributes high-quality bicycle components for real-world riders.
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8 Responses to *Science and Bicycles 1: Tires and Pressure*

Kathryn Hall *says:*
October 18, 2010 at 8:58 am

I'm hoping you'll do some tests on the new Soma 650b tires with the Pasella tread pattern.

Mike Jenkins *says:*
October 18, 2010 at 1:32 pm

Good stuff, all. I often wonder if there is not a way to predict dynamic tire performance under static conditions. I have in mind measuring foot print area as a function of load and comparing rate of change with your collection of rolling resistance data. For a long time it was asserted that area x tire pressure was equal to the load. But then someone actually measured it and found it was not.

Jan Heine *says:*
October 22, 2010 at 9:24 am

As you write, sidewall stiffness does appear to play a role in the size of the contact patch. So the assumption that with 100 lb on a tire pumped to 100 psi, the contact patch is 1 square inch, is only very approximate…
We hope to investigate size and shape of contact patches more in the future, and see what we find. Being able to

predict rolling resistance from contact patch behavior under load would be great, as it's easier to measure contact patches than to test resistance on the road.

Vincent Muoneke *says:*

October 18, 2010 at 1:55 pm

Nothing wakes me up like the application of the scientific method as opposed to the usual anecdotes that I read. Particularly captivating is your last paragraph suggesting that the the method often leaves more questions than answers. I will stay tuned to see how these hypotheses apply to spokes, frames, seatposts, handlebars etc. I recently finished PAP with a steel fork and seemed to notice more hand numbness that I get following a 1200. Now! that is an anecdote.
Certainly a lifetime of hardwork, but well worth it and you seem to enjoy it.
Thanks

Vinny

Rob in Seattle *says:*

October 18, 2010 at 2:22 pm

Something I've wondered since I first saw Frank Berto's chart: How does optimum pressure differ between wheel sizes? Assuming the same tire width, is the chart equally applicable to 20″, 26″, 650b and 700c tires? Intuitively I would assume not, since for a given width a larger diameter tire is going to have more volume, which ought to affect tire drop. Or are the differences so slight it doesn't matter?

Jan Heine *says:*

October 18, 2010 at 6:05 pm

From what I have read, only the cross-section of the tire matters, not the air volume. The increase in pressure due to tire deflection is negligible, so a larger air volume doesn't help you much. Basically, if you somehow configured a 23 mm tire with a big separate air tank, and pressurized it all to 120 psi, it still would be a hard-riding tire. And if you pressurized it to 60 psi, you'd still get pinch-flats.

AllanF *says:*

October 18, 2010 at 11:01 pm

Another excellent post, Jan.

"This was counter to our and almost everybody else's expectations… " And that is the beauty of science, it tells you when you're wrong. If only more people would humble themselves to listen, we wouldn't have to put up with so many miserable bikes.

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doug in seattle. *says:*

October 22, 2010 at 6:04 pm

Thanks for all of your hard work. Since I became started reading Bicycle Quarterly, my bicycling fun and comfort have both improved, just from following your suggestions!

Also, I was amused to see that your roll down test hill is only a couple hundred feet from my front door. Anyways, thanks again!
