Variation of Calibration Constant with Surface Texture, Part 4: A Simple Experiment to Compare Various Tyres

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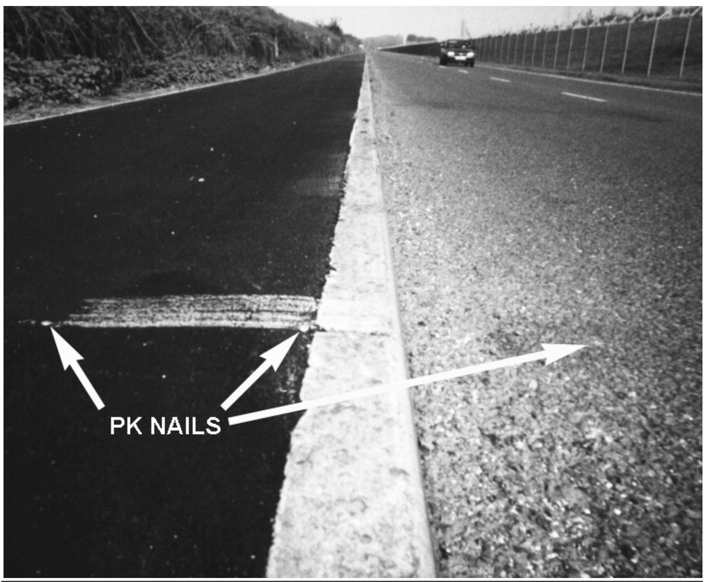
Introduction

In part 1 of this series, ***MN*** 89 p 12, I reviewed the published data on the sensitivity of tyres to surface texture. In part 2, ***MN*** 90 p 5, I described experimental results from seven riders and twelve tyres on a 4.5 km course in Abingdon. These data showed that for solid tyres the calibration constant in counts/km increases with increasing road roughness, while most pneumatic tyres have a smaller constant on rougher surfaces. In part 3, ***MN*** 91 p 5, I tried to explain why pneumatics and solids differed in this way. I concluded that surface roughness effects probably arise in the region near the point of first contact between the wheel and the ground where they affect the amount of initial circumferential compression of the tyre. I speculated that there were three possible causes: 1) tyre deformation extending beyond the point of first contact, 2) road surface irregularities modifying the geometry of initial contact, 3) varying skidding at the point of first contact.



Didcot – Milton Road.

This view is from the end of the bridge ramp looking West. Brunel's Great Western Railway Line from London to Bristol is behind the hedge on the left, and provides a dead straight boundary beside which the road was built. The new footpath is on the left. The 1 cm diameter heads of the PK nails marking this end of the course are clearly visible. The outer nails were located exactly on the same line perpendicular to the kerb by using a large set square lined up along the straight kerb edge. Using the nail head as a reference one can see that the road surface contains structure (stones) around 1 cm in size.

The other end of the course is near some traffic lights at a junction about 600m away, which is not visible in this picture. The road is quiet at 6 am on a Sunday morning and one can safely ride in both directions along the side of the road beside the footpath. Occasionally a car passes by, and one was deliberately captured in this picture. When riding against the traffic I just pause with my foot on the kerb as it

A few months ago when driving along a road which I occasionally use, I noticed that a new footpath was being constructed alongside a long straight stretch, see photo on left. Furthermore, the road had recently been resurfaced leaving a finish with tar- coated small stones partly protruding. My measurer's brain immediately kicked into action. I realised it was very likely that the footpath would be finished with very smooth rolled tar, and a there would be a big contrast in surface texture if I laid out two parallel calibration courses, one on the footpath and one about 3 feet away on the road. Furthermore, if I were to use the calibration courses only to compare the calibration constants given by the two surfaces, and not to actually calibrate my bike for a real measurement, I would not even need to go to the trouble of measuring the length of calibration courses with a steel tape. All I would need to do is make sure the parallel courses were of exactly the same length. I could then carry out a very simple measurement of the effects of surface texture on various tyres.

In eager anticipation, I detoured along the road more frequently. After remaining unfinished for some months, the work on the footpath was completed at the end of April. The next Sunday morning I was there to carry out my experiments.

In this article I describe the method and the results. They reinforce my existing data and I shall make some strong recommendations about choosing tyres for measurement.

Data Collection

I tested three pneumatic tyres, see photo on left, and one solid GreenTyre Courier mounted on a 27 x 1.25 inch wheel. For each tyre under test I did the standard calibration on the footpath, followed by one on the road, and finally a repeat on the footpath. The results are shown in the table at the foot of this page. I am satisfied that my riding was very consistent. The least repeatable data were obtained on 2 May when there was a light wind from the east. For the first two tyres which were pneumatic, the average counts for the ride 1 and ride 3 (12 rides in all) was 6744.6 counts and for ride 2 and 4 6743.8 counts. The light head wind for ride 2 and 4 is the probable reason for the counts being 0.8 smaller. With the solid tyre, which is less sensitive to the weight on the front wheel, the wind had no noticeable effect. On the 3 May when I used the Michelin World Tour conditions were perfect, no wind and a stable temperature. This is reflected in the excellent reproducibility of the rides with a total range of 0.5 counts for 8 rides on the footpath.

The three pneumatic tyres used in this experiment were all made by Michelin. The World Tour has a chunky tread whereas the Tracers have a thinner smooth rubber wall with a tread of thin cuts which are not visible in this slightly defocused photo.

Data Analysis

What is important in these experiments is not the absolute value of the calibration constant, but the fractional difference of the constant on different surfaces. I have defined this fraction as follows:

***F* = (counts on rough surface/counts on smooth surface – 1) x 1000.**

I have used the multiplying factor of 1000 to give a value that can be expressed in the units of m/km which is easy to compare directly with the SCPF, 1 m/km. A positive value of ***F*** means that, if one were to use the smooth surface to calibrate and then layout a race course on the rough surface, the course would be laid out short by the factor ***F*** . Referring to the values of ***F*** in the table below, it can be seen that this would be the case for a solid tyre. Of the three pneumatic tyres the narrow tyres are the worst, with a danger of a short course if the calibration surface is rough and the race surface is smooth.

	Ride 1	**Ride 2**	**Ride 3**	**Ride 4**	**Average**	**1000*(Rough/Av. Smooth - 1)**
Michelin Tracer 23 mm rim width, 2 May 1999 0559 to 0640						***F***
Smooth Footpath	6778.4	6779.3	6779.2	6779.6	6779.1	
Rough Road	6773.4	6772.6	6773.6	6771.0	6772.7	-0.99 m/km
Smooth Footpath	6779.9	6778.9	6779.2	6780.4	6779.6	
Michelin Tracer 25 mm rim width, 2 May 1999 0649 to 0727						
Smooth Footpath	6713.9	6712.8	6714.0	6712.5	6713.3	
Rough Road	6709.2	6707.8	6708.0	6707.7	6708.2	-0.69 m/km
Smooth Footpath	6713.1	6711.5	6713.0	6711.5	6712.3	
Green Tyre Courier Solid, 2 May 1999 0733 to 0810						
Smooth Footpath	6601.3	6601.7	6601.3	6601.5	6601.5	
Rough Road	6609.3	6610.0	6610.1	6610.0	6609.9	+1.24 m/km
Smooth Footpath	6601.7	6601.5	6601.9	6602.4	6601.9	
Michelin World Tour, 32 mm rim width 3 May 1999 0544 to 0620						
Smooth Footpath	6510.0	6510.0	6510.2	6509.9	6510.0	
Rough Road	6506.5	6506.3	6506.3	6506.8	6506.5	-0.54 m/km
Smooth Footpath	6510.0	6510.2	6510.1	6509.7	6510.0	

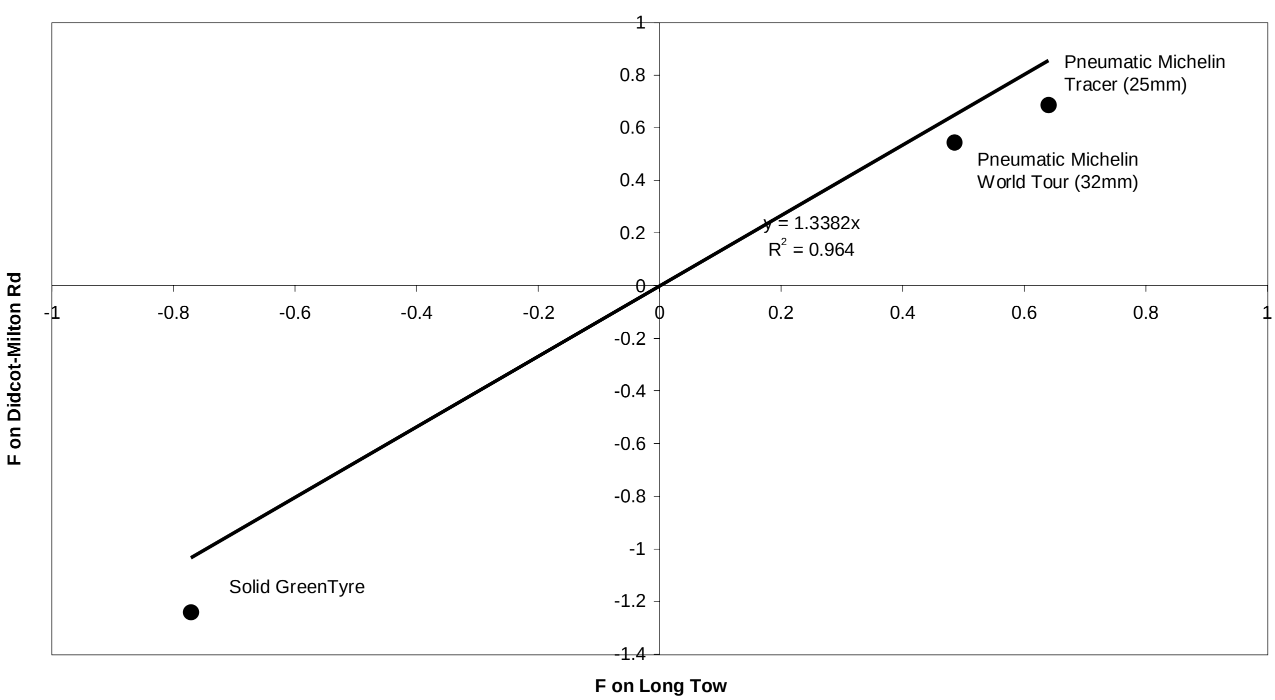
If there was a convenient method of measuring the roughness of a surface, then it might be possible to find a way of calculating the factor ***F*** directly from measurements of roughness of the calibration course and the race course. One could then make a correction to the length of the race course by using the calculated value for ***F***. However, although I can crudely estimate roughness by eye, I can not think of a practical way to accurately measure it. I have therefore tried another approach to the problem, as follows.

Since all the pneumatic tyres (except a mountain bike tyre), which I have tried in various experiments, have given negative values for ***F***, and since the two solid tyres I have tried have given positive values, I wanted to investigate whether a weighted average of the results of a measurement with a pneumatic and one with a solid tyre could be used to estimate the result which would be given with a perfect tyre, i.e. one with ***F*** = 0. The use of such a weighted average would only be valid if there was a linear relationship, true for all types of tyre between ***F*** and some unknown function of the roughness difference. Mathematically this assumption would be expressed by the equation,

F = (a constant, which depends on the tyre) x (a function of the difference in roughness of the surfaces, which is independent of the tyre)

I have no *a priori* reason to expect an exactly linear relationship. However, such a linear relationship can often be used as an approximation for a much more complex relationship. To investigate whether a simple relationship might be a good approximation for the data obtained in this experiment, I have compared in the following graph the values of ***F*** obtained on two pairs of surfaces: the pair of surfaces reported here on the Didcot - Milton Road, and from data previously reported in ***MN*** 90 p 5 for the pair of surfaces along Long Tow. I have plotted the data for the 3 tyres with which I have made measurements of ***F*** in both locations.

Correlation of F for 3 tyres on 2 pairs of Surfaces



I have fitted a straight line through the points and constrained it to pass through the ***F*** = 0 point on both axis. The constraint is equivalent to making the assumption that if a tyre is independent of surface roughness for one pair of surfaces then it will be independent of roughness for the other pair of surfaces. The fit of the points to the straight line is remarkably good. The three points all lie within a value of ***F*** = 0.2 distance from the line. If in further experiments such errors were found to be typical of other pairs of surfaces, then one would have confirmed the basis for a simple weighted average method of deriving the true distance which would be accurate to better than 0.2 m/km. This would be a remarkable result and could revolutionise the measurement community’s approach to measurement on rough surfaces, or even ordinary road surfaces.

After taking the first measurements on the Didcot-Milton Road on 2 May 1999, I actually had a sufficiently strong expectation that the tyres would behave in this linear fashion that I made a prediction which I published in Jim Gerweck's Measurement News Forum on the internet,

"Airless tyres – a cautionary tale

I used my Green Courier tyre which fits on a 27 x 1.25 inch wheel. It took me about 35 minutes to carry out a measurement sequence including the usual 4 precals and 4 post cals. I actually took 4 rides of the road course and averaged the results. During the sequence the temperature rose by 1.5 degree Celsius which has absolutely negligible effect on my GreenTyre. The rides on each surface were very self-consistent: less than 1 count variation in 6600. Without applying the SCPF to the cal constant, I calculated the road course to be 87 cm or 0.125% LONGER than what I knew it to be based on the offsetting from the cal course end points. If even if I had added 0.1% SCPF in the cal constant, it would still have calculated a length under the true distance.

I regard this result as unacceptable: either the equipment or the measurement procedure needs changing. I don't want to suggest changing our standard procedures, so tomorrow I will ditch the solid GreenTyre and repeat the measurement with a Michelin World Tour pneumatic tyre. Based on my previous experience of this tyre (published in MN and elsewhere) I expect the measurement of the road course (without SCPF) to come out about 30 cm SHORTER than the true distance. If it does I shall continue to use the pneumatic for the majority of my measuring."

The next day, when my prediction was proved right, I wrote as follows,

"Michelin World Tour pneumatic best for rough surfaces

Yesterday I predicted that my MWT tyre would give a result on the rough road 30 cm less than the true distance. I have just returned from the measurement and the result agrees remarkably well with the prediction: The measurement with the MWT gave the course to be 38 cm SHORTER than the true distance. My prediction was good to within 8 cm or less than 1 count in 6500! – **nb. I calculated using the wrong value for the course length. With the correct value of 597 m the MWT gives 32 cm short not 38cm.**

The MWT was 2.3 times less sensitive to this surface than the solid GreenTyre. Since the official measurement procedure takes no quantified account of this effect I shall continue to recommend the MWT over any solid tyre in order to reduce errors to the maximum extent possible.

The accuracy of my prediction suggests that a new procedure could be developed involving measuring each course twice - once with a GreenTyre and once with a MWT. The overall result would be determined by a weighted average giving a weight of 2.3 to the MWT and 1 to the GreenTyre. (This was effectively the method I used to make my prediction but with a ratio of 3:1 which I had obtained on another surface.) Alternatively a divergence in results between a solid and a pneumatic could be used to warn of an unrepresentative calibration surface and perhaps in extreme cases this could result in the rejection of the measurement. Measuring twice with different tyres would be too big a load to impose on measurers as a standard procedure, so why not use the MWT for best results?"

Conclusions

In the last 4 years I have published in ***MN*** the results of several experiments on the effects of surface roughness. These demonstrate beyond all doubt that significant error can be introduced in a measurement if the calibration surface differs in roughness from the measured race course. I was surprised and disappointed that third edition of the otherwise truly excellent Course Measurement Handbook, published on 14 June 1999, has entirely ignored my work. Although I can not claim that the averaging method, which I have described above, can at present be regarded as more than an experimental method still to be verified on a wider range of surfaces, I would expect at the very least the publication of the following warning to all readers of the handbook,

"WARNING: It has been shown that the calibration constant can vary with the roughness of the road surface. To be safe measurers are advised to choose a calibration course with a surface roughness which is similar to the race course. If this is not possible, make sure you use a smoother surface for the calibration and a pneumatic tyre, since this combination will give an additional safety margin. Avoid the use of solid tyres unless there is almost no variation of surface roughness. Fatter, thicker pneumatics seem less sensitive than thin racing tyres."

I know my condemnation of solid tyres will not go down well with those who place a high value in their insensitivity to temperature changes and immunity from punctures. However, temperature changes can be monitored with a thermometer and the effects of extreme changes on a pneumatic can be corrected. Also, I suggest that for the majority of unpaid measures, getting a reliable result is more important than the small risk of having to repeat a measurement due to a puncture in a pneumatic.