Round Black Donuts, or in Other Words, Tires
Part 1

Author's Note: I ask for the indulgence of the engineers and other technical readers. In the name of simplicity and understanding for the lay reader I have taken a few liberties with some technical and engineering terms and concepts. If my students had done the same I probably would have given them a D. For those readers who want more technical detail and information please feel free to contact me at your convenience.

Bob White, Dec. 2009

(Editor's note: Due to the length of the article, it will be broken into multiple parts and published over the next few months in the *LTR Newsletter*.)

Introduction

The second Saturday of the month car talk meetings at Panera's in Champaign often generate interesting questions and topics for discussion. You may recall the article I wrote some months back about a car's power requirements which was the result of a question by Russ Bedford about the Bugatti Veyrons HP meter. This time it was not chocolate donuts at Panera's (round black donuts) that engendered this article but a few questions about how cars and tires are, or are not, matched to each other and by whom.

It may come as a bit of surprise to most of you that prior to the mid 1950's with the work of L. Segel and Milliken and publication in 1969 of the book Vehicle Dynamics by John Romaine Ellis of Cranfield University in England and a few internal publications such as A Primer on Vehicle Directional Control (Eng. Publ. A-2730) by R.T. Bundorf of GM that the analytical understanding of car dynamics was still, as John Ellis once said " just a continuation of the carriage business". Ride was a primary concern and the tire companies made black donuts to which the car companies matched springs and shock absorbers to the tires spring like properties to avoid uncomfortable vibrations and resonances. Recommended tire pressures were typically 24 psi.

In 1971 the director of engineering at one of the major tire companies was at the U. of I. to give a seminar on tires. After showing him John Ellis's book he asked where he could get a copy. I told him the University book store had it and he immediately went and purchased a copy. During the last 37 years or so the proliferation of high speed digital computers has allowed the solution, in essentially real time, of the multi-degree of freedom coupled differential equations that describe the motions of an automobile. This has lead led to a better understanding of the importance of tire properties and their relation to car control. Further, due to small size and cheapness of computer chips every car now has many built in to control various vehicle functions varying from the CD drive to the stability control systems and ABS brakes on literally every car sold in the U.S.. The cars are now smarter than almost all drivers, of course my self excluded.

The modern pneumatic tire is a truly remarkable engineering development. Think about it. Most people expect them to last 50,000 or more miles, to cost less than $79.95 (some think $39.95), to work in the rain, snow, ice, in100+ as well as -10 or 20 degree temperatures, hit curbs and pot holes some of which are larger these days, run over bottles, etc. and all with little or no maintenance. They are also expected to be quiet, stop quickly in emergencies, as well as get you around corners and keep ones duff comfortable. Amazingly they do!!! Additionally, on average, the typical car owner only has a flat tire once every 60,000 miles. No mean accomplishment. Clever people, these engineers.

Enough of that. A little history at this point is enlightening. Some interesting time lines and developments are:

1835   The first solid rubber tire is patented

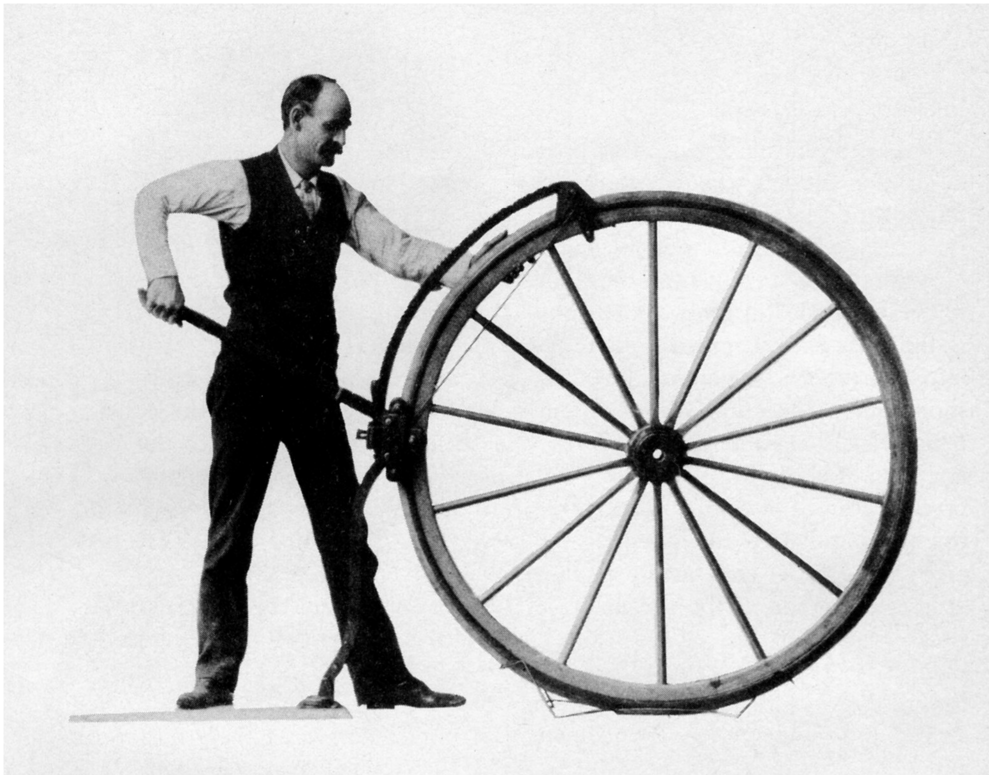

Figure no. 1 Ahhh, the good old days. Picture from “The Story of Tire Beads and Tires”, Mc Graw-Hill by W.E. Burton, 1954.

1845   Robert William Thomson patents the pneumatic tire and it includes essentially all of the elements of the modern tire except for the wire beads at the rim-tire interface.

1888   Dr. John Boyd Dunlop “reinvents” the pneumatic tire after his son complains about the ride of solid rubber tires on the cobblestones. It was made of 1/32” rubber covered with linen from a woman’s dress and was nailed to the wooden rim through the linen. They were often referred to as rags. Dunlop is said to have been irked when the older patent was discovered. Amazingly they also had a lower rolling resistance compared to the solid rubber tire.

1895   Michelin gets into the tire business when their company, which made rubber balls among other products, are asked to repair a Dunlop tire.

1905   The first pressed steel rim is developed.

1930 – 1936   The Michelin brothers develop the steel belted radial tire for use on trains since one of them disliked the clickety-clack of the steel wheels at the rails’ junctions.

1939   Michelin develops a steel belted radial tire for heavy trucks.

1946 – 1951 The Michelin X steel belted radial tire for cars is introduced (which in its initial form lasts into the 1960's). It is finally patented in 1951.

The Tire on the Car and Then Some

For Porsche and other sports car owners ride is seldom, if ever, the primary consideration in tire choice. Rather, the ability to stop in the shortest distance and turn at extreme gee levels is the major interest and almost without regard to cost (although at roughly $450 for a 997S rear tire it does give some second thoughts). The tire wear rate is also typically not a major player for the sport car types in contrast to the economy car owner. Some Porsche models, for example, barely get 8 to 10,000 miles out of the rear tires even under moderate driving. Typically wear rate and high performance braking and steering response are mutually incompatible. You normally get one or the other, but not both.

The important characteristics of rubber and the tire for braking and cornering are the maximum coefficient of friction and the cornering force as well as the latter's rate of build up with steering input. The properties of rubber are unusual and when it comes to its frictional properties everything you learned in high school physics about friction no longer holds. Additionally the tire itself is a very complex structure of rubber (a minimum of 8 or 10 different types or formulations), steel (belts, side wall support, and beads), and synthetic materials (nylon, rayon, Kevlar). All elaborately put together and then cooked (vulcanized) into this black donut we call a tire.

The primary focus here will be on tire performance and not ride. Ride, despite studies to quantify it analytically, is inherently subjective. What my mother liked was certainly not to my tastes. Further, it involves many subtle perceptions such as noise, vibration, softness, harshness, etc. which vary from one person to the next.

So how does the car and the tire finally come together to give us the feel and characteristics that are associated with, say a Porsche, compared to some other make and who makes these decisions. Why does it "feel" like a Porsche and not a Corvette or Mercedes ?

For all the analysis, design, and engineering that goes into making a car, relatively few people do the final "calibration" that determines the cars handling and feel and their dependence on the tire and it's properties. What happens, and this occurs many times before the final configuration is set, is John Doe Motors is working with various tire Manufactures and asks Igod Tire Inc. to bring some tires in for testing. Doe Motors has several test cars which have flares etc. to take any tire Igod shows up with, although sizes are normally specified in advance. When Igod shows up with a truck full of tires and their test driver they all, including Doe's test driver, go out to Doe's test track or Nürburgring along with various suspension components as well as mechanics and engineers to evaluate the tire-vehicle combination.

A set of previously approved, calibrated, and known tires are installed on Doe's test car and Doe's driver and the Igod Co. test driver each flog the car around the track for several laps . While the mechanics change over to Igod's first suggested new tire the two drivers go off to the side, different sides, and make notes etc. and then discuss them with their engineer in charge. Back to the car with the next set of proposed new tires and off they go again both flogging the car around the track. Then, like boxers, off they go again to their respective corners for more notes. Back to the calibration tires for another round. Then to the next set of Igod's new tires. You get the picture. This goes on until all of the prospective tires have been tested or the car or drivers give up in pain. Porsche, for example, had a skid pad test car with the seat installed at an angle so the constant gee loading on the drivers neck etc. would be reduced

Finally the drivers and test engineers get together to compare notes, comments, and conclusions. Doe's driver may say "...at the up hill 100 mph left hand turn leading to a slightly off camber short straight, I don't like the transition from solid grip to drifting " Igod's driver says "well it wasn't that …" and so on. At the end of the day Igod goes back home and makes up another batch of tires. They return in a couple of weeks for another go around until every one is "happy" or at least Doe. Of course, in the mean time the tires are checked for noise (some countries have restrictions on the noise the tire can make), wear, wet as well as snow and ice performance, and in some cases even "look".

That is how it is done. A few "expert" drivers make the final calibration. This assumes that none of the vice presidents or even the president, with their great driving expertise, override the decisions!

(Editor's note: Next month will feature Part 2, Some Tire and Vehicle Parameters That Affect the Story)