The Rubber That Meets The Road

The Pneumatic Tire

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Without the pneumatic tire, automobiles, trucks, motorcycles, and bicycles, as we know them would not exist.

The pneumatic tire is one of the most complicated and useful devices that is reliably manufactured by man and machine.

The safety and performance of a driven vehicle depend upon the interaction between the driver, vehicle, and tires.

Reflect on these three statements. The pneumatic tire has evolved to the extent that it is seldom considered by most people, except for the thousands involved in its design, application, and manufacture. The rubber tire has long intrigued me since I was first exposed to its complexities in the quest to obtain better performance on the race track. Most people give little consideration as they hurtle down the highway at speed in a 3,000 or 4,000 pound car that their control, their safety depends upon the interaction of 4 small patches of rubber, about 30 square inches each, with the road surface. Even among those involved in the automobile hobby in its broadest sense, except for racers, there is little understanding and appreciation of the pneumatic tire's complexities in manufacture and its impact on vehicle dynamics. Therefore, in keeping with this column's emphasis on basics, I thought some attention to tires would be appropriate. Even scratching the surface will take several columns. So, let's begin.

A Definition

"In its simplest form a pneumatic tire is a doughnut-shaped balloon with enough air pressure in it so four tires can support the weight of a car. The strength needed to hold the internal pressure and external loads comes from a flexible but amazingly strong "construction" of textile "cords" bonded in a rubber matrix. Strong bands of steel wire called beads hold the inside diameter of the tire onto the wheel rim. A rubber "tread" glued onto the outer diameter of the construction provides a road-contact surface that has good traction and wear characteristics. Rubber, with its elasticity and natural adhesion, is what makes a tire so useful." — Paul Haney, *The Racing and High Performance Tire*, 2003

A Tire's Complexity

The technical literature on rubber and tires is extensive as various experts have studied and tried to understand both the application of the materials – rubber, cord, steel – and the manufacture and operating characteristics of the pneumatic tire. A couple of individuals, far more expert in these subjects than I, attempt to put a tire's complexity into words.

"Those of us who are active in research and development as applied to rubber-

like materials are well aware of the truly inter-disciplinary nature of the tire-to-ground traction. Physics, chemistry, metallurgy, dynamics, tribology, thermodynamics, heat transfer, elasticity, viscoelasticity, rheology, elastohydro-dynamics, and lubrication technology play complex and intertwined roles in determining the magnitude of the frictional coupling that ultimately exists in the contact patch. It has been claimed that at least 50 variables are operative during the simple free rolling of a pneumatic tire." — D. F. Moore, Symposium on The Physics of Tire Traction, 1973

1940 Buick Special

"If you want to appreciate the complexity of a tire you need to know that it has maybe 18 different components. Two of them: the bead and the belt, are made of steel. The others are some type of polymeric system which can give a different mechanical response depending on time, temperature, or frequency variables in the operating condition of the tire. These components are all interlinked either in series or parallel or combinations thereof in both the normal – up and down – loading of the tire by the suspension, torsional for steering, and shear or lateral slip for acceleration and deceleration. These 16 rubber components are comprised of maybe 12 to 15 ingredients on an average which have their own normal variation during production, especially natural rubber, which is a product of nature." — Lou Gatti, ACS Tire Symposium, Spring 2001

A Practical Tidbit

With each subsequent column I will try to provide some of the underlying theory to enhance your appreciation of the pneumatic tire along with some practical information that may be of use. The contact patch, the area of the tire that helps accelerate, brake, and steer a car, depends upon the applied load, the internal pressure, and the width of the tread. The variable size of this patch is easily calculated.

As an example, let's examine a 4,000 pound 1940s vehicle riding on period tires which typically have a tread width of 4 to 5 inches and an air pressure of 25 psi (often recommended in Owner's Manuals) or an air pressure of 30 psi (a commonly recommended tire pressure). The area of the contact patch is the load (weight of car), divided by 4 (4 wheels equally loaded [this equal weight distribution seldom occurs]) divided by the air pressure.

4000 lbs/4 wheels/25 psi = 40 square inches

If the tread width is 4 inches wide, then the contact patch is 10 inches long [40 sq.in./4 in.]. If the tread width is 5 inches, the contact patch is 8 inches long.

Repeating these calculations for the same car with tires inflated to 30 psi, the contact patch is 33 square inches; note the patch is smaller. The corresponding

patch length for a 4 inch wide tire is 8.25 inches and for a 5-inch wide tire it is 6.6 inches.

There are many practical implications to these facts. For example, less air pressure puts more rubber in contact with the road. Sometimes this is a good thing, sometimes not. For the best steering and handling characteristics, a wider tire with a shorter contact patch is better than the opposite. Why this is so will be explained later in another column.