

## Just The Basics – 8 - The Friction Circle & Slip Angle

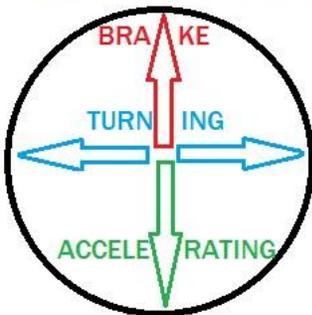
The late, great Mark Donahue was one of the world's best racing drivers of the 60's and early 70's. In addition to numerous Can-Am, F1 & F5000 victories, he held the closed course speed record of 232 MPH, in a Porsche 917-30, like the one pictured here. It was a record that stood for THIRTY years. He also had a degree in mechanical engineering.



He was also famous for his contributions to high performance driving theory. The concept most recognized by the general public was his idea of racing on 'bald' tires. The idea was that the bald tires would have a larger 'contact patch' with the road and there would not be any flexing of the tread blocks, known as 'tread squirm'. He postulated the result would be better and more predictable handling in the turns. When all the tread was removed they didn't last long, so he convinced his tire suppliers to make some tires without treads. We now know them as racing "slicks".

Another concept of his is the "**Friction Circle**". The "Friction Circle" deals with tires and how they interact with the road surface at the limits of adhesion.

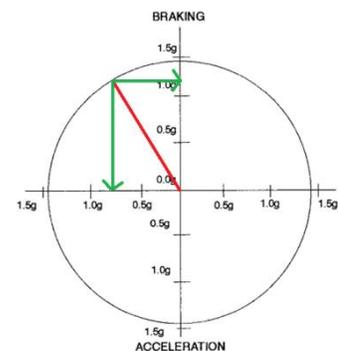
### FRICION CIRCLE



In discussing the Friction Circle we need to begin with some physics. Most of us know a law of physics that states a thing in motion has a tendency to stay in motion. And a thing at rest tends to stay at rest, unless acted upon by outside forces. When it comes to cars and driving, these outside forces are acceleration, braking and turning. Changing the course of the car generates friction. The more friction you can generate and manipulate the car will be quicker and handle better.

The Friction Circle says that a tire can generate 100% of its maximum potential (threshold) either by turning, braking or accelerating. These threshold limits can be represented by a

circle. When you start combining turning with braking or accelerating, you begin to lessen the threshold limits of each. The second drawing shows what happens to the limits when braking and turning are introduced. The red line shows the direction of travel. The braking limits are reduced by 30% and cornering ability is reduced by 50%. If you are at the threshold, and you attempt to add more turning, braking or acceleration, you will exceed the tires capability and the tire will go off in the direction of travel. On dry asphalt roads, when you exceed these limits of friction potential, the excess friction will cause the rubber on the tire to melt. If not controlled by the driver (or driver aids such as ABS, PSM, PASM, et al) the tire will hydroplane on this melted rubber, leaving a "skid mark". This is why DE instructors will tell you to brake in a straight line and to take turns with "even throttle" – neither accelerating nor braking. This allows the maximum limits to be utilized. The Friction Circle is not static for a given tire. Many factors can change the size of the circle including tire design, road surface, weather conditions, speed (inertia) and the weight load the tire is carrying.



Design: a soft “high performance” tire that is good for about 15,000 miles has more friction generating potential than a hard compound tire that has a 60,000 mile warranty.

Surface: asphalt provides more friction potential than dirt or sand.

Weather: warm dry weather allows tires to get better traction than cold or wet weather.

Speed: you can negotiate a right turn onto another street at 10 MPH easier than trying the same turn at 70.

Weight: Think of those up North who used to put bags of sand in their trunk to get better traction in snow. As you accelerate, brake or turn, the weight of the car shifts. The nose dives down upon braking, the rear end squats under acceleration, and the body rolls towards the outside of a turn. The more weight you put on a tire, the better it will grip.

Anti-Lock Braking systems (ABS), Stability Management Systems (PSM/PASM) and other driver aids were developed to help prevent exceeding the thresholds of each tire while allowing some steering input all within a fraction of a second. These will help in an emergency situation but they cannot save you in all situations.

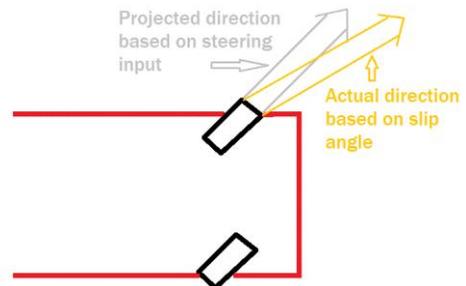
The bottom line is that the laws of physics define the “Friction Circle” and it applies in any set of circumstances.

**Slip Angle** is the term used to define the difference of the angle of the steering input versus the actual direction the tire travels.



Tires are air filled rubber balloons around the wheels. The rubber flexes up and down, which absorbs road imperfections and the like. It also flexes side to side. The more friction induced in a turn, the more the flex. The diagram to the left gives you an idea of a cutaway view at the “Contact Patch”, where that portion of the tire is in contact with the road.

The individual tire tread blocks also flex, called tread squirm. Remember what Donahue’s solution was for this? When the tire is not in contact with the road, the tire attempts to return to its normal, ‘non-flexed’ position. As the tire rotates to the contact patch again, that portion of the tire starts flexing again. The result is the line or angle the tire takes is going to be less than that of the wheel. See diagram at the right. Think of it like ‘crabbing’. The more the tire can flex combined with more friction (speed, steering input, etc)



the greater the slip angle. As tire manufacturers built in more grip to the tires, they ran into an issue of having the tires roll off the wheel rims. The answer was to reduce the side wall height (or aspect). The photos show the aspect, measured in inches, for a GMC Envoy (4½”) and a Porsche Boxster (2 3/8”).

When on the track, we are concerned about another large part of the slip angle pie that lies between the tire and the road surface. The tire can slide over the road surface and grip can actually increase. The rule of thumb is that a slip angle of 10° or less is the most efficient. A slip angle of 7° is considered ideal. More than 10° and you will be sliding too much to get the maximum out of the tire. Experiencing this and learning how to find the limits of the tire is part of what makes DE’s fun.