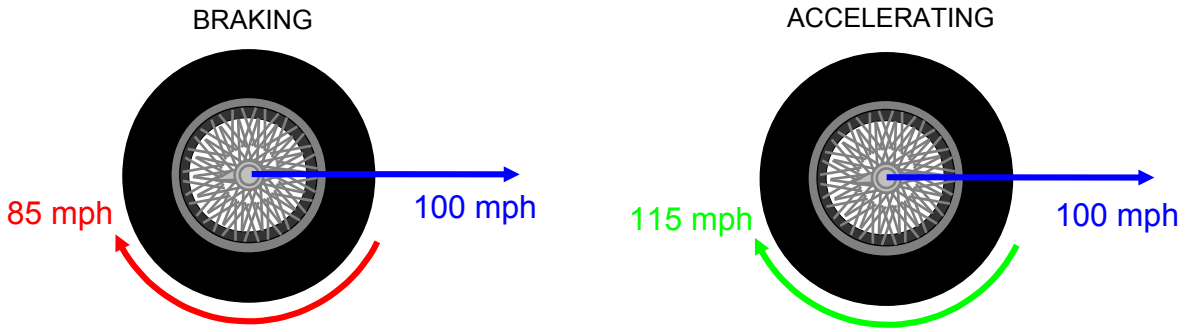
Understanding “The Limit”

In one of our newsletter submissions we discussed testing the limit; in another we discussed how proper use of the eyes allows us to maintain the car at the limit. But what does all this “limit” business really mean? If you ask your average Walter Mitty, particularly after he’s unwound at the Inn, he’ll tell you that it’s a frightful place to visit. He’ll tell you how with veins popping and jaw clenched his white knuckles managed lap after lap to wrestle his raging mount from the very brink of death and destruction. This is a bunch of BS, of course, even if the guy *is* an Allard driver.

“The Limit” as we in this sport generally refer to it is not a point of no return... it’s not like the slot car that suddenly departs the track and goes flying into the sofa. Nor is it a literal term. According to Merriam-Webster the limit is something that “bounds, restrains, or confines.” Guard rails, Jersey barriers and tire walls would be good examples. And while many drivers, including yours truly, have reached these unfortunate limits they are not the kind of “limit” we’re looking for. In fact, we’re not looking for any kind of limit at all. Instead, we’re looking to exact the maximum potential out of our vehicles, and whether accelerating, cornering or braking, this maximum potential is found in very subtle “sweet spots” that are somewhat removed from and much harder to find than true limits. A car driven at “The Limit” will feel almost exactly the same as it does when driven 5% under or 5% over the limit. There are, of course, distinct limits in driving, such as tires locking-up under braking or lighting up under acceleration, but if these extremes factor much into our driving then we’re a long way from “The Limit” used to describe a car’s ultimate performance. We’ll revisit the visceral perspective in a bit. First however, let’s do a little dissecting...

PERCENTAGE SLIP / SLIP RATIO

Most novice drivers of vintage and purpose-built race cars have their first brief flirtations with Percentage Slip, or Slip Ratio, on their way to total brake lock-up. This usually occurs soon after they realize, a little too late, that they have too much speed coming into a given corner. The braking foot presses harder and all of a sudden the steering goes numb and tire smoke starts to curl into the cockpit. Just before that happened, however, the driver experienced what is called “Threshold Braking”... his tires were spinning slightly slower than the pavement was passing beneath them.

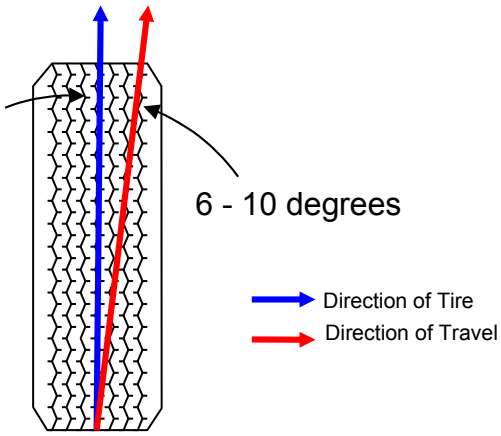


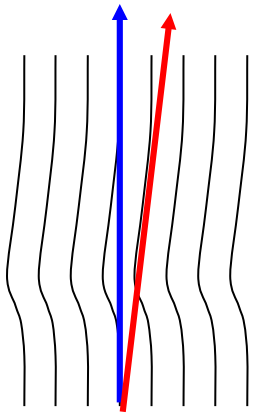
As illustrated above, a tire produces its greatest grip, under both braking and acceleration, when generating a slip ratio of approximately 15%. Normally, when a vehicle is traveling at 100 mph the surface of the tire is traveling at exactly the same speed. If we’re threshold braking, however, we’ve slowed the tire surface down so that it is traveling, in this example, only 85 mph. Under what could be called threshold acceleration, our example shows the tire surface spinning 15mph (15%) faster than the pavement passing beneath. Understandably, tires being treated this way often complain and the scuffing and chirping sounds they make are very distinct from the howl and screech of a locked or spinning tire. With full racing gear and a loud exhaust

note it's impossible to actually hear a tire at threshold level, though in our driving school there is a corner entry exercise that allows the driver to hear this feedback. Without auditory clues, we have to rely on feedback from the car. If the steering starts to feel light, the nose of the car darts to the outside of the corner or tire smoke appears from the front wheel wells, we can be pretty certain we've locked our front brakes. If we see smoke from the rear wheels and/or the tail end starts to come around, we can assume we've locked our rear brakes. Obviously, if all of these things are happening at once the driver is likely staring with pie plates at something ahead that wasn't there the last time around. And if we're traveling backward up the hill in NHMS's Turn 4, with tire smoke pouring out of the rear wheel wells, we can assume we're using a little too much throttle.

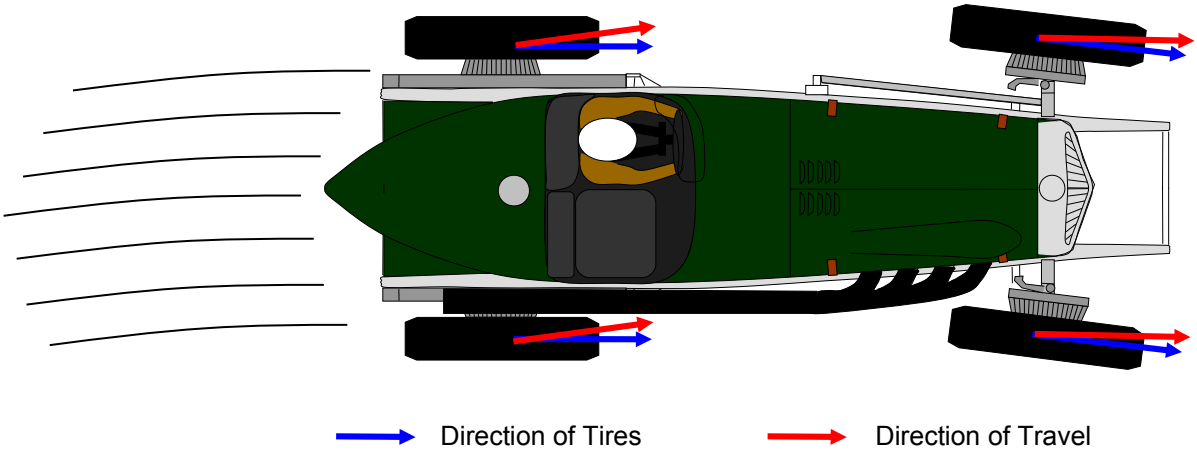
SLIP ANGLE

Like the term "The Limit", the term "Slip Angle" is actually a misnomer because, unlike the "slip" we discussed relative to braking and acceleration, the tire tread at the limit under cornering isn't actually slipping across the pavement. Instead, it's experiencing the automotive equivalent of an Indian Burn. The illustration on the left below shows a tire that is producing its maximum possible grip under cornering loads. The blue arrow shows the direction the tire is pointed, while the red arrow shows the direction the tire is actually traveling. The difference is called the Slip Angle. The illustration on the right shows the deflection of the Contact Patch (the portion of the tire touching the road) that creates this phenomenon. As the tire tread meets the pavement it is literally twisted and deformed toward the inside of the corner, and then, as it breaks contact with the pavement, it springs back in line with the rest of the tire tread.





So the tire producing a "Slip Angle" isn't really slipping across the pavement, it's merely being tweaked so much that it actually begins steering itself to the outside of the turn. In poor grip conditions, such as rain and snow, our slip angles are in fact caused by the tire literally slipping across the surface of the road, but in doing so they may not necessarily be generating the greatest possible grip (which is another subject entirely).



For our purposes the classic “Four Wheel Drift”, illustrated above, shows slip angles being used to their greatest advantage. It’s important to note that the front tires, while pointed into the corner, are actually traveling more or less straight and it is the slip angle of the rear tires that is turning the car through the corner. The distinction between the steering angle turning the car and the slip angle turning the car, which we experience viscerally, or in our nether-regions, represents the “sweet spot” that tells us that we’re driving the car near its limit. Instead of the front end pulling us around we feel the back end swinging us around. And this brings us back to the visceral perspective...

IDENTIFYING THE LIMIT

It’s said that whenever Hans Stuck is given a new race car the first thing he does is unbolt the seat and throw it away. This is probably apocryphal... who could possibly race a car without a seat? It’s more likely that he takes the padding out of the seat and throws that away. First off, he’s tall enough not to need the extra boost and, secondly, he has remarked on the importance of being firmly in touch with car. The phrase “driving by the seat of his pants” is not a pejorative in racing; it describes a driver who is maximizing his ability to receive feedback from the car.

This is where our slide rules, dynamic modeling CAD programs and Computational Fluid Dynamics software are subordinated to the carbon-based instrument between the seat and the steering wheel. Once a driver learns where to place the car, i.e. the “racing line”, he must then concentrate on what the car is doing on that line. In order to determine a) whether he is producing slip angles and b) whether these slip angles are balanced between the front and rear of the car, a driver must be very sensitive to both slip and yaw. Yaw describes the extent to which a car is rotating around a vertical axis. In airplanes, yaw is induced with the vertical stabilizer (rudder). We’ve all probably seen, or been a passenger on, a plane landing in a strong crosswind. The plane crabs or slides while traveling on a straight line toward the runway, with the pilot applying enough rudder to offset the speed of the crosswind. If we’re driving our car to maximum potential we’ll spend a great deal of time, particularly on corner entry, with the car in a similar but more subtle slide, where the rear tires are generating slightly larger slip angles than the front tires.

Judging the percentage of slip from the driver’s seat is, admittedly, a little tough… manipulating this slip accurately is tougher still. Those who have sailed will understand the analogy of perfectly trimmed sails, where a minor adjustment of sheet, vang or Cunningham will yield an improvement in speed that is barely discernable but very real. Likewise, truly skilled drivers make only very slight adjustments with steering, brake and throttle while keeping their tires always near optimal slip angles. When you see a driver working really hard behind the wheel, chances are he isn’t spending much time near optimal slip angles. At times this is due to the handling characteristics of the car, but most often the driver is making a dramatic correction in an effort to compensate for the poor condition created by the prior dramatic correction. He is, in other words, chasing his tail.

It can take years to become a truly smooth and quick driver, particularly when we do only a handful of racing events each year. Further, at these events we're traveling very fast and we're surrounded by other drivers chasing their tails. Simply put, races are not the best place to learn how to become a skilled driver… there's simply too little seat time, too much going on and the potential consequences of a mistake are simply too dire. This is why VRG offers its Level 2 school, for more advanced drivers. The perpetual corner known as a skid pad, combined with various other exercises, provide a low-risk venue where repetition, observation and coaching are used to hone a driver's skill and sensitivity, and all of this is done in the same car the driver will actually be racing. If you think there may be room for improvement in your driving ability, or you simply want to get back in form for the coming season, we highly recommend a visit to our Level 2 school.