Suspension Dynamics

To optimize the performance of your car's suspension it's essential to have an understanding of suspension dynamics. This includes and understanding of the concepts of "oversteer" and "understeer" and what must be done to correct these conditions when necessary. Now, I'm sure many of you know what oversteer and understeer are, but you may not have a complete understanding of what causes these conditions. Still others may have no idea what understeer and oversteer are. So, we'll start by discussing some suspension basics and work our way on from there.

If you follow any type of auto racing, you may have overheard conversations between the driver and pit crew where the driver tells the crew that the car is "pushing" or the car is "loose". There are actually referring to understeer (push) and oversteer (loose) conditions.

During hard cornering the weight of the car shifts away from the inside wheels toward the outside wheels. The softer the suspension, the more weight is transferred to the outside wheels. The added weight on the outside wheels causes the outside tires to grip better allowing the car to steer safely through the turn. With a perfectly "neutral" suspension setup, the weight would transfer such that the front and rear tires would have the same amount of grip and, at the limit, both tires would lose traction at the same time.

If the suspension is set up so that, during cornering more weight is shifted to the outside rear tire than the outside front tire, then the rear tire will have more grip during cornering than the front tire. So, the front tire will lose traction before the rear. This is referred to as ***understeer***. The effect is that the car takes a wider radius curve than the drive intended. The reason you hear this referred to as "pushing" is that the driver feels the rear of the car trying to push the car off of it's intended line.

Conversely, if the suspension is set up so that, during cornering more weight is shifted to the outside front tire than the outside rear tire, then the front tire will have more grip during cornering than the rear tire. So, the rear tire will lose traction before the front. This is referred to as ***oversteer*** or as the car being "loose". The effect is that the rear wheels steer a wider path than the front wheels, rotating the car more than the driver intended, forcing the car into a smaller radius turn. Most passenger car suspensions are designed with a certain amount of understeer because it is much safer than oversteer. If the car understeers, the car makes a wider turn than intended, but the car remains stable. If the car oversteers, the car makes a smaller radius turn. This increases the cornering force on the outside wheels which brings the rear wheels even closer to the point of losing traction. This results in even more oversteer. If no correction is made, the situation will continue to become worse until the rear wheels lose grip completely, the car spins, and all control is lost.

Realize that the above discussion assumes a constant velocity during cornering. Even in a car with a completely neutral suspension setup, you can induce oversteer or understeer via acceleration or braking during cornering. And, the effects of acceleration are different depending on whether the car has FWD or RWD.

Ideal Setup?

So, the big question you might ask right now is "What is the ideal suspension response - oversteer, understeer, or neutral?" The answer - all three. During straight

line acceleration, a slight amount of understeer is desirable because it makes the car very stable, requiring few driver corrections to keep the car moving in a straight line. At the turn in point, you again want a slight understeer to keep the car stable while the brakes are being let off and cornering forces are building up. Through the apex, neutral steering is desirable as the car's cornering traction is at is maximum and it allows the car to drift through the corner should you come in a bit too hot (instead of having the front or rear lose traction in the middle of the turn). And finally, at the turn-out a slight amount of oversteer is desirable to allow the car to take a tighter path through the turn-out.

Slip Angle and Suspension Dynamics

Now we're going talk about oversteer and understeer using a new term called slip angle. The concept of slip angle is a little more complex. However, understanding slip angles is essential to understanding how acceleration and braking affect steering.
When you're driving along in a straight line the car, wheels, and tires (including the tread on the tires) are all moving in the same direction. However, when you make a turn, the treads on the tire which are in contact with the ground (contact patch) resist the turning action due to friction between the tire and the ground. Due to the elasticity of the tires, the tread will distort creating an angular difference between the treads in the contact patch and the direction the wheel is turned. This angular difference is referred to as slip angle. When more weight is transferred to a particular tire, the slip angle increases because the tread in the contact patch area develops a higher resistance to turning (due to the increase in friction between the contact patch and the ground). So, when the slip angle of the rear tires is greater than the front tires you have oversteer. Likewise, when the slip angle of the front tires is greater than the rear you have understeer. And finally, when the slip angles are the same, you have neutral steer. So you ask, "where is all this leading?" Bear with me and hopefully it will all become a bit clearer shortly.

Steering Response Under Acceleration

As I mentioned before, acceleration and braking have an effect on steering dynamics. If we consider a neutral steering car that is cornering and we accelerate the car, tractive force from the engine is applied to the drive wheels. Tractive force is the force applied by the engine necessary to overcome the force of gravity and cause the car to move. This force is ultimately felt between the tire and the ground which causes the tread on the contact patch (already distorted from turning) to distort even more, thus increasing the slip angle for the drive wheels. As we stated, if the car had neutral steering before acceleration was applied, it will cause oversteer in a RWD car (increased slip angle in the rear tires) and understeer in a FWD car (increased slip angle in the front tires). Is it starting to make sense?

Steering Response Under Braking

During braking, there is a weight shift from the rear of the car toward the front of the car. This applies more weight to the front tires increasing the front tire slip angle and inducing oversteer. In this particular case, it's very easy to put the rear of the car into

a spin if you enter a corner carrying too much speed, panic, and get on the brakes. The effect is similar if you're on the throttle in a fast corner and suddenly lift (take your foot off the gas). Rear engine cars are particularly bad about spinning out the rear if you lift in a turn due to the high concentration of weight behind the rear wheels.

Handling Corrections

Now that we've discussed what oversteer and understeer are and what causes each, let's take a look at what can be done to correct oversteer or understeer conditions.

Oversteer Corrections	
Front Suspension	**Rear Suspension**
Stiffer front springs	Softer rear springs
Front sway bar or a thicker one	Thinner or no rear sway bar
Lower front tire pressure	Higher rear tire pressure
More positive front camber	More negative rear camber
Add weight to the front	Remove weight from the rear
Less down force in the front	More down force in the rear
Narrower tires in the front	Wider Tires in the rear
Stiffer front shocks	Softer rear shocks
Understeer Corrections	
Front Suspension	**Rear Suspension**
Softer front springs	Stiffer rear springs
Thinner or no front sway bar	Rear sway bar or a thicker one
Raise front tire pressure	Lower rear tire pressure
Softer front shocks	Stiffer rear shocks
More negative front camber	More positive rear camber
Remove weight from the front	Add weight to the rear
More down force in the front	Less down force in the rear
Wider tires in the front	Narrower tires in the rear
More positive caster.	Limited slip rear differential or stiffer rear diff