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PART II

SUSPENSION Tech

BY MARTIN MUSIAL (WWW.AUTOMOTOSPORTS.COM)

IN OUR LAST INSTALLMENT of suspension tuning we covered the basics. Suspension 101, as easy as it gets. Unfortunately performance handling is not an easy topic to understand. It's important to get the basics down before you dive into dialing in your ride for optimal handling. The worst thing you can do is go to the autocross track or road course and start messing with dampening, ride height, and tire pressures without knowing how they will affect the control of the car. This can lead to an embarrassing situation where you wind up spinning out into the grass, or worse, smash up your beauty into a concrete wall.

We equipped our Lancer Evolution VIII with some adjustable suspension components and took her to Talladega Grand Prix for a suspension tuning session. In four lap sessions we kept adjusting the suspension until we got to the point where the car was fast around the track and safe to drive. I'll start by explaining some of the key components and ideas of what makes a car handle well and then get into examples of how changing settings made the car respond better on the track.

TIRES

We're starting with tires because they have the single most pronounced effect on how your car will handle. I don't mean put on wider tires and then you car will handle 1.5Gs, I'm talking about how the tire interacts with the road. Traction is what will make your car turn, accelerate, or brake. How much traction you have is a function of how many rubber molecules (contact patch) are touching the road and how much weight you have on that contact patch.

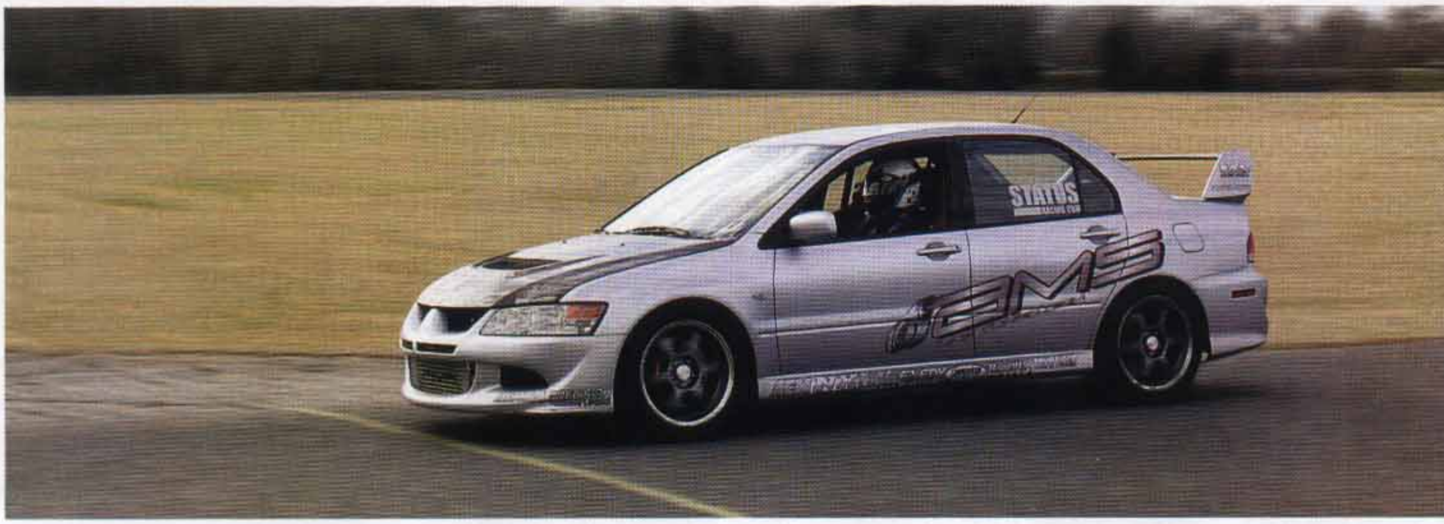
One way we can increase traction is to increase the vertical load on the tire. Just put more weight in the car and the tire will have more traction, right? Not so. The relationship between traction and vertical load is not a linear one, meaning the two are not increasing at the same rate. If you put 100% more vertical load (weight) on a tire you will only get back 90% more traction. Now this same tire has to handle 100% more cornering load with only 90% more traction, not a winning combo. One way vertical load does help cornering is downforce. Formula 1 cars have tremendous amounts of downforce created by aerodynamic forces. As the Formula 1 car takes a corner at high speeds the vertical load on the tire might increase by 150%. But because the downforce only imparts a vertical load and not a side load like adding weight would, there is now 150% more traction available with 0% added corner load.

The other way to increase traction is a larger contact patch. A wider tire is the first thought that comes to mind, but there are other and possibly better ways to do this. The contact patch doesn't always maintain the same area as the car is in motion. With the suspension compressing under load and the camber changing we might lose some of our contact patch. Adjusting the suspension geometry and minimizing the suspension movement can alleviate this problem. Tire pressures also plays an important role in the size of the contact patch. There is an optimum pressure range that will give the largest contact patch. Experimentation and tire temperature readings will reveal this setting.

CENTER OF GRAVITY & WEIGHT TRANSFER

I'm sure all of you at one point have raced your friends at a go-kart track. I bet you were pretty surprised how well they took corners with such skinny tires. Now I'm also sure that most of you at some point, have ridden in a minivan or for the lucky few, a fully done conversion van. A hot ticket to ride no less, but unfortunately probably the worst handling vehicles on the road. The reason I'm comparing go-karts to conversion vans is simple, center of gravity and weight transfer.

The center of gravity is an imaginary point at which you could suspend the vehicle and it would maintain equilibrium with no force acting upon it. It's an imaginary point at which the average of the mass of the car is located. Huh, you say? Center of gravity has to do with mass and its location. A Honda that is front wheel



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drive and has the engine located up front will have it's center of gravity further forward than an NSX for example, which is rear wheel drive and is mid-engine. This means more weight is put on the rear tires of the NSX. Remember that vertical load on a tire increases traction but not proportionately. Ideally we'd want a 50/50 split, meaning that center of gravity would be in the middle of the car with the front tires and rear tires sharing an equal load. The same goes for lateral center of gravity; we want the weight in the middle, not offset to one side. A car with a good suspension design and a 50/50 weight distribution will handle very neutral and be easy to drive fast.

Vertical center of gravity is interesting. Many people don't realize how important it is to the handling characteristics of the car. Just like the conversion van, a top heavy car will have tendencies to roll during cornering. The location of the center of gravity will cause weight transfer during any type of acceleration. Weight transfer occurs during acceleration, braking, and cornering. The higher the center of gravity the more weight transfer will occur. In a right hand turn the weight will transfer to the outside (left side) tires. As weight transfers we increase vertical load, and remember we lose total grip capacity as we increase vertical load on a tire.

So now that we know we want to reduce weight transfer, what can we do about it? The first thing we can do is lighten the car. The less the car weighs, the less weight will be transferred. Removing unnecessary components or swapping out heavy items for trick lightweight pieces are some things that can be done to reduce weight. Another thing we do is widen the wheelbase. Although a little harder to do, we can use wider rims with a different offset to place the center of our contact patch further away from the vehicle. Thirdly, we can lower the vertical center of gravity. This is tied in with reducing vehicle weight, but where you remove the weight will determine how much you lower the center of gravity. Swapping out those heavy power seats for some lightweight composite buckets and lowering the seating position an inch or two can have some drastic effect on how the car handles.

UNDERSTEER & OVERSTEER

If the front tires lose traction first we have a condition called understeer. The car will push the front wheels and it will try to go in a straight line instead of turning into the corner. Although it can be dangerous, understeer is more controllable than oversteer. With oversteer the rear tires loose traction first. The back end of the car will kick out and can go into a spin. Obviously neither way is the fast way around a track. A neutral handling car will slip out of the intended path equally on all four tires, giving great feedback and not pushing either end of the car around. The vehicle's tendency to oversteer or understeer has to do with the location of the center of gravity, the suspension setup, and driver input. We will now look at the complications of suspension settings and how they will affect weight transfer, understeer and oversteer. But before we do that I want to give a brief summary of what happens when you go from a high speed straightaway to a slow right hand corner.

There are three parts to taking a simple corner: how you enter the corner, how the car responds during steady cornering, and how you exit the corner will all determine how many

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To fix mid corner and corner exit handling characteristics we looked over the spring rates. We would like to see a higher rear spring rate in the rear, something along the lines of the 500-600 lb/in range. A higher spring rate will increase roll resistance and will keep a larger contact patch. Higher spring rates also increase how fast weight transfer is occurring. A car with very soft springs will exhibit a lot of body roll and will wallow into turns. A car with hard springs will not lean and the weight will transfer quickly to the left side wheels. The quicker you transfer weight to a tire the quicker you will approach its traction limit, making the car snappier. Unfortunately we didn't have stiffer springs with us; we took note to change them once back at the shop.

We also looked at the tires, since tire pressure will affect the contact patch. We noticed the outside of the front tire getting hot and wearing quicker. This can be caused by a few things. Tire flex will allow the tire to roll over and wear on the outside. Camber changes during body lean and suspension compression can lead to a positive camber and put the contact patch on the outside of the tire. We decided that we could change the camber from -2.5 degrees to -3 degrees to help maximize our contact patch. We also upped the pressure in front a few psi to reduce tire flex and to try to increase the contact patch. The rear tires were showing no signs of roll over or wear on the outside. In fact it looked like the tire wear riding less on the outside than the inside. An overinflated tire will bubble out and ride more on the middle of the tread than the outside edges. We dropped a few psi on the rears to see if we'd get more even tire wear. Also noted was that we could probably change our rear camber from -1.5 degrees to -1 degree for the next test session.

With a good grasp on fixing the mid-corner and corner exit, we tackled the corner entry problem.

Corner entry is a little tricky because of the transition from braking to cornering introduces a lot of dynamics into the suspension. A lot of things are changing and we need to control how the car settles from braking transition to cornering. If we are deep into a corner and the suspension still hasn't settled from entering the corner, we need to quicken the response of the suspension. If the suspension reacts too quickly then we run into the same problem of the driver not being able to feel the car as it's approaching it's traction limits. If we change the balance of how the car will settle into the turn we will change the understeer or oversteer characteristics of the car. In other words quicken or slow down the response of the front or rear of the car to make it do what you want it to. Since we wanted to reduce the amount of understeer, we tightened up the dampening in the rear to 12 and kept the front the same. Stiffening the rear anti-roll bar or increasing the rear spring rate will also have the same affect. All of these settings need to be done in balance; you can't have a very stiff roll bar to compensate for soft springs.

Upon succeeding laps the car handled more neutral and lap times dropped. Each lapping session the tire pressures were tweaked, dampening settings changed and camber adjusted. At the end we made the improvement we wanted and the car was fast around the track but was still safe to where a new driver could get into the car and not get himself into trouble. After a total of 40 laps of abuse we were at the point where next time we can throw in another 50-75 horsepower at it. Even at the low horsepower level we were running on the EVO VIII, Krolewicz wound up beating the SCCA track record for the competing class.

As you can see there is much physics behind suspension tuning. I briefly touched on a few important subjects and hopefully gave you a grasp on how to dial in your suspension. The key for beginners is to do small changes at a time and understand what each change will do. If you really want to dive into the mechanics behind suspensions there are many books out there that will swallow up your free time and give you the information you desire. For track time look into local SCCA (Sports Car Club of America) or other car club chapters as they organize high speed autocrosses at road courses around the country. Happy turning!

seconds you can shave from your lap time. One optimal suspension setting for mid-corner might not be optimal for corner entry, let me explain.

CORNER ENTRY

Coming down from a 120 mph straight we enter a slow right turn. Hitting the brakes we transfer weight to the front tires and unload the rear tires. We now have more traction available up front compared to the rear. As we turn the wheel right we are now going to impart weight transfer from the right side to the left side wheels. Now more weight is on the front left wheel than any other wheel on the vehicle. More traction is now available to that wheel but remember that our gain is not linear with the weight transfer. If we transferred 40% more weight on that front left wheel we might have only gained 30% more traction. If we could have altered the vehicles center of gravity, total weight, and track width, we might have only transferred 20% of the weight and only lost 4% traction potential instead of 10%. The important thing to understand is that in corner entry when under braking, we have sudden weight transfer to one of the front tires and we unload the rear tires. Depending on how we setup the suspension this can lead to understeer, oversteer, or a neutral handling condition.

MID-CORNER

In the middle corner we are not accelerating or braking much, possibly just holding the throttle down a bit to keep our speed constant. At this point the suspension has settled down and we are not suddenly changing weight transfer. The outside (left) tires, front and rear, on our car are now carrying more vertical load than our inside tires. We can call this a steady state condition. Again the car can respond by oversteer, understeer, or neutral handling depending on how we setup the suspension.

CORNER EXIT

Corner Exit is similar to mid-corner but we are applying more throttle, thus accelerating and transferring weight to the rear tires from the front. The car will respond similarly to mid-corner suspension changes. How much power is available will determine weight transfer. Get on the gas too hard and you spin the driving wheels, leading to understeer or oversteer in the rear of a front wheel drive car.

To simplify suspension tuning, I'll relate our track experience with our EVO VIII to how the suspension was set up and what we did to improve handling at the track.

Here are the initial settings.

FRONT

Camber: -2.5 deg camber
Toe: 1/16-inch toe out
Tires: 255/40R17 TOYO Proxes RA-1
Tire Pressure: 40psi
Struts: Buddy Club Racing Spec (15 way adjustable)
Dampening: 7 (out of 15)
Spring rate: 560 lbs/in
Sway Bar: Cusco 25mm sway bar

REAR

Camber: -1.5 deg camber
Toe: 0 toe
Tires: 255/40R17 TOYO Proxes RA-1
Tire Pressure: 40psi
Shocks: Buddy Club Racing Spec (15 way adjustable)
Damping: 7 (out of 15)
Spring Rate: 336 lbs/in
Sway Bar: Cusco 23mm sway bar

If you notice we left the adjustable settings right in the middle to start out with. Our test track was Talladega Grand Prix raceway, a 1.3 mile road course. The test driver was Jon Krolewicz, an experienced driver with a couple of 24 Hours of Daytona in a Lemans prototype racecar under his belt. Krolewicz took the car out for four laps at a time and then we'd make adjustments according to how the car was responding. For the road course I installed the smallest turbo in our EVO VIII turbo-kit lineup, the GT3071R. Running at minimum boot, 15psi, we were running a conservative 360whp on 100 octane gas. If you're dialing in the suspension you cannot throw lots of horsepower at it. First you must always get the suspension right and then slowly start adding horsepower. Many times you find that as you add horsepower you will have to upgrade and adjust the suspension to keep up with the extra power.

On the first four laps Krolewicz noticed the car understeering. The car would understeer in mid-corner and corner exit and it didn't want to turn-in (rotate) as well under corner-entry. The car would exhibit body roll and push it's way around corners.