

The Mark Ortiz Automotive
CHASSIS NEWSLETTER

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MOTORSPORTS COMMUNITY

July 2010

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WELCOME

Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. This newsletter is a free service intended to benefit racers and enthusiasts by offering useful insights into chassis engineering and answers to questions. Readers may mail questions to: 155 Wankel Dr., Kannapolis, NC 28083-8200; submit questions by phone at 704-933-8876; or submit questions by e-mail to: markortizauto@windstream.net. Readers are invited to subscribe to this newsletter by e-mail. Just e-mail me and request to be added to the list.

TUNING TRANSIENT BEHAVIOR OF FRONT-WHEEL-DRIVE AUTOCROSS CAR

I'm an autocrosser driving a left heavy FWD car. I run in the SCCA Street Prepared class, allowing me spring and swaybar changes. The car as it sits right now is roughly 2500lbs with driver, 63% front, 54% left, with ~210hp. I'm running ~550lb front wheel rate, and a ~495lb rear wheel rate. I'm contemplating changing the right side springs so that they are softer than the left side springs to improve rotation and power down in right hand turns. I expect that this should give more even front tire loading under acceleration, but more uneven front tire loading under braking. I'd also expect that the car would be looser under acceleration when turning right, but tighter turning right under braking. It seems as if the drawbacks will outweigh the benefits, considering the car brakes at 1.1g's but accelerates at only .3g's. Is there a better way to get better tire loading of the inside front tire in right hand turns on a left heavy car under rules that prohibit moving mass around in the car? Perhaps preload on the swaybar?

The second question pertains to slaloms. In case it matters, my car uses a 275/35/15 Hoosier R6 front tire on a 15x10.5" wheel with a 205/50/15 Hoosier A6 rear tire on a 15x6" wheel. I'm familiar with your article on shock tuning for the various phases of a corner. However, in a high speed slalom reality seems to diverge from theory. What I mean by that is that on my car, if I need to tighten the car in a slalom, increasing front damping seems to make the car looser. Conversely, increasing rear damping makes the car tighter. I do feel the damping changes affect normal corner entry as expected, so I'm wondering if my simple analysis of a slalom being a series of corner entry events is flawed. My shocks do have independent compression and rebound adjustment, but partly due to lack of testing time I've been erring on the side of caution and changing both compression in rebound settings in equal amounts and direction (IE, add 2 clicks of rebound and compression). The other part of the reasoning comes back to the analysis of a slalom. If one thinks of it as a series of corner entry/corner exit events compressed closely together, it would seem adding front compression would tighten the entry portion and adding front rebound would tighten the exit portion. Instead it seems as if I speed up how quickly the front of the car reacts to the steering inputs and then the outside rear tire can't get to a point where it is generating sufficient grip as quickly as it needs to.

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Other adjustments to tighten the car in slaloms seem to tighten the car everywhere else. I've tried rear toe in (I currently run between 1/16" to 1/8" total rear toe out), less rear tire pressure, more rear camber, softer rear bar, and softer rear springs. While effective to varying degrees, the increase in understeer on sweepers is undesirable. Since this seems to be a transitional issue, it would seem that shocks would be the proper tuning tool.

Another thought on this subject is that, since I run the rear tire on a rather narrow wheel for the express purpose of getting the rear tires to operate at a higher slip angle and thus make the car looser in sweepers, would it be possible that a wider rear wheel might help the rear tires get to the slip angle they need to generate grip sooner, thus mitigating the "snapping towel" effect I am picturing?

Taking the first part first, the questioner's analysis of the effects of left-stiff springing in a right turn are essentially correct: the car should be tighter when trailbraking, and looser under power, and the tendency toward inside front wheelspin should be reduced. In left turns, all these effects should be reversed.

Note, however, that this only applies when the car has all four wheels on the ground. Once the inside rear wheel lifts, it is no longer possible to affect wheel load distribution using the right/left pitch resistance distribution or the front/rear roll resistance distribution. The questioner does not mention whether the car runs on four wheels in right turns, or three.

A case can be made that the right/left wheel rate split should be roughly proportional to the right/left static weight split. This would make the percentage-wise longitudinal load transfer on each side similar, or at least the elastic component of it. That would actually tend to keep the left percentage at each end more nearly constant in pure longitudinal acceleration than a setup with identical wheel rates right and left. It also would, in theory, give a better ride, because the car would have similar natural frequencies right and left.

If this approach were pursued by softening the right side of the car, we would shoot for a right front wheel rate around 470 lb/in and a right rear wheel rate around 425 lb/in.

It would probably also make sense to put one or two more clicks in the shocks on the left than on the right, to keep the damping ratios more similar on both sides of the car.

Now, regarding the case of a slalom: a slalom is indeed a series of corner entry events interspersed with corner exit events, usually with nothing else in between. We are adding lateral acceleration and yaw velocity in one direction, and roll displacement in the opposite direction, until we are alongside the cone. Then we are decreasing lateral acceleration and yaw velocity, and de-rolling, until we are midway between cones. Approximately midway between cones, we reach a point where roll displacement is zero; roll velocity is inward with respect to the cone behind us and outward with respect to the cone ahead of us; yaw velocity is zero; yaw acceleration is outward with respect to the

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cone behind us and inward with respect to the cone ahead of us; the car is at something very close to static attitude (zero suspension displacement), but it is not at zero yaw or roll velocity, nor zero yaw or roll acceleration.

Up to the point where we are beside the cone, we have a corner entry event. From there to the approximate midpoint between cones, we have a corner exit event. Then we more or less seamlessly enter the next corner entry event, for a turn in the opposite direction.

Depending on the car and the driver's style, there may be some application and release of power, just to affect the car's oversteer/understeer balance, or the whole slalom may be taken at constant throttle. Either way, speed is not going to vary a great deal, and longitudinal accelerations will be modest. Accordingly, pitch displacements and velocities will be small. Except possibly for the very first and very last cones, straightaways are not a factor, so we are not concerned with trying to get "in fast" by braking late, or "out fast" by putting a lot of power down.

In most cases, the surface will be approximately flat. In some cases there may be some humps and dips in the surface, or a bit of tilt, but it is very uncommon indeed to have banked turns in a slalom.

The whole process can be thought of as a series of roughly sinusoidal cycles, in yaw displacement, yaw velocity, and yaw acceleration, and in roll displacement, roll velocity, and roll acceleration, with not much else going on. The respective cycles of displacement, velocity, and acceleration will be offset, or phased, 90 degrees apart.

To illustrate, suppose we are in a slalom, midway between cones, approaching a cone that we will go around on its right, turning the car leftward. The cone after that will be taken on its left, turning the car rightward. After that one, we will be in a condition similar to our starting condition. That will be one cycle. For simplicity, let's suppose that the car takes one second to get from one cone to the next. A full cycle then takes two seconds. Let's call the condition where the car is parallel with the line of cones zero yaw displacement.

Let's follow the car through a cycle, and look at the velocities and accelerations. To begin with, let's ignore effects resulting from vehicle attitude angle or drift angle and from damping, for simplicity.

At $t = 0$, the car has roughly zero roll displacement and yaw velocity. It is in the middle of a transition from turning rightward to turning left. Its roll velocity is rightward, and at a maximum. Its roll acceleration is zero, transitioning from leftward to rightward. Yaw displacement is rightward, and at a maximum. Yaw acceleration is leftward, and at a maximum.

At $t = 0.5s$, the car is beside the first cone, to its right, and cornering hard leftward. Roll displacement is rightward, and at a maximum. Roll velocity is zero, transitioning from roll (rightward) to de-roll (leftward). Roll acceleration is leftward, and at a maximum. Yaw displacement is zero. Yaw velocity is leftward, and at a maximum. Yaw acceleration is zero.

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At $t = 1.0$ s, the car is midway between cones, halfway through the cycle. Roll displacement is zero, transitioning from rightward to leftward. Roll velocity is leftward, and at a maximum. Roll acceleration is zero, transitioning from leftward to rightward. Yaw displacement is leftward, and at a maximum. Yaw velocity is zero, transitioning from leftward to rightward. Yaw acceleration is rightward, and at a maximum.

At $t = 1.5$ s, the car is beside a cone again, to its left, cornering hard rightward. Roll displacement is leftward, and at a maximum. Roll velocity is zero, transitioning from leftward to rightward. Roll acceleration is rightward, and at a maximum. Yaw displacement is zero, transitioning from leftward to rightward. Yaw velocity is rightward, and at a maximum. Yaw acceleration is zero, transitioning from rightward to leftward.

At $t = 2.0$ s, we have completed one cycle, and are back to our starting condition, two cones down the line.

Acceleration changes velocity, and velocity in turn changes displacement. Acceleration leads velocity by 0.5s or a quarter of a cycle, and velocity leads displacement by a similar amount. Displacement and acceleration are half a cycle out of phase: they zero together, and they peak together, but in opposite directions. All the functions are approximately sinusoidal, but with phase shifts between them. This is the expected pattern for first and second derivatives of a sinusoidal function. Velocity is the first derivative of displacement with respect to time, and acceleration is the second derivative.

In general, any car wants a tighter setup for slaloms than it wants for other situations. This is partly because the magnitude of peak yaw accelerations (in the preceding example, these would be at or near $t = 0$, $t = 1.0$, and $t = 2.0$) increases as the vehicle's attitude or drift angle mid-turn ($t = 0.5$ and $t = 1.5$) increases. The car's yaw inertia tends to tighten it during the entry events and loosen it during the exit events. The most common problem is that the car is too loose during the exit phases ($0.5 < t < 1.0$; $1.5 < t < 2.0$), rather than too tight during the entry phases ($0 < t < 0.5$; $1.0 < t < 1.5$). Thus, any problems with the car's balance will tend to be most conspicuous during the exit events.

How does this relate to damper tuning?

First of all, everywhere except right beside the cones, we have something approximating pure roll velocity. Therefore, we have extension velocity on both shocks on one side of the car, and compression velocity on both shocks on the other side. This is true during both the exit phases and the entry phases. So we can't tune entry with compression and exit with rebound. What we can do is tune the relationship between entry and exit with the relationship of front and rear low-speed damping, meaning both compression and rebound. That is, we can stiffen the front damping in compression and/or rebound, relative to the rear, or vice versa.

The dampers generate a roll moment that is opposite in direction to roll velocity. During the entry events, they fight the roll and generate an anti-roll moment. During the exit events, they fight the de-

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roll and generate a pro-roll moment. Consequently, adding damping at one end of the car makes tire loading at that end more unequal during entry and less unequal during exit.

So at least in theory, adding front damping should not loosen the car in all parts of the slalom, but it should loosen it during the exit events, and that is exactly the type of balance problem that tends to be most conspicuous in a slalom.

In general, it helps a car in a slalom if we stiffen the rear damping. This does tend to hurt our ability to put power down on exit with the inside front wheel, unfortunately. One way to mitigate this is to take advantage of the fact that the car has some rearward pitch velocity as we add power during exit, meaning that the inside rear is compressing faster than the outside rear is extending. If we add our rear damping mainly in extension, and not in compression, we maximize the effect in slaloms and minimize the effect on exit drive traction around the rest of the course.

Regarding the choice of rear tires and rims, it is important to remember that balancing the car by reducing grip at the rear, or just adding slip angle at the rear, may make it feel better, but it doesn't make it faster. If the front end is what limits the car, the car goes just as fast through sweepers with stiff, sticky tires on the rear as it does with floppy, slidey ones. It has more understeer, but only because the rear has more grip, not because the front has less. And the car will be faster in the slaloms.