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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: markortiz@vnet.net. Topics and questions are also drawn from my posts on the tech forum at www.racecartech.com , where readers can see chassis consulting done for free. Readers are invited to subscribe to this newsletter by e-mail.

COMPUTER PROBLEMS AT RACECARTECH

The tech forum mentioned above at www.racecartech.com has been down for about two weeks at this writing. Some people are under the impression that I own the site, but actually I just post there regularly. The timing of the problem leads me to suspect it may be related to a reported long-running tunnel fire in Baltimore which has damaged fiber optic cables. One would think the internet would have enough circuit redundancy to make damage to one cable inconsequential, but news reports are saying this fire has massively disrupted internet communications. Whether this is the problem or not, the forum will hopefully be up and running again soon. Meanwhile, my services remain available privately, as always.

THINGS THAT MAKE SPRING CHANGES WORK BACKWARDS

Last month I presented a chassis troubleshooting chart. I took care to point out that the recommendations in that chart apply only for a certain set of assumptions, including a fairly flat track and suspension with no large jacking forces. This month I'm going to supplement last month's information by discussing some factors that make spring changes work differently.

TRACK BANKING

In a flat turn, on most cars the inside suspension (left side, for a left turn) extends and the outside compresses. As the track banking gets steeper, the inside suspension extends less and the outside suspension compresses more. The car still rolls outward, but the entire chassis is pressed down due to the banking. Steep bankings are generally only encountered on oval tracks, so we will be discussing left-turn situations here.

Beyond a certain banking angle, the left suspension no longer extends, but compresses instead. This reverses the effect of left side spring changes: stiffer left front reduces instantaneous diagonal percentage and loosens the car, while a stiffer left rear adds instantaneous diagonal and tightens the car, in steady-state cornering. Right spring changes still work the same as on a flat track, except they have *greater* effect, due to the greater deflection.

I like to speak of a *critical angle* for track banking. This refers to the angle at which the left suspension neither compresses nor extends in steady-state cornering. The critical banking angle varies with springs, anti-roll bars, suspension geometry, aerodynamics, and amount of grip. It is usually somewhat different for the front and rear of the car. As a rule of thumb, critical banking angle for stock cars on asphalt is around 15 degrees.

The slipperier the surface, the smaller the critical banking angle. Or more accurately, the slipperier the track/tire combination, the smaller the critical banking angle.

The less the car relies on its springs for its roll resistance, the less the critical banking angle. If you increase the anti-roll bar stiffness and decrease the spring stiffness, that makes the car corner at a lower ride height on the banking, and reduces the critical banking angle. This has been a major issue in Winston Cup lately. Some teams have tried outrageously soft springs on the front, with very stiff bars, to make the car corner lower on relatively flat tracks. This was the reason for the bump rubbers which NASCAR recently outlawed.

Raising the roll center on a beam axle, and softening the springs, also reduces the critical banking angle. Raising the roll center on an independent suspension can have a similar effect, although we may also encounter jacking effects that can reduce or reverse this. On beam axles, we can have jacking effects that are separable from roll resistance. For example, if we raise the left end of an “across-the-car” (or long) Panhard bar, and lower right end an equal amount, we make the car jack up in a left turn, with little effect on the roll center. Such a change increases the critical banking angle.

It is difficult to calculate the critical banking angle precisely, but it is quite easy to know when we’re there if we have electronic data acquisition. When we are close to the critical banking angle, the ride height traces from the left wheels will correlate heavily with longitudinal acceleration, throttle position, and brake pressure, and will be largely insensitive to lateral acceleration. In this situation, the car’s steady-state cornering balance is insensitive to left spring changes, but left spring changes do affect its entry and exit characteristics. This means we can tune mid-turn properties with the right springs, and tune entry and exit with the lefts.

LARGE JACKING FORCES

Note that steep bankings reverse the effect of left spring changes because they reverse the usual direction of suspension motion on the left side of the car. It is a basic rule that anything that reverses the usual direction of suspension motion at a particular corner of the car reverses the effect of spring changes at that corner. The other very common cause of reversed suspension motion is large jacking forces: forces that try to extend or compress the suspension when the tire generates horizontal forces.

Designers deliberately build jacking properties into suspensions to resist roll and pitch, and to raise the center of gravity under power, which increases load transfer to the rear wheels.

At the front end, we call upward jacking forces (ones that try to extend the suspension) in braking *anti-dive*. At the rear, we call downward jacking forces (ones tending to compress the suspension) in braking *anti-lift*. In rear-wheel-drive cars, upward rear suspension jacking forces under power are called *anti-squat*. It is also possible to have *front anti-lift* under power when the front wheels are driven.

The front suspension is said to have *100% anti-dive* if the jacking force is exactly sufficient to prevent the suspension from compressing under braking. Most cars have less anti-dive than this, and many have none at all. When the anti-dive is zero, jacking forces are absent in braking, and the forces tending to compress the front suspension are resisted entirely by the springs. If downward jacking forces are produced in braking, anti-dive is said to be negative. Negative anti-dive is also referred to as *pro-dive*.

If a car has exactly 100% anti-dive at the front, the left and right front suspensions neither compress nor extend in braking, regardless of spring rates. This means that, in pure braking, front spring choices have no effect on instantaneous diagonal percentage. If anti-dive exceeds 100%, the front of the car actually lifts in braking, and instantaneous diagonal percentage increases if we soften the right front spring or stiffen the left front – opposite of the usual.

Note that these are mainly hypothetical cases, since most cars have far less than 100% anti-dive. Most stock cars nowadays have moderate anti-dive at static, and lose anti-dive rapidly as the suspension compresses, sometimes going to pro-dive. When a car has pro-dive, front spring changes affect entry balance in the usual way, only their effect is greater. When a car has moderate anti-dive, front spring changes affect entry balance in the usual way, only their effect is less. These comments also apply to individual corners of the car: when we have pro-dive on the right front and anti-dive on the left front, entry is highly sensitive to right front spring changes, and much less sensitive to left front spring changes.

Similar effects occur at the rear in braking. If the car has 100% anti-lift, the rear suspension neither extends nor compresses in braking, and spring choices have no effect on instantaneous diagonal percentage in pure braking. Of course, to meaningfully say that the car is loose or tight, we must have some cornering, and therefore some roll, along with our braking, and front and rear springs will have effects on instantaneous diagonal percentage due to their effect on front and rear roll resistance, even in the case of a car with 100% anti-dive and 100% anti-lift at all four corners.

Unlike 100% anti-dive, 100% anti-lift (or more) is common in road cars, or in production-based road racing sedans and sports cars. Cars that react rear brake torque through a simple trailing arm or semi-trailing arm generally have more than 100% anti-lift. Examples include C2 and C3 Corvettes, many BMW's, Porsche 911's and 356's, and all but the first Mazda RX-7's. Some dirt modifieds and Late Models also have more than 100% anti-lift, though others have pro-lift. Anti-lift exceeding 100%

will be evident in data acquisition outputs or trackside observation: the rear will drop rather than rise
when the car slows. The anti-lift effects may be different for engine braking than for actual brake forces, and a car can have anti-lift on decel yet have pro-lift on the brakes. A typical dirt car 4-bar rear with a torque arm, and calipers on the birdcages, usually exhibits this mix of properties. Most trailing arm independent rears are the opposite: pro-lift on decel, anti-lift on the brakes.

Under power, the right and left rear suspensions may either extend or compress. In addition, live axle suspensions transmit driveshaft torque, which tends to extend the left rear suspension and compress the right rear, adding instantaneous diagonal percentage. The effect on suspension position is called *torque roll*; the effect on wheel loads is called *torque wedge*.

If the rear suspension as a whole neither compresses nor extends under power, that is 100% anti-squat. In this case, rear spring changes have little effect on wheel loads in pure forward acceleration, except that in live axle rears, torque roll and torque wedge still occur unless the suspension is carefully designed to eliminate this. Softening either rear spring, or both, increases torque roll and torque wedge, regardless of overall anti-squat.

Stiffening the front anti-roll bar decreases torque roll but increases torque wedge. Stiffening the left front spring likewise decreases torque roll but increases torque wedge. Stiffening the right front spring also decreases torque roll and increases the *torque-related component* of wedge change. However, in most cases the unloading of the front end under power extends the right front suspension more than torque roll compresses it, so the net effect of a stiffer right front spring is to de-wedge the car in pure forward acceleration.

We can also speak of anti-squat effects at each rear wheel individually, even in live axles, and we may include driveshaft torque effects when considering these, or not – as long as we don't forget that the driveshaft torque is there. When either rear spring extends under power rather than compressing, the effect of spring changes at that corner of the car is reversed. A common instance of this occurs on the left rear of typical 4-bar dirt Late Models, where a softer LR spring will tighten exit.

INTERACTION OF THESE EFFECTS

As if we didn't have enough complexity just considering these effects in isolation, in the real world we often have banking effects and jacking effects acting together. Without electronic data acquisition, it may be difficult to know or predict whether, or when, a particular corner of the car compresses or extends. However, we do know this much: if the actual direction of suspension motion is opposite to what we'd get on a flat track with small jacking forces, effects of spring changes will be opposite too. If motions are bigger, effects of spring changes are bigger. If little motion occurs, spring rate will have little effect.

With electronic data acquisition, we can use these principles to predict effects of spring changes in particular parts of the turn, even with complex jacking/banking combinations. And even if we don’t have electronic data acquisition, these principles can still help us make sense of our observations.