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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. Readers are invited to subscribe to this newsletter by e-mail. Just e-mail me and request to be added to the list.

RAISING MY RATES

For the first time in three years, I have decided to raise my hourly rate for consulting. The new rate will be $50/hour, which is still reasonable compared to what other consultants have told me they ask. Retainer rates will likewise go up proportionately. A month will be $300; a year will be $1500.

I was considering having the new rate take effect at the turn of the year, but what I'm going to do instead is offer the old rate of $40/hour, and the corresponding $240/month or $1200/year for all services paid for before March 1, 2004.

MORE ON RACING FRONT-DRIVE CARS, AND ON LOAD TRANSFER

Racecar Engineering based my column for the December 2003 issue on my March 2002 newsletter, which dealt with some aspects of racing front-wheel-drive cars. Some readers have written in response to this column, and one of the questions also relates to the basics of load transfer, the topic of the August 2003 newsletter and November 2003 column.

I am a new (1 year) racer who bought a used VW Sirocco mini stock. We race on a slightly banked ¼ mile paved oval. The suspension is VERY stiff, and the right side springs are a higher rate than the left. I do not know the rates, and I plan to install new springs this winter.

Two of the fastest fast guys at the track tell me they use soft suspension, and what perplexes me, their right side springs are softer (by 100 lb.) than the left side springs. Their logic is that the inside wheel will now carry more load as the car moves downward in the corner, therefore giving more equal tire loading and less push on our FWD cars.

Does this make sense to you?

The reasoning doesn't, but running softer springs on the right does, when the track is close to flat – or at least for many cars it does.

Having softer springs on the outside wheels does not reduce overall load transfer. If the turn is slightly banked, and we are comparing setups with the same average spring rate, there will be slightly more roll with a left-stiff setup than with a right-stiff one. Since roll slightly increases load transfer, the left-stiff setup will actually have slightly more overall load transfer – but not by enough to worry about.

On a perfectly flat turn, the car will roll about the same amount with a left-stiff setup of the same average stiffness, but the right wheels will be better able to follow bumps – at the expense of the left ones. Since the right tires provide more than half of the cornering force, it is worth more to have them follow the road surface better.

There will not necessarily be less understeer (push) with a left-stiff setup, in steady-state cornering.

Now, if we were to take your car, which you say is relatively stiffly sprung overall, and we soften just the right front spring, that will reduce understeer. If instead we soften just the right rear, that will increase understeer. If we soften both the right front and the right rear, the effect on understeer will depend on how much we soften each one.

If the track is banked modestly enough so that the left-side suspensions both extend in the turns, we will also reduce understeer if we soften the left front or stiffen the left rear, and we will increase understeer if we stiffen the left front or soften the left rear.

If the track is banked steeply enough so that the left-side suspensions compress in the turns instead (the car still rolls rightward; the right-side suspensions compress more than the lefts), then the effects of left-side spring changes reverse. More left front spring reduces understeer. More left rear increases understeer. Effects of right-side spring changes do not reverse on steep bankings. They just get bigger.

As we encounter steeper banking, it becomes easier to keep the inside rear wheel on the ground. Recall that stiffening the rear suspension relative to the front reduces understeer, at least up to the point where the inside rear wheel lifts. If the turns are banked, we can go much stiffer on rear roll resistance, either with springs or anti-roll bars, before we encounter the limitation of wheel lift. This is very important when racing front-drive cars on ovals.

One other effect of left-stiff springing is that it loosens the car when braking or decelerating, and tightens it under power. This is true for both front-drive and rear-drive cars. So if you enter the turns while slowing, as is usual in oval-track racing, the car will be freer (have less understeer) on entry with a left-stiff suspension. And since a push, once initiated, tends to persist, a freer car on entry may also be freer mid-turn.

One drawback to watch out for when pursuing this approach is that the car will be more prone to inside front wheelspin on exit. This may or may not be a problem on your oval, with a small engine. In road racing and autocross, or on a very small oval with tight turns, it is definitely a factor. I don't

know if your rules allow you to use a spool in that car, or if you are allowed to run a limited-slip. If you are, then you definitely need to pay attention to front tire stagger. Your tire rules may or may not allow you much choice of stagger, but the car will be sensitive to it. With a spool or limited-slip, a larger tire on the right will help the car turn. With an open diff, you want a bigger tire on the left instead.

Finally, be aware that the car is sensitive to static wheel loads, just like a rear-drive car. These work about the same as they do in a rear-drive car. Less diagonal (RF + LR) percentage frees up the car, just like stiffening the left rear spring or softening the right front.

SINGLE OR DUAL REAR BRAKES FOR FSAE?

I am a Formula SAE team member. As you know, some teams use one differential-mounted rear brake disc and some use two discs mounted on the driveshafts or outboard on the wheels. I am having a bit of a time rationalizing the idea of using one rear brake. I spoke to the Wollongong team president at the '03 Detroit event, and he explained that a single rear brake causes corner entry understeer (bad for small-radius SAE courses!) by effectively "locking" the diff. You said basically the same thing in the FSAE message boards. We are using the common Torsen 1 type diff. Does this diff lock in the same way when applying a braking torque as if you were applying an acceleration torque? Looks as if it would. I realize that a clutch diff could act differently under brakingdepending on ramp angles.

Situation:

- *Maximum torque bias ratio 80:20*
- *Diff mounted disc*
- *Car approaches corner. Brakes are applied. Enter left hand turn.*
- *Weight is transferred to front and to right side. Left rear wheel loses most of its normal load and traction.*

Will 80% of the braking force be sent to wheel with traction, while the wheel with low normal load receives 20%? Does the unbalanced braking or the locked diff create the understeer, or is it both?

Now with 2 outboard mounted discs it is obvious that I will always have 50% available rear braking force at each wheel (but different normal loads).

Is this correct? What equations can I use to calculate my braking force, or acceleration force distribution through a locking diff?

P.S. Are you a design judge, and where can I get info on FSAE-sized cam and pawl diffs?

Taking the last items first, a few people have talked with me about the possibility of my doing design judging, but this has all been purely tentative. My understanding is that SAE is no longer even paying expenses for judges, so the judges are actually taking a loss on the activity. I try to get paid if I'm going to have to work.

The only ready-made diffs for FSAE that I know of come from either Quaife or Gleason. These are both Torsen style. The UNC Charlotte team made their own in 2003, using Gleason gears. This was done purely to reduce weight.

You could probably make a ZF-style clutch diff, with the ramps on the pinion shafts, but I think you'd need to do the clutches and carrier yourself, and maybe use spider and side gears from a small car. You could probably also make a Detroit locker style diff yourself, but you'd probably have to make everything.

All things considered, I think it's easier to make or find two small brakes instead.

Somebody may have some equations that describe the behavior of limited-slip diffs, but I don't. Even modeling the friction in these units at known speeds and forces is a bit tricky, because the friction forces are a combination of Coulomb and viscous friction, in proportions that vary with load, speed, temperature, and lubricant properties.

Not only that, the forces are **history-sensitive**! That is, to model or understand the unit's behavior at a specific instant, we need to not only know the speeds and input forces at that particular instant, we need to know the events immediately preceding that instant. For example, suppose we have either a clutch or a Torsen diff, with no preload. If there is no force on the diff, and we jack one wheel off the ground, and apply rotation to the carrier, we just spin the airborne wheel, get no locking, and transmit no torque to either wheel. But if the car is in motion, and the diff is transmitting torque, and then one wheel gets airborne, there is torque on the diff, and therefore loading on the clutches or worm gears, and therefore locking or friction in the unit, at the time the wheel goes airborne. That means we will continue to transmit torque to the wheel that's on the ground, as long as there is no interruption of input torque.

Now, examining the situation you've posited, where we apply the brakes before a turn and continue braking while initiating a left turn, with a single brake acting through a Torsen: First of all, yes the diff does act the same when transmitting reverse (braking) torque. If the diff locking or transfer torque is less than half of the brake torque, both rear wheels are retarding the car (exerting a rearward force), but the torque on the outside wheel is half of the brake torque plus the transfer torque, and the torque on the inside wheel is half of the brake torque minus the transfer torque. If the transfer torque is large enough, it may exceed half of the braking torque. In that case we may have a forward force at the inside wheel. In either case, in a left turn we have a rightward yaw moment due to the diff locking effect, and this moment adds understeer.

It is more common for the inside front tire to reach the limit of grip during trailbraking than for the inside rear to do so. But if the inside rear locks, the outside rear is seeing whatever torque it took to lock the inside rear, plus the transfer torque. In an FSAE car with a single rear brake and a Torsen, there will be more transfer torque if there is continuous braking up to this point than if the brake is applied with the inside rear already unloaded due to cornering.

With two rear brakes, the rearward force is equal on both rear wheels up to the point where the inside one locks. If there is a limited-slip diff, there will be transfer torque. This may be very small, or if there is substantial preload and engine braking, it may be considerable. Even with an open diff, when one wheel locks, the braking forces are no longer necessarily equal on both sides of the car. We can say with certainty that the force at the unlocked wheel is at least as great as on the locked wheel, and possibly greater.

This also applies on the front wheels of a rear drive car, and the above remarks also apply to the front end of a front-wheel-drive or four-wheel-drive car, and to the front end of a rear-drive car with frictional device connecting the front wheels to prevent lockup and flat-spotting of the inside front tire. In all of these cases, the presence of limited-slip or anti-lock transfer torque creates a yaw moment that adds understeer.