The Mark Ortiz Automotive

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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.

RIGHT REAR SPRING STIFFEST?

I frequently watch the pre-race shows for NASCAR events and listen carefully when they are speaking of setups. Two times now in the past year they have spoken about the stiffest spring on the whole car being the right rear. One crew chief asked a former driver if he ever thought he would see the day that was the case. The driver said he had won many a race with the right rear being the softest spring, and that has been the case with my experience as well. They spoke further to say that the trend now was for the younger former open wheel drivers to run off the right rear tire. Physics to my knowledge haven't changed. Are they running extremely heavy front bars and super light springs, or what gives? I thought the jounce bumper trend had been made illegal. Are their ways of thinking something we local drivers could apply to our cars for an outside-the-box thinking advantage?

At the risk of disillusioning my legions of admirers, first let me confess that I do not have throngs of Winston Cup crew chiefs and engineers climbing over each other to tell me their setups. I've worked with just a few, and a few get this newsletter. However, maybe I can be of some help, and if I say anything wrong, maybe I'll get straightened out.

Traditionally, the most common approach to spring splits has been to run the front end right-stiff and the rear end left-stiff. This usually makes the right front the stiffest spring and the right rear the softest. I never really understood that approach, and I have generally advised either running right-stiff or left-stiff at both ends, except perhaps in cases where the rear end lifts under power – a condition normally only seen in dirt cars.

Two main considerations determine whether we run the car right-stiff or left-stiff: cornering balance when forward and rearward accelerations accompany cornering, and adapting the car to the banking angle of the track. Taking the former of these first, when a car has different amounts of pitch resistance on the right and left sides, and the tires are accelerating the car forward or rearward, the diagonal percentage changes. If the car is right-stiff, that tends to make the diagonal percentage increase in rearward acceleration (braking) and decrease in forward acceleration. That tightens entry and loosens exit. If the car is left-stiff, that does the opposite: frees up entry, tightens exit.

Regardless of banking angle, stiffer right springs add roll resistance. However, if the track is banked enough so that the left springs compress (I don't mean more than the right ones, just compress rather than extend), we actually increase the roll resistance with softer springs, on the left side only. This means that with soft left springs, we can make the left wheels more compliant over bumps, and improve camber control by reducing roll, at the same time. This is in contrast to our usual dilemma of having to stiffen up the suspension to control roll and camber change, at the expense of roadholding.

On a short track, with tight turns, especially on dirt, it is most common to have trouble getting the car to turn readily enough on entry, and to have trouble hooking up the rear tires on exit. If this is a problem, that argues against right-stiff springing. But on high-speed tracks, it is common to want to tighten entry. The driver is going in as deep as possible, and braking hard while cornering, from speeds as high as 190 or even 200 mph. It may take as long as ten seconds to complete the turn, and the car is following a very large-radius path. We don't want to achieve large yaw accelerations then. The need is for a car that doesn't want to come around when braking and cornering at the same time.

On top of that, the front ends on stock cars generally lose anti-dive rapidly as the suspension compresses, because the side view projected control arm is shorter for the lower control arm than for the upper. This means that when the car is rolled to the right, anti-dive asymmetry de-wedges the car when braking, unless the right front has a lot more anti-dive than the left front at static position. Right-stiff springing helps compensate for this.

It is possible to tighten entry by using lots of front brake. However, if the turns require significant braking, using lots of front brake overworks the front brakes. As the front brakes go away, the brake bias shifts toward the rear again. Also, we really would like to set the brake bias for shortest stops, which means we want the rears to do around 30% of the work. If we run more than 70% front brake, we hurt the car's ability to stop quickly for pit stops, and to brake well when avoiding accidents on the track. Therefore, it's best to get the desired entry balance with the suspension.

What about exit balance? On a short track, we are often fighting to get the car tight enough, to control wheelspin. However, even on a short track it is possible to get exit too tight, and have a power push. At high speed and with steep banking, it is harder to get wheelspin. Cup cars do have stout motors, but they also have ample tire loading from the banking and the aero, and a lot less torque multiplication from the gears than they would on a short track. It is therefore not uncommon for the driver to report a "push-loose" condition. That means the car is basically tight power-on, so the driver feeds in more power trying to get it loose, but this doesn't happen until power is sufficient to really cause wheelspin, whereupon the car goes wheelspin-loose. The driver then has a hard time finding a stable point where the car has good balance. In this situation, if the car is freer power-on, the driver can find good balance at moderate throttle.

We see an analogous situation in road racing or short-track racing in classes like Formula Ford or pavement mini-stock, where the car has good grip and modest power. Such cars often want a freer setup than more powerful cars would, to get proper exit balance.

Are soft front springs and stiff anti-roll bars still favored since bump rubbers have been outlawed? Yes. The springs can't be as soft as when bump rubbers were legal, but it is common to run the front end as soft in ride as is possible without the rubbers. This soft ride rate makes the front end run lower through the turns. That adds aero downforce. This will work on a short track too, though the effect will be less pronounced. One might think we could do the same thing by running a lower static ride height, but stock car racing rules usually include a minimum static ground clearance.

In the August 2001 newsletter, I addressed the subject of things that make spring changes work backwards. I introduced the term *critical angle* to describe the track banking angle at which the left spring neither compresses nor extends. This angle is usually not identical for both ends of the car. At angles steeper than critical, effects of left spring changes reverse, for the end of the car in question.

Running soft springs and a stiff bar reduces critical angle. The left spring will compress rather than extend at surprisingly small banking angles. (Putting it another way, with the soft ride rate, the entire front end will drop more on the banking.) That means a softer left front spring tightens the car. This is neither a disadvantage nor an advantage, just something to be aware of when running such setups.

Regarding the suggestion that the young drivers come from open-wheel racing and therefore like to run a stock car with the right rear tire heavily loaded, I question that.

First of all, it may be true that some drivers are getting seat time in sprints and midgets – Jeff Gordon and Tony Stewart for example – but the most common road to Cup is through lower pavement stock car divisions: NASCAR Weekly Racing Series, USAR Hooters Pro Cup, ARCA, ASA, Busch. It is normal for young drivers to spend time in these series before transitioning to Cup. And not all drivers who do well in sprints and midgets are able to run well with a stock car. Some do, some don't.

As you correctly note, no laws of physics have been repealed. A stock car doesn't have 60% rear and a huge right rear tire, or a big rear wing. If you make the right rear carry a lot of load when cornering in a stock car, you get a loose car. Driver preferences on car balance vary, but only within a narrow range. Nobody likes a car that's way loose at 150+ mph. Also, the car has to be fairly neutral to avoid having a tire wear problem.

But you can't necessarily conclude that the right rear is more heavily loaded just because the spring is stiffer. Other things being equal it would be, but other things don't have to be equal. If you combine a stiffer right rear spring with more static diagonal, a bigger front anti-roll bar, or a lower Panhard bar, you can compensate for the effect of the spring and load the tire about like you were loading it before.

Of these different possibilities, the one that looks most appealing to me is running more static diagonal. If we do that, then when grip is poor and lateral acceleration is less, the springs have less effect on wheel loading and the static loadings have more influence. That means the car loads the right rear less, and runs tighter. When grip is good and lateral acceleration is greater, the spring

affects wheel loadings more, so right rear loading is greater and the car runs looser. This means that with more right rear spring and more static diagonal, the car will have less tendency to go loose on slick, as stock cars have traditionally done. With enough rear roll resistance and static diagonal, a stock car can even be made to go tight on slick. Between these extremes, we can find a setup whose balance varies relatively little with changes in the condition of the track or the tires.

I have clients successfully applying this reasoning on dirt and pavement short tracks, although generally the added rear roll resistance is achieved without a right-stiff spring split, except in cars that lift the rear under power.

INFLUENCE OF PUSHROD ANGLE ON WHEEL RATE

I would like to know how to calculate vertical stiffness and roll stiffness taking into account the angle of the pushrods. I have seen lots of formulas but none of them take into account the pushrods. Also, how do I calculate the total roll of the car starting with the difference in movement between the wheels?

Taking the second question first, take the difference between the right and left wheels, and divide by the track width. The quotient is the tangent of the roll angle, so you find the angle that has that tangent. As an equation:

$$\theta_r = \tan^{-1}[(h_l - h_r)/T]$$

where:

θ_r = roll angle
h_l = left ride height (average of front and rear)
h_r = right ride height (average of front and rear)
T = track width (average of front and rear)

Now, as to the angle of the push rods, you need that if you want to calculate stresses in the pushrods. But to calculate wheel rate in ride or roll, you just need to know the motion ratio from the spring to the wheel. Everything in between – the pushrod, the rocker, the control arm – only matters to the extent that it influences the motion ratio. The pushrod angle does affect the motion ratio, but it is just one factor. For an existing car, the easiest method is to simply measure how much the spring shortens or lengthens for an inch or centimeter of wheel motion. For a car that's in the design process, if you're designing on a computer, you can move the wheel and measure the spring length on the computer. If you're drawing manually, you basically do the same thing by hand and estimate the motion ratio.

Once you have the motion ratio, square it and multiply by the spring rate, and you have the wheel rate in ride. Then do the same for the anti-roll bar, which may have a different motion ratio. Add the rate from the anti-roll bar to the wheel rate in ride, and that's the wheel rate in roll. Be sure that when figuring the rate of the anti-roll bar, you calculate the pounds or Newtons per inch or millimeter **per wheel** – that is, the force change per unit of opposite motion on both wheels, not just one.