The Mark Ortiz Automotive

CHASSIS NEWSLETTER

PRESENTED FREE OF CHARGE
AS A SERVICE TO THE
MOTORSPORTS COMMUNITY

February 2011

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.

SWAY BAR/SPRING RATE EQUIVALENCY

Do swaybars reduce mechanical grip?

From what I understand, theoretically a swaybar is supposed to act just like a spring but only reduce body roll when a car experiences lateral forces. I also believe most swaybars are linear in rate. Is this true? Therefore, if we compare two identical cars in all aspects except:

Car A has:
200lb/in front springs and a 200lb/in swaybar rate
300lb/in rear springs and a 300lb/in swaybar rate

Car B has:
400lb/in front springs and no swaybar
600lb/in rear springs and no swaybar

Since both Car A and B have the same amount of roll resistance and the same ratio of front/rear roll stiffness, both cars should handle identically and achieve the same lateral acceleration on a smooth surface correct? I ask this because I've come across a post made by the 2010 SCCA DP Champion (he has one other years in various classes but I don't remember them) and he states that swaybars do reduce mechanical grip. If this is true, how would they do this and where would the static load go under cornering? Here's his post, and here is the link to the message board:
http://www.mr2oc.com/showthread.php?t=298272&page=2&pp=30

"Installment #4:

"Now that we understand the function of the springs and how they interact with the body to determine ride quality and body roll we can now directly address the swaybars. To achieve our target body roll and roll ratio we have chosen specific wheel rates. However, the rates we have chosen would result in a very stiff ride if we used only springs to achieve that wheel rate. To soften

the ride we need to lower the spring rates, especially in the front (to achieve a positive favored speed) however, that will upset our chosen roll ratio so we add back wheel rate by supplementing spring rate with swaybar rate.

"From installment #2 we had chosen 550 lbs/in front and 400 lbs/in rear spring rates. Its easy to now choose a front spring rate that will produce a more comfortable ride. Say 300 lbs/in front springs would give us a positive favored speed and move the center of suspension closer to the CG of the car, just aft of the center point between the two axles. We can then add back the spring rate by installing a swaybar with a rate of 250 lbs/in.

250 lbs/in front bar + 300 lbs/in spring = total rate of 550 lbs/in.

"That looks pretty easy. However, it's hard to find an off the shelf swaybar that has exactly the rate you want. In reality, unless you want to fabricate a custom bar every time you want to test a different setup, you need to calculate the rates of the available bars and then determine how much spring rate you need to achieve the desired total rate. So lets say you measure your existing swaybar and find it has a rate of 200 lbs/in. The spring rate you would want is determined by subtracting the existing bar rate from the target spring rate.

550 lbs/in target rate – 200 lbs/in bar = 350 lbs/in springs.

"Easy enough. But we have a problem here. Swaybars are not the dynamic equivalent of springs. A swaybar transfers load from the inside tire to the outside tire and thus reduce mechanical grip as they add spring rate. And the effect is not linear. The stiffer the bar in comparison to the springs, the greater the effect (loss of mechanical grip). To give an example of the effect, if we set our proposed STS2 car up using the target data we have assumed above using the target spring rates without any swaybar, the car should have good balance. However, if we achieved that same target spring rate using a front swaybar, the car would tend to understeer more than if we used only springs and no swaybar. And the greater percentage of the total front spring rate the bar accounted for, the more the car would understeer. I noted as much early in the thread.

"We now must choose how much bar we want to use for our final setup. As the reader may know, I don’t use swaybars on my DP car. Nor did I use swaybars on my previous racecar, a DSP X1/9. For me it is far easier to manage the setup of the car without swaybars. I also prefer the feel of the car without swaybars. It has long been my thought that; because a swaybar reduces mechanical grip, why would you want to put anything on the car that reduces mechanical grip?

"With this simple method, it is easy to compare the effect of the front bar by comparing the same total spring rate using just springs and no front bar to the same total spring rate incorporating a front bar. I have done extensive testing and have proven to my own satisfaction that the theory is in fact accurate. The same total front spring rate achieved using a front swaybar will produce more understeer than the same total front spring rate achieved using springs only. In addition, the effect of the front bar changes based on the level of grip the surface offers. As a result, the car does not have

consistent balance from surface to surface or even from run to run as the tires heat up from and the surface cleans and heat up throughout the day. I have found that my no-swaybar setup is very consistent on different surfaces and conditions seldom if ever requiring any changes to setup. At most, a pound or two of air pressure is all that is needed to tune the balance even in the most extreme of conditions. In fact, I don't even change the setup for rain. All I have to do is bolt on the rain tires and the car is fine.

"If one chooses to use a front swaybar, the effect resulting from the loss of mechanical grip will have to be accounted for by softening the front springs enough to bring the balance back to neutral. Choosing the amount of swaybar to use is now easy and dependant on driver taste. If the driver prefers a smoother/softer ride, use a very stiff front swaybar and subtract the front bar rate from the total spring rate to determine the required front spring rate. Testing can then determine how much less spring rate is necessary to bring the handling balance back to neutral. One could also compromise and use a very soft front bar, thus minimizing the loss of mechanical grip.

Sway bars (anti-roll bars) are in fact dynamically equivalent in roll to springs; they are generally linear; and they do not transfer weight or wheel load any differently than ride springs.

However, many people get confused about this because of a subtlety in measuring and expressing rate of a sway bar, and evaluating its roll resistance equivalency to ride springs. This causes people to think they are adding one amount of roll resistance with the bar, when in fact they are adding twice as much as they think. Of course the effect on the car reflects the difference, and they then erroneously conclude that the bar must work in some fundamentally different manner in roll than the ride springs do.

Ordinarily, a ride spring has one end (often the top) that is fixed with respect to the frame, and one end (often the bottom) that moves with respect to the frame. An inch of movement or displacement of the spring is simply an inch of movement at the end that moves. Simple. No way to get confused about that.

But a sway bar has a middle portion that is fixed with respect to the frame, and two ends that move. In roll, the ends move oppositionally. So, what then is an inch of movement for the device as a whole? Is it an inch of movement at each end relative to the frame, which is two inches of relative movement between the ends? Or is it one inch of relative movement between the ends, which is half an inch of movement at each end relative to the frame? Both definitions make semantic sense, and neither is right or wrong. However, the two methods produce rate numbers that differ by a factor of two.

A typical sway bar rate testing fixture measures the force produced at the moving end of one bar arm when that arm is moved an inch. That is the bar's rate in pounds per inch per end pair. The bar's rate in pounds per inch per end is twice that value.

When we multiply the bar rate in lb/in/end pair by the square of the bar-end-to-contact-patch motion ratio, we have the bar's contribution to wheel rate in roll in terms of pounds per inch per wheel pair. An inch per wheel pair is half an inch per wheel.

When we multiply the bar rate in lb/in/end by the square of the bar-end-to-contact-patch motion ratio, we have the bar's contribution to wheel rate in roll in terms of pounds per inch per wheel. An inch per wheel is two inches per wheel pair, and that displacement results in twice as much force change as an inch per wheel pair does.

We evaluate wheel rate in ride, and roll resistance contribution from the ride springs, in lb/in/wheel. Therefore, to have an equivalent value for the bar's contribution we need to also use lb/in/wheel, which is double the number we get if we simply multiply the number from the bar rater by the square of the motion ratio.

So if we take a front bar that contributes 200 lb/in/wheel pair and add it to ride springs that give a wheel rate of 350 lb/in, we don't have a wheel rate in roll of 550 lb/in; we have 750 lb/in in roll. So of course the car has more understeer than it has with 550 lb/in wheel rate in both ride and roll. If we used a bar that contributed 100 lb/in/wheel pair, then we'd have an equivalent setup, and very similar car behavior.

WHAT WHEEL RATE FOR DAMPER CALCULATIONS?

Normally when we calculate the damping rates we calculate the Ccr = 2 Kwmsm and then we apply the damping ratio. By theory the damping ratio for best grip should be about 0,4 at high speeds. In all the books and articles that I read the way of calculating the Kw is $Kw = Ks/MR^2$ where Kw = Wheelrate (N/mm) Ks = Spring rate (N/mm) MR = Motion Ratio (wheel/spring travel).

When we need the best grip is when we are cornering. At this moment we have lots of weight transfer and we have the roll bars acting like springs and at some cases, like at the front of a modern Formula Ford, we have a roll bar that is several times stiffer than the spring itself.

My question is: when we calculate the damping ratios for the best grip should we enter with the total rolling stiffness and with the weight transfer?

Or making the question by another way: when we increase significantly the stiffness of a roll bar should we increase the damping rates?

I would not advise using something other than sprung mass per wheel and wheel rate in ride for calculating damping ratios. However, I do think it's advisable to bear in mind that this is only a crude way of modeling car behavior, and getting the best performance from an actual car may require us to deviate.

In practice, a car with a lot of anti-roll bar relative to its springs generally will work best with somewhat more damping than those springs would require with less bar. However, there is no simple way to calculate an optimal damping coefficient for such cases.

"Weight transfer" in cornering is really wheel load transfer. The mass is what counts when examining oscillatory behavior, and the sprung mass per wheel doesn't change when we corner. However, the car's equivalent mass per wheel in roll is different, and generally smaller, for roll motion than for ride. This means that even with no anti-roll bars, the car has a higher natural frequency in roll than in ride. This is especially true when the sprung structure is vertically and laterally compact, as in a formula car.

So the answer is yes, generally we need more damping to go with more bar, but exactly how much, and in what shaft velocity range, we have to determine by test. In general, the optimum will depend some on the driver as well as the car.