The Mark Ortiz Automotive

CHASSIS NEWSLETTER

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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.

EFFECT OF CALIPER MOUNTING POSITION

What effect on wheel loading does the positioning of the calipers in a leading or trailing location have – i.e. mounted at 3 and 9 o'clock positions? Does a trailing caliper add or subtract load on the front tires? In a rear independent suspension, does a leading caliper add or subtract wheel loading, and is it the same in a live axle situation?

The short answer is no. Caliper location has no effect whatsoever on wheel loading. Having the caliper's mass lower or higher does have a very minute effect, because it affects the CG location a tiny bit, but there is no difference between a 3 o'clock mounting position and a 9 o'clock position.

However, there is an effect on bearing loads. It might seem counterintuitive that we can change the bearing loads and not change the tire loads, but that is in fact the case. As the questioner appears to have considered, the disc tries to carry the caliper upward if the caliper is trailing, and downward if the caliper is leading. That reduces bearing loads if the caliper is trailing, and increases bearing loads if the caliper is leading. However, these forces are reacted entirely within the hub/bearing/spindle/upright/caliper/disc/hat assembly, and do not change the loads on other parts of the car.

We can think of it like this: Gravity acts downward on the car, with additions and subtractions due to inertia effects and aerodynamic effects. The road surface holds the car up. Or, we may say the road holds the tire up; the tire holds the wheel up; the wheel holds the hub up; the hub holds the bearings up; the bearings hold the spindle up; the spindle holds the upright up; the upright holds the suspension up; the suspension holds the sprung mass up. If the caliper exerts an upward force on the upright and a downward force on the disc, that just means the brake is helping the bearings and spindle hold the upright up. It doesn't change the total support force, only the load path within some of the unsprung components.

It is worth noting that in braking there are also horizontal forces acting through the wheel bearings. The car is trying to keep going forward at a constant speed. The road surface is exerting a rearward force on the car, through the tires, wheels, hubs, bearings, spindles, uprights, and suspension. We can reduce the bearing loads due to this component if we mount the caliper above center, or increase the bearing loads if we mount the caliper below center. In fact, the horizontal force may be greater than the vertical force on the tire. With racing slicks on dry pavement, the horizontal force may be 1.3 or more times as great as the vertical load on the tire. So for least bearing loads during braking, the caliper should be somewhere in the upper rear quadrant – around 1 o'clock or 11 o'clock, depending on which wheel we're looking at, and from what direction.

Now, do we actually want maximum cancellation of the bearing loads by the brakes? We might suppose so, but actually there is an argument for not having maximum cancellation. The effective radius of the brake (roughly the radius to the middle of the pad) is often less than half of the tire effective radius. This means that the force at the caliper is more than twice the rearward force at the tire contact patch, and it may also exceed the vector sum of the vertical and horizontal forces at the contact patch. Consequently, the caliper force may not only reduce the bearing loads, but reverse them. If there is any free play in the bearings, or deflection in the components, this load reversal may result in a vibration or a small variation in the steer angle of the wheel. So there is a case for building the components nice and strong, and positioning the calipers so the bearing loads will not reverse.

Of course, as a practical matter, if we are using purchased calipers we need to mount them with the bleed screws at the top, or very nearly so, just to facilitate good brake bleeding without requiring the calipers to be dismounted. This may well outweigh any theoretical considerations. If we are designing from a blank sheet of paper, we don't face this constraint, but most of us, most of the time, are designing around purchased calipers.

Another practical constraint is packaging, particularly of the steering arms and cooling ducts.

There are some ways in which we can affect wheel loads by the design of the brake system and the suspension. I am referring here to the longitudinal "anti" or "pro" effects: anti-dive or pro-dive in the front suspension, anti-lift or pro-lift at the rear. With independent suspension, it makes a difference to these effects whether the brakes are inboard or outboard. With a beam axle, it makes a difference if the calipers are mounted directly to the axle, or on birdcages or floaters that rotate on the axle and have their own linkages.

However, with all of these, we cannot significantly alter the loading on the front or rear wheel pair, nor on all four wheels. We can change the way the sprung mass moves in response to braking, and this may have small effects on CG height, with corresponding small effects on overall load transfer. But the big effects come from having geometry differences on the right and left sides of the car. These may be present even in supposedly symmetrical road racing cars, because no car stays symmetrical when it rolls. In oval track cars, we often design in, or adjust in, asymmetry even in the static condition. Such asymmetry can produce significant changes in diagonal percentage when braking, and we can use these to tune corner entry behavior.

All such effects are independent of the "clock" position of the caliper mount.

MORE ON WEIGHT DISTRIBUTION

In the April 2004 issue of Racecar Engineering [see November 2003 newsletter], *you mentioned that a 52/48 front to rear percentage works well on medium to high speed tracks. How does it change when you go to a short track? Is there an optimum left/right percentage and cross weight for medium speed track with moderate banking (18 degree corners and 12 degree straights)?*

Regarding rear percentage, it depends to some extent on the design of the track, but assuming that we are required to use equal size tires front and rear, and assuming the bodywork rules permit only very limited downforce, something close to 50/50 works well for mid-turn speed. More rear helps braking. More rear also helps forward acceleration, provided that the car is traction-limited.

So if that short track is bowl-shaped – short straightaways and long turns, no really straight running, small speed variations between mid-turn and end of straight – we want close to 50/50. If the track is paperclip-shaped – tight turns, long straights, two drag races and two hairpins per lap – we want more than 50% rear, especially if the tires are narrow and hard, and the car has lots of power.

If the track has more banking, that tends to make the car less prone to wheelspin, at least during corner exit. That reduces the need for rear percentage greater than 50%.

Regarding left percentage, there's no such thing as too much, at least within most rules. Ordinarily, you are limited either by an outright limit on left percentage, or by a minimum right side weight, or by rules on engine and frame offset. In west coast supermodifieds, these days you have a choice of two left percentage limits. If you use the lower left percentage, they let you run a bigger wing.

Having more left percentage does change the car's behavior, so it only makes the car faster if the setup is suitable. It can happen that a team will reduce left percentage and find speed, but this is because they haven't figured out how to make the left-heavy setup work.

When the car has lots of left percentage, it tends to turn right when braking and turn left under power. That makes it tighter on entry and looser on exit. So the key to making the car work is to compensate for this, but not overcompensate.

Regarding diagonal percentage, there is no ideal amount just based on the track and type of car. It interrelates with the rest of the setup. If you have more roll resistance at the rear compared to the front, you need more diagonal, to keep the same amount of understeer. If the car goes loose on slick, add diagonal percentage and add rear roll resistance or reduce front roll resistance. If the car goes tight on slick, do the opposite.

SPRING SPLITS WITH BIG BARS

I just read your article in the Racecar Engineering *October issue* [see July 2003 newsletter], *about stock car setups where the right rear spring is the stiffest, due to the front end having soft springs* *and a stiff anti-roll bar. You say that you have some clients using this type setup without the right-stiff spring split. How are you doing that?*

What effect does the left rear spring have on these setups, and does a stiffer LR tighten or loosen the car on entry?

We are running on a D-shaped 5/8-mile track, with a maximum banking of 6 degrees, minimum of 2.8 degrees. The surface is old, worn out, and bumpy. The car is a Howe XL Late Model with coilovers all around. It weighs 2900 pounds, 56% left side, 58% diagonal.
Spring rates: LF 200 RF 200 LR 150 RR 200
Front bar: 1.250 dia., 9.5inch arm Track bar height: 11.5 inches

To answer the first question, of course if the RR spring is the stiffest on the car you do have a right-stiff rear spring split, but you can have the car rear-stiff in terms of roll resistance with geometry, or a rear anti-roll bar – or with a stiff LR spring if the turns are flat enough so the LR extends in the turns.

Those are definitely soft springs for the weight of the car, even allowing for using coilovers, which improve the motion ratios compared to a big spring car. I can't actually calculate the wheel rate contribution from the front bar without knowing its length and the motion ratio from the arm end to the wheel, but it appears pretty substantial compared to the springs. The Cup cars are using much stiffer ones, though. Their diameters can get as large as 2 inches in some cases, and the wheel rates in the rear are also higher than yours. They sometimes use rear anti-roll bars too.

As to what happens in your case when you stiffen the left rear spring, all I can say for sure is that any time the LR spring is compressed relative to static position, a stiffer spring will add diagonal and usually tighten the car. Any time the LR spring is extended relative to static, a stiffer spring will reduce diagonal and loosen the car. These effects can sometimes reverse during early entry, if the car is being slowed mainly by the rear wheels.

To really know what that spring is doing, you need to have data acquisition. The best way is to have motion sensors and electronic data logging like the big boys use, but you can also improvise with video cameras. Either mount a camera under the car aimed at the spring, or clamp a piece of welding rod to the axle near the spring, with the rod poking up into the interior through a hole. Then mount the camera in the interior and aim the camera at the rod.

My guess would be that the spring is extended most of the way through the turn, with the greatest extension occurring during late entry, and the least extension during exit. Based on that assumption, I would predict that a stiffer LR would loosen the car through most of the turn, with the greatest effect about ¼ of the way through, and the least effect on exit. If you add more diagonal or more front roll resistance to tighten the car back up, you may have a condition where entry is looser, mid-turn is similar to before, and exit is tighter. Remember, this prediction is based on a number of assumptions, so if the driver reports different results, don't automatically assume he's wrong.