The Mark Ortiz Automotive

CHASSIS NEWSLETTER

PRESENTED FREE OF CHARGE AS A SERVICE TO THE MOTORSPORTS COMMUNITY

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.

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WEIGHT DISTRIBUTION AND TIRE SIZE

At what point is it worthwhile to install wider wheels and/or tires on the back of a rear-wheel-drive car - specifically if the car has close to 50/50 front/rear weight distribution? Directly related to this point, I often wonder: why is it that an F1 car can brake so much more rapidly than it can accelerate, even though the front tire contact patches are smaller?

The basic rule of thumb is that tire size should be roughly proportional to tire loading, assuming we are talking about a car that has to corner well. So if the rear percentage is close to 50%, the tires should be equal size, and if the weight distribution is 40/60, the rear tires should be half again as wide as the fronts. Ordinarily, we go by tread width for this, rather than overall width at the sidewalls. Of course, the rule is only an approximation in any case.

The rule gives us roughly optimal values for steady-state cornering. That may not be the only thing we're trying to get the car to do well, but it's certainly important in most cases.

In many cases, we do not have a free choice of tires or tire sizes. Often, our task is to optimize the car for the tires, rather than the other way around. With race cars, our tire sizes are usually limited by the rules. For street cars and some race cars, we may be constrained by the fenders.In many production cars, if we just put the biggest tire at each corner that will fit without hitting the fenders, we end up with the rears bigger than the fronts. This is partly because the rears don't have to steer, and partly because it is usual to allow for snow chains on the rears, with equal size tires.

Other practical constraints may intrude as well. I have an old Chevy Impala station wagon that serves as both my transportation and my bedroom. When I first got the car, I set it up with 8" wheels with ½" offset all around, a rear anti-roll bar, and a much stiffer front anti-roll bar than stock. The car was fun to drive, cornered quite flat, and was well-balanced. Only trouble was that it kept breaking front a/r bar links and other a/r bar hardware, and I couldn't keep front wheel bearings in it for more than 10,000 miles. I could have put a full racing front end in, but this is an old, beat-up car that I don't want to put huge amounts of money and time into. So I went to 7" wheels with zero offset in front, a much softer front a/r bar from a sedan, and 8 ½" rear wheels with the same stiff rear bar as before. The car is balanced this way too. It rolls more, but less than stock. The ultimate lateral grip is less, but acceptable. And I don't have to fix the front end all the time.

I help out a Formula SAE team. Sometimes they take my advice, and sometimes they don't. They have had a policy of doing their car in a single year, and making minimal changes from the previous year's car. One consequence of this is that many design elements get adopted simply as carryovers. The team has been using wider tires in back, and the 2003 car had the same feature, despite my urging the team to use the widest and biggest tires possible all around. The car has only 52% rear. The rear tires have 58% of the tread width. We still managed to get balanced handling, by using stiffer springs and anti-roll bar at the rear.

My point here is that in many cases tire sizes are chosen based on factors other than vehicle dynamics theory - sometimes rationally, sometimes irrationally. And because cornering balance depends on suspension as well as tires, a surprisingly wide range of tire size combinations can be made to work acceptably on any given car.

Well, okay - but limiting ourselves to considerations of vehicle dynamics, why might we want bigger tires on the rear, when the car is not markedly tail-heavy?

Depending on aerodynamic balance, higher speeds may argue for bigger rear tires, or alternatively for more nose-heavy weight distribution. We know that a tire has limited capability for combined lateral and longitudinal force. To get more longitudinal force from a tire, we sacrifice some ability to generate lateral force. We speak of the traction circle, traction ellipse, traction perimeter, or traction envelope, as a representation of the limiting values for the vector sum of lateral and longitudinal force.

When somebody mentions steady-state cornering, we may think of a typical skidpad test, with speeds somewhere in the 60 mph (100 kph) range. Throttle application to maintain this speed will probably be fairly moderate, meaning the rear tires have a large percentage of their traction envelope available for cornering. But we can also have steady-state cornering at, say, 150 mph (250 kph). Just to run that fast in a straight line requires a fair amount of power. Add the drag of four tires operating near peak slip angle, and the car may need full power, or something close, just to maintain constant speed. And powerful cars can sometimes spin the wheels in top gear, in a straight line. So in this situation, how much of our rear tire traction envelope do we have left for cornering? Not a lot, unless the traction envelope was generous to start with (big tire). Or maybe quite a lot, if the car generates sufficient rear downforce at high speed to compensate for the other effects. In a case such as a NASCAR Cup car, both the tires and the aerodynamics (except for details) are dictated by the rules, and we pretty much tune the suspension and the ballast placement around the tires and aero package. The tires are required to be equal size at both ends, and for medium to high speed tracks, the car likes around 52% front. To run more rear percentage, wider rear tires would be helpful.

We could run more rear, with equal tires, but we would be making less use of the left front tire, and mid-turn speeds would be lower. We may want to run larger rear tires in search of greater forward acceleration. Any tire has an optimum inflation pressure for making lateral force, and another, lower, optimum pressure for longitudinal force. Consequently, if we have a car that's balanced with equal size tires front and rear, and then we install larger rears but run them somewhat underinflated for cornering, we still have a balanced car, but it puts power down better.

We can take this a step further, and add roll resistance at the rear, reduce roll resistance at the front, and further increase the tire size disparity. If we take this to an extreme, we have a car that is optimized for drag racing, but also has acceptable cornering balance - although it isn't really optimized for cornering. The inside rear tire will be very lightly loaded when cornering, but with a limited-slip diff, this may be acceptable. With a live axle rear, we improve the car's launch at the drag strip if we provide a very stiff wheel rate in roll at the rear and a very soft wheel rate in roll at the front. This helps because driveshaft torque produces less change in diagonal percentage when the car is stiff at the rear and soft at the front. We may disregard cornering completely in a car we only race in a straight line, but even if we are concerned with balanced cornering behavior on the street, a drag racing suspension setup will often call for larger tires in back. Note that this reasoning regarding reduction of driveshaft torque effects does not apply with independent rear suspension, where these effects are absent regardless.

Looking at the opposite end of the spectrum, IMCA-style modifieds, as raced in the US, may have as much as 59% rear, or even 60% with a full fuel load, and they are required to run equal size tires front and rear. In this case, we have a car that often runs on very slick dirt tracks, with tires that don't give much grip, and has lots of power. It needs the rear percentage to put power down. Even in the turns, a large percentage of the cornering force is car-longitudinal drive force from the rear tires, applied at an angle to the car's direction of travel because the car is powersliding. To get decent cornering balance in such a car, we have to make it corner on three wheels, or very nearly so. We under-utilize the left front tire, but we accept this to get forward traction.

If we run the same car on pavement, we need to move ballast, and perhaps even the engine, forward in the car. In answer to your question of why F1 cars achieve greater accelerations rearward when braking than forward under power, even though the front tires are smaller than the rears, actually almost all vehicles exhibit this property.

The main reason is that we have brakes on all four wheels, but propulsion on only two. A secondary reason is that drag, aerodynamic and mechanical, acts rearward, so it assists braking but opposes propulsion. About the only way we could produce a vehicle that accelerates faster forward than rearward would be to have no front brakes.

WIDTH VERSUS DRAG

I'm preparing an SCCA GT2 car (production car shape fiberglass body, tube frame). I have the opportunity to increase the car's width up to 4 inches, either by splitting the body or extending the flares. I have always assumed that going with the widest width is best chassis-wise, to minimize load transfer and maximize grip. However, I would think that at some point you lose more due to drag than you gain from improved cornering. These cars don't make much downforce, so I don't think there's much gain there from building the car wider. Is there any way to calculate an ideal width?

As long as cornering is an important part of the game, the best approach will usually be to go for greatest allowable width. This is particularly true when power is ample. Certainly, the drag does cost you some speed on a long straight. But if you come out of the preceding turn faster, and you also enter the following turn faster, you are faster not only through those turns, but also over the first and last portions of the straight.

Width is a mixed blessing though, even for cornering. A narrow vehicle lets you take a better line, especially if the turns are tight and the road is narrow. This is one of the main reasons motorcycles are as fast as they are. Narrowness can be very important in autocross, especially for slaloms. A narrow vehicle also can have an easier time passing other cars, which was the reason the FIA narrowed the width limit for F1 cars a few years ago. But on most road courses, the cornering power gained from a wide track width is worth more than the improved line and reduced drag with a narrow track width.