

The Mark Ortiz Automotive

# CHASSIS NEWSLETTER

PRESENTED FREE OF CHARGE  
AS A SERVICE TO THE  
MOTORSPORTS COMMUNITY

**August 2003**

## 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](mailto: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.

## LOAD TRANSFER BASICS

*I am a bit confused regarding the subject of load transfer. I have always thought that the load transfer in a curve should be maximized (if tire wear is not an issue), and that one will achieve that by stiffening the suspension.*

*Now I have met people saying that load transfer should be minimized and the reason is that you want as near the same load at all tires as possible – claiming decreasing tire friction with increasing load. Okay, a softer suspension gives more grip, I know, but how come you run faster with a stiffer setup (to a certain limit).*

*I have also met people saying the opposite is the truth. By softening the suspension, the CG moves more towards the outer side in roll, and therefore more load will be transferred to the outer side. Sounds reasonable, but isn't it so that the shocks have a role here, absorbing energy?*

*Another point of view from a well renowned man is that you will always have a certain amount of load transfer at a constant speed in a constant-radius turn, no matter the chassis setup – the thing is to find the balance front to rear. Okay, I fully accept that, but what is the importance of the general stiffness of the setup then? Why are we bothering at all about roll centers, cambers, springs, and anti-roll bars?*

*Can you please enlighten me (and probably many more) what is happening when load transfers, and what it is we want to achieve? Can you please also discuss how this applies to different types of cars and the differences in thinking regarding suspension design and setup?*

This is not exactly the first time the subject of load transfer has been addressed, even by me. In fact, the April/May/June issue dealt with the influence of springs and dampers (shocks) on load transfer at considerable length. So by addressing the basics of the

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subject now, I'm doing things backwards. But the question above came in recently, reminding me that the whole world hasn't been reading my newsletter like a textbook, and the newsletter cannot have the logical progression of information from issue to issue that a textbook has from chapter to chapter, and still respond to questions.

So we will tackle the basics of load transfer this month. Hopefully, those readers who found the April/May/June discussion a bit over their heads can read this, and then read April/May/June and have it make more sense.

For simplicity, I will ignore aerodynamic factors, even though these are often highly significant. Let's also consider pure steady-state cornering only, for now, and assume that the turn is unbanked.

I share the preference for calling what we're discussing load transfer rather than weight transfer. Actually, if we are considering an unbanked, level turn, and we're ignoring aero, then the total tire

loading really is due to gravity acting on the car's mass, and therefore is weight. Any transfer of this load can then legitimately be called weight transfer. However, since the terms *weight* and *mass* tend to be confused, and used interchangeably in informal discourse, "weight transfer" suggests that the change in tire loads is primarily due to movement of the center of gravity, or center of mass, relative to the tire contact patches – and that is not mainly what's going on, although it is a small factor.

What is mainly happening when load transfers is this: The tires are generating a horizontal force (toward the center of the turn, called centripetal force) at ground level. This produces an acceleration of the car (toward the center of the turn, called centripetal acceleration). The car resists this with an inertia force (centrifugal force) which acts horizontally at the center of mass, in the opposite direction to the tire force.

These two forces are equal and opposite, but their lines of action are offset. The sum of the tire forces acts at ground level; the inertia force acts at CG height. We therefore have a *couple*: a torque or rotational force due to the offset lines of action – equal to the force times the offset: the centrifugal force times the CG height. This torque acts about an axis lengthwise to the car, so it tries to move the car in the angular mode we call roll. It is therefore called a *roll couple*. It acts opposite to the direction of the turn: in a left turn, it tries to roll the car to the right.

Short of the point of rollover or wheel lift, this couple is resisted by an *antiroll couple* which takes the form of a load increase on the two outside wheels and an equal load decrease on the two inside wheels. Essentially, the ground pushes up harder on the outside wheels, and less hard on the inside wheels, in response to the way the tires are pushing down on it, and exerts a counter-torque on the car that keeps it right side up. The load change on the inside or outside wheel pair, times the track width, has to equal the centrifugal force times the CG height.

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So the person who told the questioner that suspension design and setup have no effect on total amount of load transfer is basically correct. The important factors are CG height, track width, and the amount of centrifugal force. It is true that when the vehicle rolls, the CG moves a little bit toward the outside wheels. Therefore, softening the suspension increases load transfer slightly, and stiffening the suspension reduces load transfer slightly. However, for cars these effects are small. For tall vehicles such as trucks, CG movement is somewhat more important. For trucks with cargoes that can shift or slosh, CG movement can become highly significant.

So the questioner's idea that stiffening the suspension increases load transfer is incorrect – **as it relates to TOTAL load transfer**. But it's correct as it relates to the front or rear wheel pair's **share** of the total.

The anti-roll couple we mentioned is actually the sum of two anti-roll couples – one from the front wheels, one from the rears. These two couples are not necessarily equal. The front and rear tire pairs split the job of resisting roll according to their **relative** roll resistance: the stiff end sees a greater share. In considering the roll resistance, we need to include both the springs (anti-roll bars are interconnective springs) and the suspension geometry.

In steady-state cornering, on a smooth surface, the suspension is not in motion, so the shocks, at least theoretically, have no effect on load transfer. For a more detailed discussion of the effects of springs and dampers on load transfer, see the April/May/June 2003 newsletter.

Now, is lateral load transfer beneficial or harmful to cornering (centripetal) force capability? The questioner correctly notes that the answer to this is directly dependent on how friction varies with load.

Does friction decrease with load? No, it increases. But the **coefficient** of friction decreases with load. The coefficient of friction is the ratio of friction force to normal (road vertical) force – how many pounds of cornering force we can get from the tire, per pound of loading.

According to the classical model of *Coulomb friction*, which models sliding friction between hard, dry, clean, smooth materials, the coefficient of friction is a constant for any given pair of materials. The friction force is directly proportional to load. For many situations, the Coulomb model is fairly accurate. However, tires and roads do not conform to this model. This should not be too shocking, since neither the tire nor the road is smooth and hard. The road is generally hard compared to the tire, but it isn't generally smooth. It is gritty, like sandpaper. The tire may be smooth, but it isn't hard. It is soft enough to conform to the road's gritty surface, and interlock with it. It is tough, meaning

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it resists being torn apart. If it is a racing slick, it may actually be tacky, meaning it sticks to a smooth surface even in the absence of sustained normal force.

Moreover, a tire is not a rigid structure; it is a flexible – but not totally limp – bladder, carrying an inflation gas under pressure. This means that the macroscopic, or visible-scale, size of the contact patch increases with load.

These factors make it very difficult to mathematically model a tire's behavior. That hasn't kept people from trying, but any equation that seeks to express the relationship between tire loading and limit cornering force will not only be complex, but must necessarily include values for the particular tire that can only be determined by test, because whatever the relationship may be, it isn't the same for all tires. Therefore, it is impossible to accurately know the relationship between loading and cornering force without testing. And any equations seeking to describe tire behavior must be developed by fitting curves to experimental data, rather than predicting behavior from abstract

theory. And if this weren't enough, tire properties vary with temperature, tire age, camber, inflation pressure, and of course the road surface – which also has properties that vary with the weather, the age of the surface, how much rubber and oil have been deposited, and so on. To avoid the effects of real-world road surfaces and weather, tires are now tested indoors, under fairly careful climate control, against belts or drums rather than roads. This is a valid necessity if we want to meaningfully test one tire against another, but it is important to remember that tire behavior in the real world is much more variable than tire behavior in a controlled environment.

Fortunately, it is much easier to look at trends in tire behavior than to predict precise numbers. And one trend that all tires exhibit is that the coefficient of friction decreases with load. It may decrease rapidly, or almost imperceptibly. It may decrease very little at light loads, and more rapidly at greater loads. But it always decreases with load. This property is termed *load sensitivity of the coefficient of friction*, or just *load sensitivity* for short.

This means that a pair of identical tires has the greatest cornering capability when loaded equally, and as we load the outside one more and the inside one less, we lose cornering capability. It's not that the outside tire loses friction force. The outside tire gains grip – but the inside one loses grip at a greater rate, so the total decreases.

Some writers contend that there are times or conditions where load sensitivity reverses. Some say it reverses on dirt, some say just on dry-slick dirt, some say on snow or ice, some say when the tire is cold, some say during corner entry. I don't believe any of these theories myself. If load sensitivity worked backwards, the car's responses to roll stiffness adjustments and static corner weight adjustments would also reverse, and I have not encountered this – except in situations where there was clearly some explanation other than reversal of load sensitivity.

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Now, if load transfer in cornering does not depend significantly on overall suspension stiffness, why does overall stiffness of our setup matter at all? It matters for other reasons than load transfer: control of camber and aerodynamics, ability to absorb road irregularities, how high we have to set the static ride height.

A stiff setup reduces camber changes, particularly with independent suspension. It reduces changes in the car's roll and pitch angles, relative to the airflow and relative to the road. It allows the car to run with a lower static ride height, without bottoming excessively. It makes the car more responsive to driver inputs.

A soft setup allows the wheels to follow bumps better. Loads on the tires vary less, and they spend less time airborne. The tires often heat up more slowly, and wear less. The car and the driver don't get beaten up so badly by the bumps, improving endurance of both car and driver.

So overall stiffness has to be a compromise that balances these conflicting factors in a manner appropriate to the conditions, while relative stiffness of the front and rear suspensions manages load transfer distribution.