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: 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.

## TORSION BAR TUBE HEIGHT

*What is the significance, if any, of the torsion tube mounting height on the chassis of a sprint car or Northeastern DIRT modified which both use cross torsion bar springs? Sprint cars at both front and rear (usually) and modifieds in the rear. I hear a lot of talk about low rack, mid-rack, flop tube, stack tube etc. To my way of thinking the only differences that any of these configurations can make are torsion arm angles (static/dynamic) and torsion arm lengths left to right. Arm angles would determine if the torsion arm/bar has a rising or falling rate. And arm length would just effect the effective rate of the bar at the axle. Am I missing something? For that matter, we are always discussing spring mounting in general at the axle end – spring base, front or rear of axle, directly on the axle or on a control arm (introduces side view motion ratio) but what are the implications of the upper spring/coil over chassis mounting points (excluding mounting angle)? i.e. upper spring mounting point height.*

When the springs, regardless of their type, act only as springs, and not as part of the locating linkage, it shouldn't matter much how high or low the springs are. What matters is how far the spring displaces, for each inch of displacement at the wheels, in the mode we are examining. Spring mounting only matters as it relates to that.

However, when the spring doubles as a locating member, a part of the suspension that positions an upright or an axle, then its location determines some aspect of the suspension geometry.

In the case of a simple beam axle on leaf springs, the leaf springs locate the axle laterally, and therefore their height determines the roll center height.

Although the front and rear torsion bar installations on a typical sprint car may look similar, they are dissimilar as regards the use of the torsion bar arms as part of the suspension linkage. At the front, the bar arms simply rest on the axle tube, and are free to slide on the tube. They do not act as suspension links. All they do is hold the car up. In some cases, a separate roller above the axle tube may be provided, but the effect is the same.

At the rear, the situation is different. The torsion bar arms serve as the leading links in a Watt linkage that locates the axle longitudinally. The leading end of the arm typically has a spherical joint. The spherical joint rides on a bolt or pin on the bottom ear of the birdcage, on which the spherical joint can slide laterally. This allows the suspension to move freely in roll. A tubular trailing link runs forward from the top ear of the birdcage to the frame, completing the Watt linkage mechanism.

Ordinarily, at static condition both the trailing link and the torsion bar arm are close to horizontal, and the axle moves very nearly vertically near static position. The system has little roll or bump steer, and little thrust anti-squat or anti-lift. It does have considerable torque anti-squat and anti-lift, from the vertical forces at the ball of the torque tube (sprint car) or front of the torque arm (DIRT Modified).

If we just raise the rear of the torsion bar arm, and leave all other points unchanged, the axle moves forward as the suspension compresses, creating thrust pro-squat and pro-lift, and roll understeer. The Watt linkage has a side-view instant center behind and above the axle.

Thus, although the roll resistance and wheel rates are not necessarily affected by torsion bar mounting height, the side-view geometry, and attendant properties, do change.

## TWIN I BEAM SUSPENSION

*I am designing a vehicle to be raced in the desert and I have been looking at different front suspension designs and have been considering using the twin I beam suspension seeing it allows a lot of travel and has been known to do well in the past. So I am interested if you might know how to calculate the roll center with the twin I beam, and if there is anything else I may want to look for when using the twin I beam?*

For readers unfamiliar with this suspension, it is basically a modified swing axle suspension, used mainly on Ford trucks (the questioner's e-mail address suggested the vehicle is a Ford Bronco). Each wheel is on a single transverse arm, with a leading arm added for longitudinal location and torque reaction. The only difference between this and a classical swing axle is that the transverse arms extend past the middle of the vehicle, crossing over each other. Usually, they extend to the opposite frame rail.

The spindles are similar to those on a beam axle. There are no ball joints, so there is no worry about running these out of travel. This accounts for the system's compatibility with large amounts of travel.

The disadvantages are similar to the disadvantages of a swing axle suspension, only not quite as bad. The camber changes a lot as the suspension displaces, typically around a degree and a third per inch of displacement. The roll center is a bit higher than we would really like, and the system jacks noticeably when the ground-plane forces get large. It also jacks in braking; it has more than 100% anti-dive.

But if the surface is loose and slippery, and the tires are squishy and rounded in profile, and the bumps are huge, the system's drawbacks don't become too conspicuous, and its advantages – simplicity and long travel – begin to make it attractive.

It is even more attractive if the vehicle we're using comes with this suspension from the factory. In that case, using anything else requires a lot of fabrication, and using the factory suspension, with minor modifications, saves a lot of money and work.

The earliest Ford Broncos used the twin I-beam system only on the two-wheel-drive models. Four-wheel-drive versions got a beam axle on coil springs, located laterally by two transverse links anchored to the frame where the pivots would be in a two-wheel-drive version. This would have created a bind, but Ford made it work by using highly compliant rubber bushings on the links.

So if the off-road racer being contemplated really runs off-road all the time, this suspension is worth considering. If there is a prospect of competing in events with significant pavement stages, it starts to look less attractive. It can be lived with on pavement, if the driver is brave, but a short-and-long-arm system will outperform it, and so will a beam axle.

As to where the roll center is, the system can be thought of as a short-and-long-arm system with the front-view instant center at the beam pivot. To find the approximate roll center graphically, we construct a line from the contact patch center to the pivot in front view, and see where that line crosses the vehicle centerline. This is not exactly correct, but it's close. Typically, the roll center ends up somewhere around eight inches above the ground, give or take a couple of inches. That's higher than we would really like, because an independent suspension with the roll center that high will tend to jack noticeably, but this really only becomes a problem on pavement, and perhaps on tacky clay.

## RELATIONSHIP OF TIRE SIZE AND WEIGHT DISTRIBUTION

*Many car owners say that because their car has 50/50 weight distribution, they inherently have the best handling possible. However, many owners install wider tires at the rear to improve traction. My opinion is that by doing so, while their car may still have 50/50 weight distribution – at rest – the dynamic balance will be a car that understeers. True?*

*On a related note, let's say we have a mid-engine car with 40% front / 60% rear weight distribution. If the rear tires are made 50% wider than the front tires, wouldn't this negate the static weight distribution, essentially creating a car with more balanced traction front and rear (granted, on a* *constant-speed circle?) I understand there may be an issue with getting enough heat into the tires to generate traction proportional to their width. This assumption aside, is this thinking correct?*

It is definitely correct that, at least up to a point, we can compensate for weight distribution with unequal size tires. We can also compensate with roll resistance distribution, camber, tire pressure, and aerodynamics.

So it is safe to say that if the car has 50% rear weight, rear drive, and bigger tires in back, it will probably understeer in steady-state cornering if camber properties and settings, overall roll resistance, tire pressure, and downforce are equal at both ends, and if speed is low enough so that the rear tires do not have to transmit a huge amount of power just to maintain steady speed. If any of these conditions are not present, all bets are off – and usually not all of these conditions are present.

We can at least say that if we take an existing car, and add tire size at the rear only, leaving all else unchanged, the tire size change will move the car toward understeer.

In many forms of racing, we do not have free choice of tire sizes; the rules impose a maximum size. This may be the same for both ends, or not. The rules often also impose restrictions on other aspects of the car's design, which limit what sort of weight distribution we can have, and what sort of downforce distribution we can have.

Nonetheless, it is interesting to consider what we should want in terms of weight distribution and tire size in a rear-drive car, given a free hand.

It is useful to note what course car evolution took in F1 and in sportscar racing, before tire sizes were limited. The cars were decidedly tail-heavy – around 60% rear – and the rear tires were about a foot and a half wide. Front tires had about 2/3 the tread width of the rears. The cars had more aero downforce at the rear than at the front.

Why would this be better than 50% rear, and equal-size tires? There are various reasons, but probably the main one is that the car doesn't just have to corner; it also has to brake and put power down. It brakes with all four wheels, and propels itself with only the rears.

Even without downforce, in straight-line limit braking about 20% of the wheel loading transfers from the rear to the front. Even with 60% static rear, the car does 60% or more of its braking with the front wheels. A car with 50% static rear and modest downforce does about 70% of its braking with the front wheels. It is possible to get the brake bias needed, but it becomes difficult to sustain it over the length of a race. The front brakes tend to overheat and go away.

As for putting power to the ground, there is no mystery as to why more rear percentage is an advantage with rear wheel drive.

Finally, in most cases it is difficult to accommodate foot-and-a-half wide tires on the front of the car, especially without power steering. The scrub radius ends up being really large, and the car gets difficult to steer.