

Mike's Big T.O.E. on Dirt

I have been a dirt track racer for life, attending micro sprint and mini sprint races since I was 3. I am a fan of theoretical physics. There are proven formulas for Newtonian physics (basic understanding of how things move) and there are formulas for quantum physics (how atoms and particles move). But the two fields of study have great contradictions among them, things seem to work differently on an atomic level than they do at our level. Ever since Albert Einstein's theory of general relativity, physicist have been trying to tie the two fields together, to devise a theory that fully explains all known physical phenomena into a Theory Of Everything (T.O.E.). Einstein himself died trying to develop a big T.O.E. Theoretical physics is the field of cutting edge theory in this area.

Dirt track racing needs a big T.O.E. A theory to explain why the adjustments we make on our race car have the effects they do. Although we may know how adjustments affect the car, we do not always know why the adjustments do what they do. Oh we may think we know or we may develop some theory of why they do what they do, but do we really understand? It has been my life long search to understand all that I can about dirt track chassis setup. Not until after reading tons of books, talking to hundreds of racers, thinking obsessively about it, praying about it, and racing for 27 years that I think I may have a big T.O.E for dirt track racing. Although I think I have it clear in my head, writing it down is another issue. I also must warn you, I got a D in college English grammar.

Side Bite? Where did that term come from?

On asphalt, without wings, there are lots of books written based on the laws of physics, with tons of skid pad testing to back them up. Dirt track racers have never paid attention to these formulas and principles because when you take a car that handles well on asphalt, it does not do to well on dirt, many changes need to be made to get it to work to the best of its potential when sliding on dirt. It was discovered that the right side tires needed to be moved in and the center of gravity needed to be moved up. The idea of side bite, the tires digging into the dirt when sliding, then became someone's reason of why these changes needed to be made. Makes sense and explains why the adjustments work.

Let's clarify here that **side bite** is defined as traction available to the car, when there is some side g-force on the chassis, to cause the car to roll to the right, forcing the tires to **dig** into the dirt providing more traction. Kind of like a paddle in the water, the further you push the paddle down into the water, the more force you can put through the paddle to propel the boat.

However, it is my proposal that the only time the traditional understanding of side bite really applies is when the tire grooves (paddles) can work into the dirt (water), which is when the track is wet or slightly wet, in this condition traction is not a problem. Wouldn't you agree? After warm ups, or maybe into the heat races, the tire's grooves can no longer work into the dirt, at least not much because the dirt is harder than the rubber (kind of like the water is frozen and we can't get the paddle into the water). So this idea of side bite and trying to make the grooves work into the dirt by applying more weight to the right rear for traction doesn't make much sense.

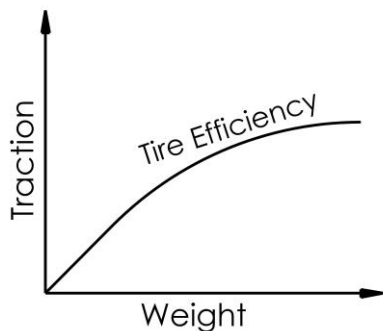
I have proven this to myself in years past by loading the right rear more and more trying to achieve more traction. While at times it would work, many times it did not. I could not put my finger on why this was the case. I suspect many of you have had similar trials.

I would like to change that term side bite to **lateral traction**, lateral means side to side. I want to redefine the idea of side bite, lateral traction, and why dirt chassis need to be setup different than asphalt cars.

Forward bite is still an accurate term but would be more accurately be called **longitudinal traction**, lengthwise or in our application front to back. Forward bite we will discuss later, for now let's focus on lateral traction. It will get confusing because many of the things we need to do to gain lateral traction contradict what we need to do to gain longitudinal traction. Be patient and try to understand.

Maximum Traction Defined

So how do we achieve maximum traction? Maximum lateral traction? When we add weight to a tire the traction goes up, but not linearly (in a straight line), according to skid pad tests, it drops off pretty quick, traction does not increase in proportion to the weight that is added.



As weight is added to the right rear tire, it will get more traction than it did with less weight on it, this much is true. But here is the catch, to gain that traction, weight had to come from somewhere, some other tire needs to lose weight and therefore lose traction. Since we are only considering lateral weight transfer here, we didn't take the weight from the front tires, it had to come from the left rear tire. So now, by definition of the above graph, the left rear tire lost more traction than what the right rear gained.

Fundamental truth: *Maximum traction in the rear of the car is achieved when both rear tires have the same amount of weight on them.*

Actually, due to the larger foot print or contact patch of the right rear tire, its efficiency curve is different than the left rear tire (it can handle more weight before the traction falls off), as a result, about **10%** more right rear weight is needed to maximize the traction. Likewise, maximum traction in the front is achieved when the two front tires are equally loaded. This is not my idea; this has been proven and is documented in many books. In physics there is a whole branch of study called **vehicle dynamics**, which is where all this language and facts come from. They have invested billions in dollars and time to document, research and test all this stuff. Again, almost all of the study is on asphalt, not dirt, which is why it has gotten misrepresented and **misapplied**, dirt is a whole lot more complicated and inconsistent than its *prissy* sister.

Keep in mind that the weight on a race car is constantly shifting around, it is **dynamic**, it is not **static** (constant, still, not changing), boy that would make life real easy. The one force we are concerned with here is the lateral (side) g-force that is on our car while negotiating a turn, it causes weight to shift from the left side of the car to the right side. The other force of course is the longitudinal (front out back) g-force.

Ideally, we would want the weight to be exactly 10% right rear heavy all the way around the track. Fortunately that is not going to happen (life would be really boring if it would). Since we know that weight is going to transfer from the left to the right, then we can assume that we will need to start out with, in the static state, more weight on the left rear and less on the right rear than what we want to end up with while in the middle of a turn. The question is how much.

Just to throw this out there now, so you do not think it is this **simple**, to get maximum longitudinal traction (forward bite) we will need to keep that 10% right rear weight optimum in the static state, because when we are exiting a turn there is very little lateral force on the car, so not much weight is transferring off the left rear. It becomes a matter of figuring out where you need your traction and what you are willing to sacrifice to achieve it. It is not simple at all, let's focus on the middle of the turn for now, read on.

Maximum Traction Achieved

How do we get the perfect amount of right rear weight to achieve the maximum traction in the middle of a turn? Now we need to look at some basic physics formulas, these are not hard to understand and you do not need to do any math, just understand the relationships between the factors. There are only four factors that go into how much weight transfers during a turn:

Center of gravity height (CGH), Tire offsets (Track Width or TW), G-force (G), and the Weight of the car.

The formula looks like this: **Lateral Weight Transfer = Weight x CGH / TW x G**

That's it! No spring rates, shock rates, tire pressure, or roll center height. It is a very simple basic formula that is fundamental in vehicle dynamics. To minimize weight transfer then, we can see that we need to:

- Keep the CGH low, although some of this is controlled by the design of the car, we can raise and lower the CGH by raising and lowering the car, the lower the car the less weight transfer.
- Increase tire offset (TW) by offsetting the tires more. Our goal is to get the weight equal on the rear tires during a turn, offsetting the tires too far will not allow enough weight to transfer causing the left rear to have more weight than the right rear, of course depending on how much static left rear weight there is.
- Make the car as **light weight** as possible. Less weight means less transfer.

The G-force we do not have any control over unless you want to slow down to keep the g-force low, which kind of hurts our overall objective of getting faster lap times.

We can now plug in the numbers and calculate the perfect amount of static left rear weight to start out with to achieve a 10% heavy right rear in the middle of a turn. That is of course if the g-force is constant which of course it is not, this is dirt, it changes **drastically** as the night goes on, or from track to track. As the track goes slick, our race car can not possibly achieve as much traction and therefore as much g-force.

I will save you some effort here and tell you that our 600cc sprints will pull between 0.8 and 2.0 g's in the middle of a turn depending on track conditions, size, and shape. The net result then is that with a normally designed car, it will be transferring a total of 180 pounds (millions of factors here, but just for conversation) and about 100 pounds of that is in the rear. That means, in this example, we need to start out with 85 pounds heavy on the left rear to end up with 10% more right rear weight in the middle of the turn. We all know that that does not work best. Two reasons, the car is too tight in the middle and does not have enough longitudinal traction because there is no right rear weight on corner exit. Let's move on.

The World is Not Flat!

We now have our weight transfer as low as possible and achieving maximum traction. How then do we control the balance of the car, make it loose or tight (over steer and under steer) without changing the design of the car at the track?

Fundamental truth 2: *A softer spring will transfer less weight to that corner of the car than a stiffer spring.*

A stiffer spring on one corner = more weight transfer to that corner, that is why a stiffer right rear spring makes the car looser. The fact about this concept is when you put a softer right rear bar in, the car rolls more to the right rear but it is actually transferring **less** weight that is why it gets tighter. Although the same amount of overall weight is being transferred, the weight is being transferred up front and less in the rear. Imagine if you took the bar out of the right rear, the car would roll a ton to the right rear but would transfer no weight there; all the weight would be transferred up front. Again, this is a fundamental law of vehicle dynamics; I am not making this stuff up.

Dirt track racers, micro sprint and mini sprint included, have botched this stuff up so bad, it took me 27 years to flush it all out of my head and rethink it all.

At this point you may want to go take a shower. Cleanse yourself of the voices that told you the world was flat and you believed them because you couldn't see the big picture. Things are not always as they appear. It may look like the car is transferring a ton of weight to the right rear and the car really is tighter than it was before, and the old idea of side bite seems to be true, **it is not**. Forget what you knew because it was wrong.

Bottom line: when you see a car rolling on the right rear, the car is tight because it is transferring less weight, not more weight. It is keeping more weight on the left rear resulting in a tighter car. It is **not** rolling more weight on the right rear pushing it into the dirt more making the car tight.

Adjustments: To make the car tighter in the middle of a turn, go to a softer right rear bar. A stiffer left rear bar will have two effects, raising the car, because the higher spring rate will hold the car up higher, and it will add static left rear weight. So for considerations of just the middle of the turn, a stiffer left rear bar will tighten the car because it will add left rear weight, but it will also loosen the car in the middle because it will raise the center of gravity of the car. In my experience, the effect is null, it does not make much of a change (again, when only looking at the middle of the turn).

In the automotive world this concept of balance is described by a term called **front and rear roll couple** or roll stiffness. An increase in front roll couple (stiffness) makes the car tighter and a decrease in rear roll couple makes the car tighter. As we stiffen front roll couple, more weight transfers up front and less transfers in the rear. The rear tires stay more equally loaded and the car gets tighter.

Right side springs affect the cars roll couple when negotiating a left hand turn and the car is rolling to the right. Because we do not **turn** right, unless we are exiting the track or avoiding an accident, the left side springs do not play much of a role except for static weight and ride height considerations which can be important, but there is more to come.

If this were it, things would be easy, but God is going to really challenge us and the way we designed our cars. Now that we understand the fundamentals of vehicle dynamics we will go on to the **truth** that really brings the light into focus, and a big part of my big T.O.E.

Winged Down

This is where none of the asphalt formulas or vehicle dynamics concepts were ever devised. The huge **wings** and side boards that we run are unique in the racing world. No where else is there a wing that has such huge side boards to cause such a drastic side force. This is the thing that throws things astray, the top wing with huge side boards; they actually cause weight to transfer to the **inside** of the car for a portion of the turn. This happens because when we enter the turn with such high speed and then we all of a sudden turn the car and make our wing panels face a huge wind. The wind pushes so hard on the side boards that it **overcomes** the weight transfer caused by the side g-force. Imagine going 90 MPH in your car and trying to hold a sheet of plywood up, can you imagine the force?



Here you can see in these three pictures the cars are all winged left and transferring weight to the left side of the car in corner entry.

We need to start looking at the corner in two distinct phases; these phases will change from track to track. It is what I will call **winged left**, or winged down. The first part of the turn when the car is winged (rolled) left due to the wing side boards, and **roll right**, which occurs when the car slows enough that the g-force is greater than the side force generated by the wing panels. The bigger the track the longer the winged left

stage will be. As a driver you need to pay attention to how the car is working when it is winged left and rolled right and make your changes accordingly. The period of the winged down or roll left phase of the turn is different for each size and shape track, and it also changes at the track during the night as the track goes **slicker**. A track with tighter turns relative to the length of the straight will have more winged left effect; tracks that are larger will also have more winged left effect.



You can see in the above pictures that the cars are now transferring weight to the right side of the car in the rolled right phase on corner exit. Interesting too you can see in Robie's 55 car, the left front shock is topped out and just about off the ground, all the weight that was on the left front has now mostly transferred to the right rear and right front, He can still steer off the right front, so this is not a bad thing.

Up until now, most of what we were using to set the balance of our car was the right side springs. Now that we recognize that weight transfers to the inside or the left side of our car for a portion of the turn we need to look at the **left side** springs and offsets. Everything we applied to the phase of our car when it was rolling right needs to be applied on the left side because it is transferring weight to the left.

Big Concept: Left side springs and offsets control the handling during the winged down phase, right side springs and offsets control the roll right phase.

Increasing the left rear spring rate will loosen the car while winged down because it will increase the roll left rear roll couple stiffness and keep the weight on the front tires more equally loaded. Softening the left rear spring will tighten the car during roll left or winged down. Of course when our car hits the ground, the spring rate not only becomes infinite, but the weight is now transferred through the frame rail to the track and not the tire to the track. The tire gets a whole lot better traction than the frame rail. Bottom line, don't let the car bottom out.

A bump rubber is a good fix for this problem and allows us to run a softer left rear torsion bar to help tighten up on entry. Another thought here is that when the car gets into the bump rubber on the left rear shock, the spring rates also climbs very high, this will also make the car loose on entry, but is a whole lot better than bottoming out.



Proper use of a left rear bump rubber. Use the shims to adjust exactly when the car gets into the bump rubber.

Corner weights

How many times have you asked the question to someone who you respect as a racer “where do you put turns in or out of in the chassis to make it tighter”? And how many different answers did you get? The reason there is no consistent answer is because both left rear-right front weight can tighten the car and right rear-left front weight can tighten a car. During the winged down phase of the turn, weight is actually rolling from the right rear to the left rear. As usual we want to try to keep the weight equal on both tires, so more initial (or static) right rear-left front weight will make the car tighter in winged down. Reason is that starting out with more right rear weight, when the car transfers to the left the end result will be the two rear tires will be more equal in weight.

The opposite is true during the roll right phase; more initial left rear-right front weight will result in a tighter car. Got it? When we add left rear-right front weight or what some might call cross bite, yes the car will get tighter during roll right, but looser during roll left. So there you go everybody's right.....or everybody's wrong.

Tire offsets

Same theory applies; moving the right rear in will add more static right rear weight and will cause more weight transfer. These effects are good for tightening up the car when winged down, but opposite for roll right.

More wing speed means we need to keep the right rear in further to get the car tighter, a slicker track means less weight is transferring to the right rear during roll right, but generally our winged down phase is just as it was on a tacky track, so the right rear can be moved in. However there is a point of no return where you can go to far and have too much weight on the right rear. The exact numbers vary from car to car, track to track, and surface to surface.

The left rear tire can be moved out to tighten up when winged down. It is the weight transfer formula being applied to roll left, a wider TW or more offset will result in less weight transfer.

Lateral Traction Summed Up

If you are loose when the car is winged left, we need to change left side springs and/or left side offsets and/or add right rear-left front weight. A stiffer left front spring or softer left rear spring will tighten the car in this phase. Move left rear out to tighten or move left front in to tighten. Static (sitting still, or on scales in the garage) to tighten car while winged left are move right rear in, add more left front-right rear weight. If you run traction (anti-roll) bars, we can tighten the car in this stage by backing off on the rear traction bar roll left screw and/or making the roll left screw on the front traction bar up against the stop screw.

If you are loose when the car is rolled right, stiffer right front spring and softer right rear spring will tighten car. Static weight thoughts while in this stage are add more right front-left rear weight (I.E. crank turns into the left rear). If you run traction bars, we can tighten the car in this stage by backing off on the rear traction bar roll right screw and/or making the roll right screw on the front bar up against the stop screw. I am not going to say that moving the right rear out will tighten the car up in this phase because the amount of weight transferring from the left to the right is less than when the track has more grip. Remember that we are trying to keep the weight equal on the left rear and right rear, if we move the right rear out, we may be loading the left rear too much and not getting enough weight onto the right rear. It is a fine line and exactly where that line is on every track for every track condition, I am afraid only God will be able to know it all.

For general considerations, softer rear springs or torsion bars will make the car tighter, and a stiffer front springs or torsion bars will make the car tighter. However, too stiff of front springs will not allow the front tires to maintain compliance with the track when they hit a bump and the front will push. On a slick smooth track it can be ok to go pretty stiff on the front, but don't try it on a track that has some imperfections in it, the car will be real inconsistent.

Keep the car as low as possible without bottoming out. The lower center of gravity keeps the weight equal on the front pair and rear pair of tires which is when you get maximum traction. Also keep the driver low.

I have found keeping the right rear at 14-3/4" works best for most all track conditions. Also running a 40.5 torsion front axle with 5/8"-3/4" offset in it works best for most track conditions.

Forward Bite Another Animal

Forward bite or longitudinal traction is the amount of acceleration our car can achieve when we are on the throttle. To get the maximum forward bite we need to get as much total weight as possible on the rear tires. Although we learned earlier that the traction achieved by a tire does not increase proportionately with the amount of weight that is added to it, it does, nonetheless, increase.

The formula for calculating the amount of weight transferred to the rear under acceleration is similar to that of lateral weight transfer. Here it is:

Center of gravity height (CGH), Wheel Base (WB), acceleration-force (G), and the Weight of the car. (W)

Longitudinal Weight Transfer = Weight x CGH / WB x G

You can derive from the formula that the amount of weight transfer to the rear can be increased by **raising** the center of gravity, or shortening the wheel base, of course increasing the horse power to increase the acceleration, assuming of course that we are not going to just spin the wheels which would lead to no increase in G anyway.

Yea, all that talk we just did above about lowering the C.G. works great for entering and in the middle, but for the last quarter of the turn, or whenever we are spinning our wheels from lack of drive, the opposite is true. So that is why there has never been a clear advantage to raising or lowering your car, you will tighten it up in one part of the turn and loosen it up in another part of the turn.

Here is what I found. On small tracks that are slick, generally, raising the car more is the way to go. I think this is mostly because the winged down phase is real short and the car will start spinning the tires quicker because of the gear ratio allowing for greater torque on the tires. On bigger tracks, 1/3 or bigger, it is better to keep the car lower to the ground. There are optimum points where balance is achieved, Just pay attention to what you car is doing, and now you know the proper adjustments to make.

Some of you caught the part about wheel base. Here is the deal, yes, you get more weight transfer from the front to the rear with a shorter wheel base, but the disadvantage to a short wheel base is you loose rear weight percentage in the static state. With a long wheel base car, at least if it is designed correctly, will have more rear weight percentage in the static state, so much so that even with the decrease in weight transfer, the end result is that it still has more rear weight under acceleration.

Another consideration with wheelbase length is the problem of the front wheels coming off the ground or even just topping out the front shocks. Either of these two scenarios will cause a lack of steering and control, not good.

A temptation, and I am guilty, is too run really soft bars in the rear to get the car tight in the middle. Problem is, these soft bars lower the car and center of gravity and promote **less** weight transfer for longitudinal traction. Yes, it looks cool to see a car squatted on the rear, it looks like it is really driving forward. Fact is, when a car is getting good forward bite, **then** it squats, **not** if a car squats then it gets good forward drive. Do not confuse the affect from the cause.

Rear geometry can greatly affect forward bite. Geometry that causes the rear to lift up under acceleration will promote more forward bite. Consider the late model design; note how the rear gets jacked up under acceleration.

Wingless

Wingless racing is a little easier to understand as we only need to look at the roll right factors. Of course with less overall traction available due to the air foil being gone (free down force), spinning the tires from lack of forward bite becomes more of an issue. A higher center of gravity and more right side offset is advantageous.

Horsepower has a lot to do with which factors you want to focus on, other classes of sprint cars will need to focus on different parts of the adjustments than 600cc sprints do.

Roll Centers

The roll center of your chassis is the pivot point around which your chassis rolls. The roll center is controlled by the lateral linkage; this linkage controls the location of the axles under the chassis in the side to side or lateral direction. The amount of chassis roll is a function of the distance between the roll center axis height and the center of gravity height. The roll center axis is an imaginary line drawn from the front RC (roll center) to the rear RC. The longer this measurement, the more roll, shorter measurement or higher RC the less weight roll of the chassis.

Although roll centers play an important part in how your car handles, it does **not** control **how much** total weight transfers, only where and how it transfers. We can control if the weight transfers to the front or to the rear through the difference in RC heights between the front and the rear. We can control if it transfers through the springs or the lateral linkage through controlling the height of the roll centers. As we raise the RC more of the weight is transferred through the linkage, as we lower the RC the weight is transferred through the springs. If we made the RC axis higher than the center of gravity of the car, the car would actually roll to the inside of the turn, like a boat, but the same amount of weight would be transferred to the right side of the car.

The two ways we control roll centers on our dirt chassis is through the panhard bar or a Jacob's ladder. The Jacob's ladder's RC can be found by intersecting the center lines of the two straps. When you change the holes where the straps mount, it changes the RC height and/or the RC side to side location. The panhard bar's RC is located in the middle of the panhard bar. One major difference between the two designs, the Jacob's ladder's RC goes up when the car rolls right, the panhard bar's RC moves down when the car rolls right.

Effects of roll center height: A higher RC resists roll, we learned in Rethink Dirt that resisting roll actually increases weight transfer; increasing weight transfer on the rear will make the car looser. Lowering the rear RC will prevent weight from transferring making the car tighter. To the masses, again, just like soft vs. stiff right rear spring rate, they had the affect of the adjustment correct, but the reasoning completely backwards.

Effects of roll center side to side location: As we move the RC to the right (depending on the exact layout and design of the chassis) generally we will make the distance between the RC axis and the CGH longer. If we move the **rear** RC to the right, it will make the car tighter because it will resist the roll less.

Bottom line: Lower your rear roll center to make the car tighter. Lower your front RC to make the car looser. Now all this explanation of course if for lateral traction considerations only (or side bite, I hate that word) For longitudinal traction (forward bite, I still like that word) the higher RC or a movement of the RC to the right, will keep the car sitting higher (to a point) which will increase forward bite.

Anti squat

Anti squat is a concept used to determine how much the rear of a chassis will squat under acceleration as a result of the rear geometry 4-link, wishbone, z-link or trailing arm type design. Conversely anti-dive is used to describe how much a chassis nose dives under braking. Anti-dive is not something we need to concern ourselves with on dirt as the braking force is not real high and wheel hop or chatter under braking never occurs.

Again, we already know what factors affect how much weight transfers to the rear under acceleration. (see Forward Bite) and anti squat or how much the rear squats from rear geometry is not one of them. Looking at that formula, to get max weight transfer to the rear, we need to raise the CGH, knowing this fundamental truth, designing the rear geometry to make the rear squat actually hurts our cause. Yes we do want the rear to squat, but not because of the rear geometry, but because the weight is transferring to the back. We want the rear geometry to drive the rear of the car up, raising the center of gravity, when the center of gravity is raised; the acceleration force will have more leverage over the ground causing more weight transfer.

Calculating anti squat: this is not so straight forward and I will not go into the numbers, just know that as you raise you linkage points in the front (wishbone, 4-link, and the top rod on a z-link) the anti squat will be increased, it will resist squatting resulting in better forward bite because it will keep the CGH higher.

If you calculate the anti-squat on a typical wishbone, it is much more than the typical z-link design used on common Jacob's ladder cars. Another consideration is chain tension, as the pivot point of the rear axle is moved to achieve different anti squat percentages, it changes how loose and how tight the chain gets as the chassis rolls. If we can achieve a pivot point real close to the front sprocket center, the result will be a chain that does not change tension as the chassis rolls, this is how the Hyper chassis wishbone cars are designed. If the pivot points are drastically moved the result may be a chain that will not stay on.

I am Humbled

Even after 27 years of racing micro sprints and mini sprints, I am still learning a ton every year, and I hope it never stops. Test my theory, develop your own conclusions, and watch my website as new truths unfold. I hope this paper inspires you and makes you want to learn more, there is a lot of information available online now, just search for some of the terms I used and you can learn a lot.