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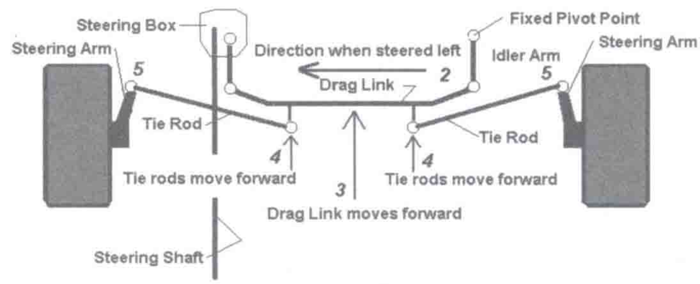
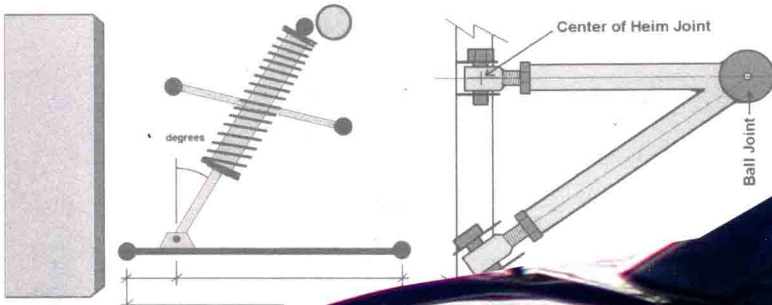
ADVANCED Race Car CHASSIS TECHNOLOGY



Winning Chassis Design and Setup for Circle Track and Road Race Cars



Bob Bolles

Previously published as *Stock Car Setup Secrets*

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The technology that forms a large part of this book was accumulated by working with a great many and varied race teams. As that work progressed, much knowledge was gained. I consider all who have asked for my help and paid my consulting fees partners in developing the information you will read in the following pages.

As with any serious, long-term endeavor, we got a lot of help along the way. It was once said by Martin Rutte, "You have to do it by yourself, and you can't do it alone." And the motto I mostly live by, from Zig Ziglar, "I believe you can get everything in life you want if you will just help enough other people get what they want." In helping others, a lot came back to me in the form of financial assistance, knowledge of systems, suggestions, satisfaction and support.

This book is dedicated to: Wes Troup who gave me much support and my first important championship; Buddy Parrott and Nick Ollila for providing me with my first hands-on experience with a Cup car, which lit a fire in me; Dewayne Ragland for his friendship and ongoing support and for showing me around the Midwest; Brian Wheeler for use of his shop and resources as well as his continued support and concern; Brian Butler, who caught on early and who is always available for a "conference;" to Charley Miles; Jon, Jim and Jeff Craig; Jay Fogleman; Greg Marlowe; Jason Boyd; Robert Ham; Jack Cook; Brian Hoppe; Bob Garbarino; and all of the hundreds of other race car drivers who went out and won with this stuff.

I also want to thank certain car builders who helped me in various ways throughout my career. To Billy Hess, Harley Boeve, Wayne Lensing, Gene Coleman, Dick Anderson, Keith Masters and Steve Leavett, thanks for your valuable support. And to Bill Montagne, for divulging the secrets of the science of aerodynamics.

I gained a lot through my association with *Circle Track* magazine. I had always valued the publication and never thought I would be lucky enough to write for the racers. I gave my very first article to famed engine builder and CT contributor Smokey Yunick to read and critique. His comment was, "If it takes longer to read than it takes to take a crap, then it's too long." I loved Smokey. I have developed many valuable friendships as a result of my association with CT. My knowledge has grown over the years, and this book is an effort to share what I've learned with the racing community.

To everyone who bought my software and paid my consulting fees, you helped to fund this research and were truly a large part of making it happen. Thanks so much, and keep those cards and emails coming.

On a more personal level, my parents, children and my wonderful wife have all supported this effort. A project such as this one tends to consume a person and those who live around that person are affected most, but without close family support, this project would have been much more difficult or impossible to complete. To my immediate family—Grammy, Pa, Karen, Sonia, Mike, Christa and Tim—thanks for your continued patience and endurance.

And thank you, Harry Hyde. I'm still listening, man.

INTRODUCTION

Around 1992 I decided to change careers and become a race car engineer. My early experience in racing was spending countless hours at Daytona International Speedway in the pits, in the stands and around the mechanics, drivers and owners listening and hearing about how the cars handled. I was always fascinated by the design and setup of race cars, be they stock cars, road racing cars, formula or weekend SCCA cars.

I attended many years of races at New Smyrna Speedway and Barberville, now known as Volusia Speedway Park. I was interested in the "race," but always fascinated by the way the cars handled and how all of that was accomplished. I watched Dick Trickle prepare his car in 1975 at a friend's garage in preparation for the Speed Weeks show at New Smyrna and thought, "I would like to be able to do that."

I am an engineer by education and nature and I knew someday I would have to get involved with racing. When that day came, I threw myself into the task of learning and inventing with more energy and determination than I ever had at any point in my life with anything. It was a passion combined with a purpose: *I would find the truth about chassis dynamics and race car setup.*

My work, and indeed my racing business, was born out of frustration and failure in trying to find really helpful information that I could use to set up a race car. So I set out on a journey that followed in no one's footsteps. Instead, I used one of my greatest personal assets, a profound and acutely developed ability to apply a commonsense approach to problem solving. That is exactly what you will find in this book, a commonsense approach to chassis setup, vehicle dynamics and race car design, together with solid engineering theory.

To a few in the industry, this is considered maybe the most controversial race car setup book ever written. To many more it has become their bible of racing knowledge. Much of the technology presented here has been more recently developed over the last fifteen years or so, and as such, it is often viewed with skepticism by established race engineers, authors and consultants, many who have come to believe that we had already pushed the envelope of vehicle dynamics about as far as it could go by the early 1990s. This book does not follow that line of thinking.

Regardless of what is on the pages, the proof is on the race track, and the methods in this book have been tested and proven to improve performance in race cars. They increase speed, improve basic stability and have already been used to win many races and championships in many classes of racing.

How, then, did this book come about? When I began my career working with race cars, I found plenty of information on chassis theory, but I couldn't find conclusive information that would tell me how to set up my race car in the shop, the right way, the first time. I had to read between the lines and keep trying different setups, working by trial and error. I personally don't like trial and error. I want to be able to know exactly how to set up my race car and know not only how something works, but why.

This book will help you avoid the trial-and-error approach to chassis setup. It will teach you sound, proven technology that is both easy to understand and easy to use, so you can set up your race car in the shop and see the positive results on the track immediately, with very little tweaking. What follows is a commonsense approach to chassis setup, vehicle dynamics and race car design, founded on solid engineering theory. However, you will need to have an open mind, and be willing to accept new ideas that may go against conventional chassis setup thinking.

Although many of the examples in this book center around stock or circle track race cars, the technology presented here applies to all race cars, from quarter midgets to Formula One and everything in between. This book is specifically written for stock car racing because it represents most of the world's automobile racing.

The theory of roll couple distribution was an early attempt to explain and quantify the dynamics of automobiles. It was a good start, but lacked a basic understanding of physics and made erroneous assumptions. In short, it was not complete. In this book, you will learn how subjects like roll couple distribution will no longer be used for chassis setup. I will explain a new method that more clearly and accurately defines what a race car wants and how to design it with that goal in mind.

Weight Transfer and Other Myths

Load transfer and dynamic load distribution are a direct result of the design of the car and the setup that is in it. The lower the center of gravity, the less total load transfer takes place. But, do I really need to know how much transfer is going on in my car at my track? It won't really help me set up my car.

Load Transfer Is Fixed—The car will transfer X amount of load no matter what I do with the springs, and that's a hard-and-fast, proven dynamic—a fact of life. If you can't easily influence it, don't fret over it. We will learn the only way to accurately predict load transfer in a race car.

There are many examples of misconceptions in automotive dynamics that have been presented over the past fifty years and many more examples of correct thinking. What this book will do is separate the correct methods from the incorrect. It will provide you with a way to avoid the crutches that have been created over the course of time.

Success comes at all levels of endeavor, and we can't all be champions. But we can all get better at what we do. The goal of this book is to give good, solid information that has been tested and evaluated and found to be the truth. It is not, and will never be, complete as long as we continue to push the envelope in the search for better performance, but it will lay the foundation upon which future race engineers can build their programs.

CONTENTS

The rules for making a stock car go fast even apply to road racing cars such as this Grand Am Pontiac GTO. Here the team prepares the setup in a controlled way to ensure a balanced setup.

Chapter 1

The Proper Approach to Chassis Setup

The approach to chassis setup and design is more mental than physical. You need to have a clear idea of what your goals are and how you intend to achieve those goals before you ever turn a wrench on your race car. Becoming educated and planning out your approach to design are the first things you need to do on the way to producing a winning race car.

The ultimate goal for all racers is to complete a lap in less time than their competitors consistently enough to win the race. It all comes down to that simple principle. But how do you do it? Exactly what are the steps to that end and where should you start? Here are some ideas that will help you answer those questions.

Setting Goals

Basically, you want to achieve the maximum traction (or tractive capacity) possible with the equipment you have. Increased tractive capacity improves performance in the areas of braking, turn speed and allowing the increased use of available horsepower during exit acceleration.

The high performance we develop must last the entire race. Races are hard to win if the handling goes away before the end of the race. Most racers would rather be fast at the end than at any other point in the race. We can have a setup that is fast all of the time.

A good, fast setup is fairly easy to achieve if you know what the car needs, but oh so easy to lose if it is not maintained. Ask any racer, and he'll tell you that there were times, with certain cars, when they just flew. Nobody knew exactly how or why, but certain cars were fast. Then, the old car got crashed or new cars were built and in many cases, the performance just could not be duplicated. The components in the new car may be mounted in different places, the weight may not be arranged in the same way or the overall design might be much different. The point is, we can make any car work with the proper approach and knowledge.

In this book, we will learn how to make all cars fast by using a system of analysis that will allow us to change the geometry, springs, roll centers and weight distribution so that the chassis will work the way it desires.

What Do We Really Want?

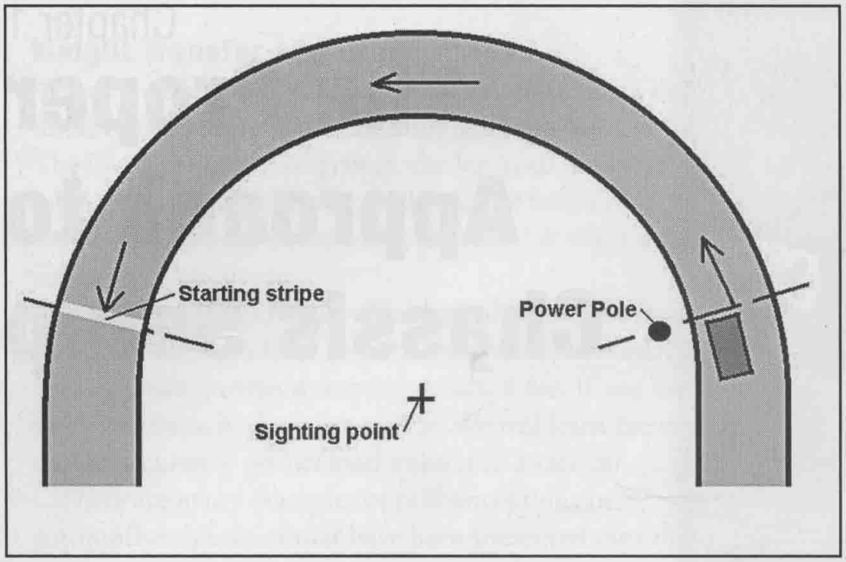
In the most basic terms: We want to make all four tires work to their highest capacity for a long period of time through the turns. Your overall goals should be:

- Balanced setup and consistent handling
- Maximized turn speeds
- Controlled entry combined with quick exit performance

Corner Entry—During braking and corner entry, we want all four tires to help to slow the car the best they possibly can and for the car to remain neutral in handling. The transition from acceleration to braking should be as smooth as possible.

Midpoint Speed—As we enter the midpoint of the turn, where the forward speed is the slowest, we want the car to be as fast as possible. Speed gained here will be carried throughout the lap.

Suppose my motor/gear combination will accelerate the

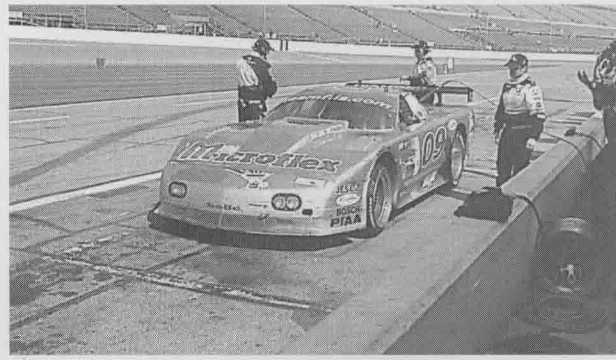


When taking turn segment times, position yourself near the radius of the turn if possible, and sight through poles or ends of walls and maintain the same position of those visual targets throughout the practice. Compare times with the other cars.

This motorsports reporter is trying to find out why this team's driver is the fastest in practice. He might say, "We have a really good motor in the car," or "The aero package is really good," but what is really working is the setup.

car a total of sixty miles per hour from the time I pick up the throttle until I need to lift for the next turn. If I am able to start accelerating from a higher speed, then the average speed for the entire lap should increase by about the same amount. There is a combination of conditions that make this possible and all of them will be covered in later chapters.

Tip: To help set a baseline for how the car is performing in a turn, I recommend timing the car only in a predetermined section of the turn. You want to know how well the car is performing in the turns from the time the driver lets off the throttle until he straightens out the steering wheel.



Even road racing cars such as this Grand Am Daytona Prototype car can benefit from a balanced setup. This car has been improved in its performance using the methods presented in this book.

I can't do much about the horsepower I have available at the track, except for the usual motor-tuning techniques. But we know that improving the mid-turn performance produces fast laps more easily. Straightaway gains in performance are raw horsepower/gear ratio influenced to a great extent and you can't buy enough legal horsepower to equal the gains found in improving your cornering performance.

Exit Performance—Exit speed and performance are very much dependent on being able to get on the gas early, and to convert the available horsepower into forward thrust. Gearing to the horsepower band, the handling balance while under power, control of wheel spin and the level of driver comfort all dictate how quickly a car can exit a turn.

Working with All Areas of Performance—All three of these turn segments—corner entry, midpoint speed, and exit performance—will be examined throughout the book, with initial emphasis on those areas of chassis setup that have the greatest effect on overall performance.

What we all need, in a nutshell, is a tool to tell us what the car wants and that we have selected the correct four springs to install in our race car in order to make all four tires work to their highest capacity. Bingo, the left-front spring should be an XXX, the right-front should be an XXX, etc. We want to know exactly what size sway bar we should use in combination with the springs and where we should locate the roll centers. We will be able to choose the right stagger that will be good for a certain race track and how much cross-weight the car will need. I want to know how to determine the correct caster/camber settings that will provide just the right tire temperatures for the best tire footprint.

I want to know how to read tire temperatures correctly and what to do if they are not right. I need to know what shocks do and what rate of shocks I will need at each corner of the car for best transition control to tune the entry and exit handling. I want good, solid advice on the best way to correct any handling problems I might encounter while racing my car. What we all want, in essence, is to know how to develop the total handling package (THP).

The Total Package

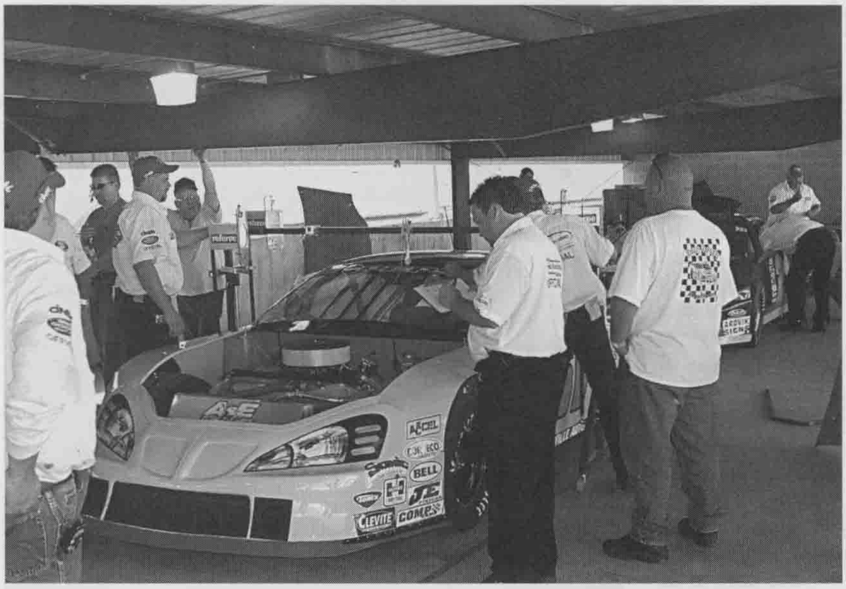
What exactly is the total handling package? It is the perfect combination of settings and setup parameters that will lead to being the fastest car on the race track. Teaching you how to develop the THP is the ultimate goal of this book. In order to achieve that end, we may have to readjust our line of thinking. This means tossing out some old chassis setup conventions and embracing new ones. Much of the information that you have come across that has been presented in the past, in my opinion, does little to help the average racer understand how to set up his race car. Most published information deals with changes to pre-existing conditions and explains a lot of theory without making definitive statements on how to ultimately set up the car. "Detroit-generated" street car technology does not even begin to relate to race car setup as far as developing the THP.

How Do We Achieve the THP?—To achieve the THP, we must select the correct front roll center location 1) to give optimum dynamics and 2) to give us the best camber-change characteristics for the front wheels.

We will have to align the entire car so that the cambers are correct, the bump steer is near zero, the Ackermann steering effect is minimal, and the rear end is squared and aligned with the rear suspension being adjusted correctly for the desired roll steer.

We will have to develop a combination of spring rates, roll centers, and weight distribution so that when the car is in the turns, both ends of the car will be balanced in their desires and will want to work together to roll to the exact same angle.

We will have to select shock rates so that we have optimized entry and exit performance to suit the driver. We will have to ensure that the aerodynamic properties of the car complement the overall setup where neither end of the car is overly burdened with down-force. If all of these areas of chassis setup have been taken care of using the skills explained in



Inspection prior to the race should go smoothly. If the car was properly prepared before leaving the shop, there should be no problems.

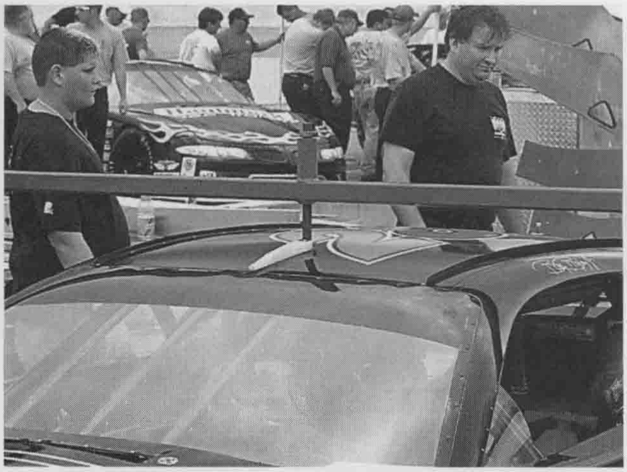
this book, then you will have the THP you have been looking for. The rest is up to the driver and pit crew as to whether you will win a race.

New Methods for Achieving Balanced Handling

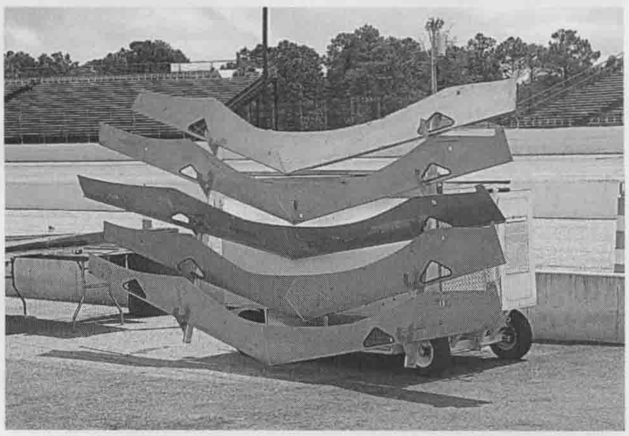
The secret to perfect handling is to develop a setup that will cause both ends of the car to want to do the same thing in the turns. That is exactly what the car wants. This is known as a dynamically balanced setup. But we need some information before we start to make that happen.

If a particular race car only likes one combination of wheel weights, roll center locations, springs and sway bar(s), then once we discover those correct elements, there should be no significant changes to make. If small changes are desired to suit driver preferences, the only way to further adjust the handling balance is to change the weight that is supported by each wheel. The way to accomplish this is to adjust the cross-weight percent. Traditionally, adjusting handling balance was achieved by experimentation—by changing one or more spring rates, raising or lowering the rear roll center and by changing the sway bar diameters.

In order to use the new technology I am proposing, you must believe that the traditional trial-and-error methods are only temporary solutions. Many of the adjustment techniques just mentioned have been used for years, but they may not be the best way to adjust the handling balance of the car. They can sometimes serve only as crutches while you properly address the chassis problems.



Special attention should be paid to the heights of the body parts. Here a car is rolled under a device used to measure the roof height. Many touring series are very tight on the rules concerning roof and fender heights in order to maintain even competition.



Many racing series require the cars to fit stock dimensioned templates. Here is a stack of templates that represent all of the possible brands and styles of bodies that are legal in this series.

You can make any car neutral in handling if you play around enough, but the setup we want in our race car is the one that will also make it faster and most of all, consistent.

If you are like most racers and believe that it is impossible to select the perfect combination of roll center locations, springs and sway bar diameter that will be just right for your car before you go to the track, then think again.

Getting Started

There are many things we need to know before we begin working toward achieving the total handling package.

This is an example of a dirt car that has been set up properly. The car looks very balanced and the angle of the front tires shows that the car is very neutral in handling. The driver doesn't need to throw the car sideways to get it to turn.

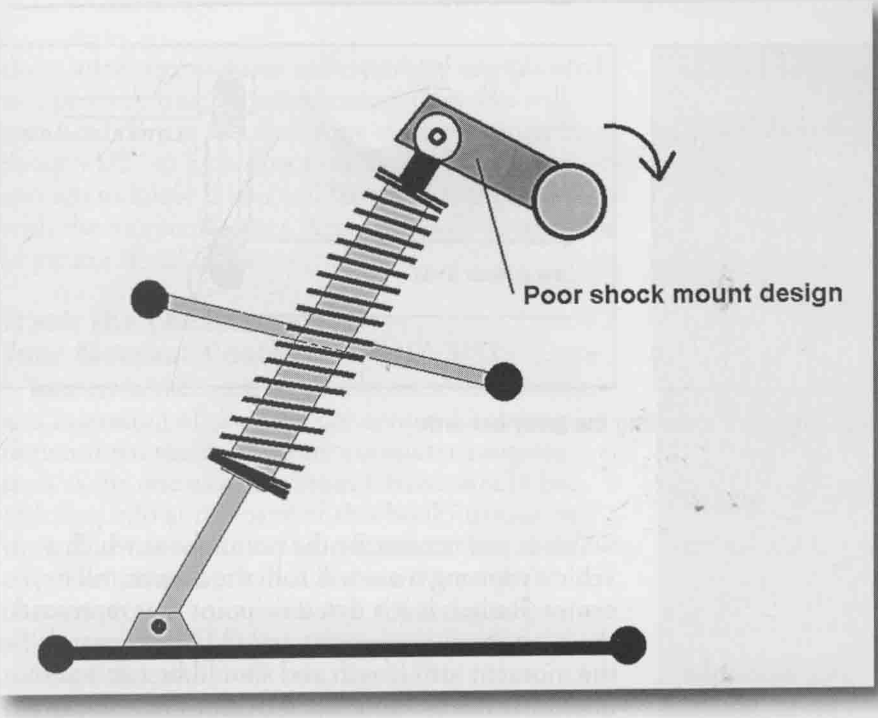
***Car Construction*—The first step is to make sure the car is built correctly. A lot of hands have probably been involved with the original fabrication, not to mention the rebuilding after the inevitable collisions. Even if the chassis builder is the best in the business, he cannot control who works on the car or what happens to the chassis after it leaves his shop. You need to really analyze how the car is put together. We'll tell you what to look for.

***Obvious Problem Areas*—Look for signs of cracks in the welded joints or control arms. Make sure there are no bent components and that all ball joints and pivot points are free of binding and well lubricated. Check for excess play in the steering system and trailing arm bushings. Get to know the overall condition of your race car.

***Understanding Dynamics*—The next step is to study and understand the basic dynamic forces and how they will influence the handling of the car as well as what the chassis basics are. We will help you understand what all of this means in practical terms, beginning with the next chapter.

Chapter 2

The Basics of a Working Chassis



This is a poorly designed shock mount. High forces put on the shock mount will cause the mount to twist around the roll bar tubing and the weld and/or the mount will eventually break.

The quest for dynamically balanced handling begins with the chassis construction. Of course, we all know that a chassis must be built rigid, with quality materials and strong welds, but what else do we look for? Here are some tips on creating a better chassis.

Front Springs

All spring angles should be set to a minimum. For coil-over designs, the top of the front springs must be angled in, toward the centerline of the car in order to clear the insides of the upper control arms. It is difficult to get these angles under about eighteen degrees. Mount the lower end of the shock/spring as close to the lower ball joint as practical.

Front Shock Mounts

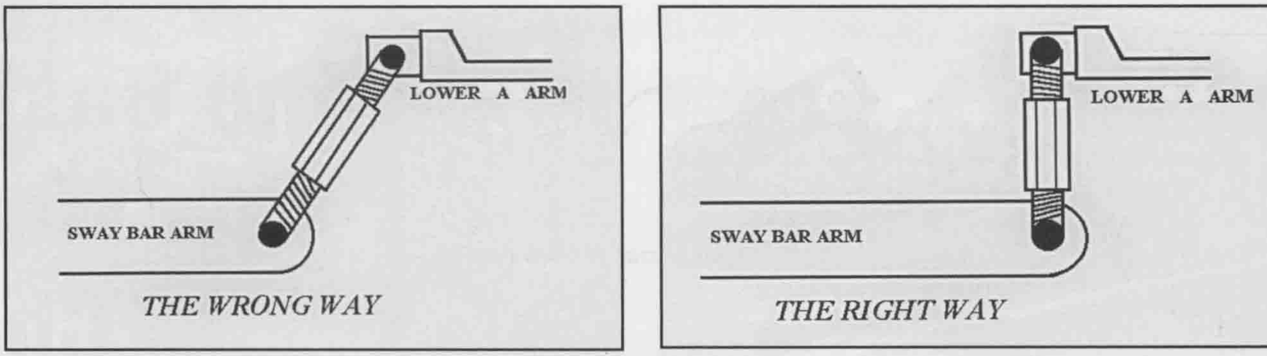
The upper end of the shock should not be mounted on any kind of perch or extension that extends to the side of the front loop bar. You might get away with it if the cross brace (between the right and left engine loop bars) is attached to the same structure to which the shock is attached. This bracing of the shock mount is necessary to minimize torsional twist in the loop bar. If this area flexes, and it will without proper bracing, the mount will eventually break.

Rear Springs

The rear springs should be mounted as far out as possible from the centerline of the car without interfering with other components and both should be nearly equidistant from the centerline between the two tires. This provides a wider spring base that is better for resisting roll.

This is the correct design for the shock mount. The bracket used to attach the shock must also be in line with the bracket used for the cross brace connected to the opposite shock mount. That way there is sufficient resistance to torsional loads applied to the chassis tubing.

The benefit of the wider spring base will be discussed further in later chapters. Cars using the truck-arm type of suspension as well as other stock designs can suffer here because some rules state that the springs are to be mounted on the arms or in their stock original location. This results in



Shown here are the incorrect and correct angles for mounting the sway bar arm.

a narrow spring base and therefore the rear has less resistance to roll effect.

Rear Coil-Over Springs

For coil-over designs, the rear springs should be angled slightly with the tops positioned in toward the middle of the car at approximately a 5-degree angle and angled at no more than 10 degrees.

Sway Bar Arm Design

Sway bar arms should be of equal lengths and the attachment between the sway bar arm and the lower control arm must be perpendicular to both the sway bar arm and the control arm. This is very important. If this attachment is mounted at an angle, there will be a binding problem that you will chase forever and never find. You need to understand this effect (see the illustrations above).

How This Is Detrimental—To quickly describe how this is detrimental, imagine trying to push a car forward using a bar that is attached at a 45-degree angle off the side of the car. As you push forward, you will have to resist the effect of the bar wanting to go to the side too.

No Direct Force —You will have to use a sideways force to resist the side motion as well as effort to push forward. This is a difficult thing for you to do and it is equally difficult for the sway bar to do. The end result is that the link will bind up and the actual "felt" rate of resistance for the sway bar will be very high. A one-inch diameter bar will resist roll like a one and one-half-inch bar in some cases. This will obviously throw a kink in your whole setup.

Front Roll Moment Center Design

The front roll center design is the basic starting point for all setups. There are two roll centers, the *kinetic* roll center and the *dynamic* roll center. The roll center we are interested in is a geometric point, which is not necessarily the point about which a vehicle's sprung mass will roll, the kinetic roll center. Rather, it is a dynamic point that represents the bottom of the *moment arm* (MA). It controls the moment arm length and should be referred to instead as the *moment center* (MC). There are two such moment center points, one at the front and one at the rear of the vehicle.

The front moment center location is determined by the angles of the upper and lower control arms. The correct upper and lower A-arm angles are determined according to the intended use, and the desired location and migration of the geometric roll center. This sounds very complicated to the average racer, but we cannot ignore the importance of this part of the setup.

The moment center design, be it good or bad, can make all the difference in the world as to how your car performs, as we will see in the next chapter. Have you ever heard a driver say after a poor performance that his car was junk and he never wants to drive it again? If the truth were known, the front moment center was probably poorly located.

Know Your Roll Center

Knowing your race car also means knowing where the front moment center is located on your car. I want to strongly stress this. Moment center location in the front end is very critical to the dynamics of the chassis. The reasons will be discussed in more detail in the next chapter, but it is important to know where it is located. There are computer programs available, such as the software manufactured by Chassis R&D, that will tell you where your moment center is. If you are racing as a hobby, say in the Late Model division, don't buy a complicated three-dimensional geometry program. You'll just get frustrated with all of the intense measurements that are required because most of these software programs are extremely complicated and produce much more accuracy than you will ever need. If you can find your moment center to about +1/2" in each direction, that will be good enough to know if you will have any real problem with the moment center. Again, we will discuss this in greater detail in the next chapter.

Track the Location of Your Moment Center

Your team will need to closely track the location and migration of the moment center. Use a two-dimensional moment center computer program such as the one available from Chassis R&D (see ordering info at the back of this book) to analyze the roll center location and migration. The more advanced programs will also show the camber changes after dive and roll and allow the user to adjust arm angles and arm lengths as part of the redesign process.

Most of the racers who do not own roll center software will be forced to trust that the car builder knows what he is doing and has properly designed the car. From my experience, many car builders are not really sure where the moment center is located nor are they convinced that it is even that important. Remember that the technology that shows us why the moment center is important is relatively new. Many racers have not been exposed to this information.

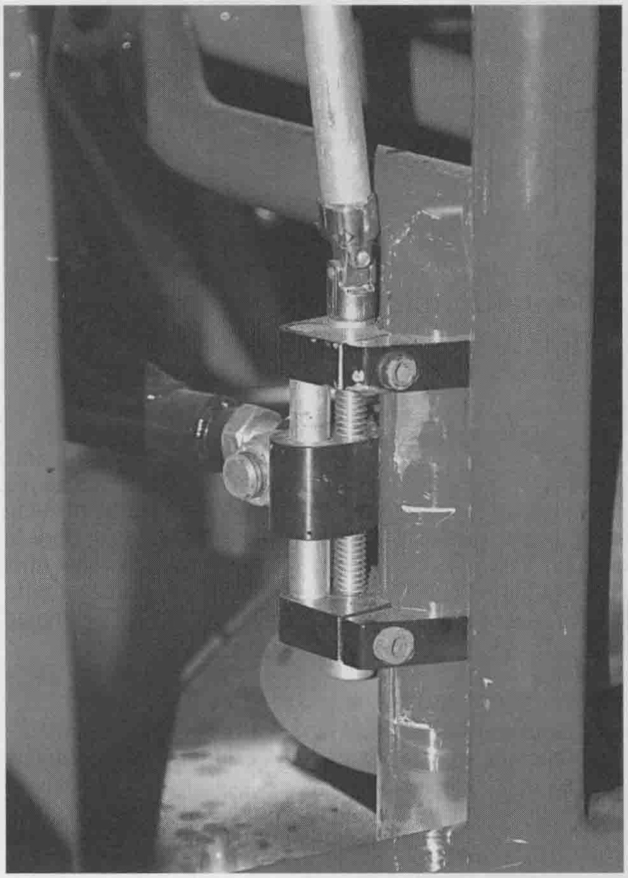
The other problem is one of changes to the original design. Anyone who has had their hands on the car could have made changes that made the car a different design. New spindles of different dimensions, new upper control arms of different length and a new clip are all examples of the ways that a car can be redesigned unintentionally.

Ask your chassis builder if he knows, and if he does not know or won't tell you, measure it for yourself or find someone who can measure it for you. A lot of chassis problems can be traced directly to improper moment center location. This is a very important part of having the correct total handling package.

Freedom of Movement

There must be freedom of movement in all suspension components. Periodically check the pivot points to detect any difficulty in movement. If there is, you have friction shock at work that you don't need.

Bent-ball joint shafts and lower control arm mounting tabs are prime areas where a bump during a race can cause a bind in your suspension.



This car has the panhard bar/track bar mounted to an adjustable chassis mount system. Note the screw and extension that makes small adjustments possible. Always mark a reference point for height.

The Panhard Bar

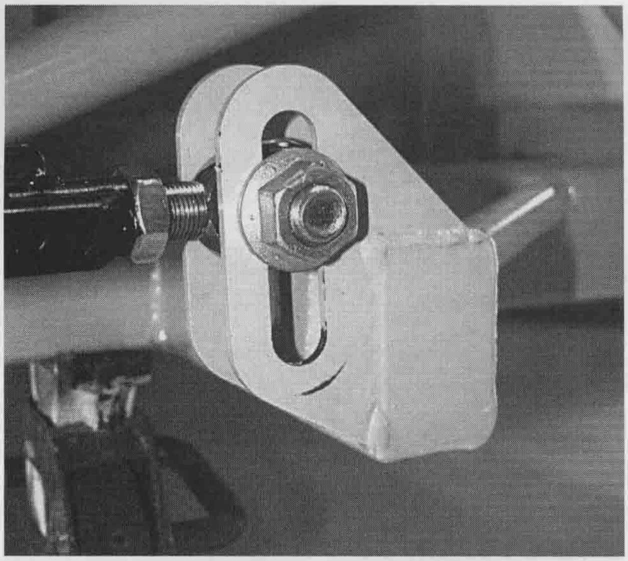
For cars that turn left and use a rear panhard, J or track bar as a lateral locating device, always mount the left end of the panhard bar to the rear end housing and the right end to the frame for an asphalt car and sometimes for a dirt car. There are other ways to mount a panhard bar, but I do not recommend other designs. They may work fine for some applications, but for consistency, I prefer to mount to the frame on the right side, even on dirt cars.

Mounting to the left side of the chassis on any car will make the car looser in the corners, which in the past has helped a car that would not turn well. Now that we know more about ways to properly design the front suspension, along with better ways to set up the car, we don't need this crutch.

Track Bar Split

Always mount the left end of the panhard bar lower than the right end on an asphalt car. As a starting point, note the total amount of travel the frame mount end experiences in mid-turn. Divide the total travel by two and mount the frame mount one-half of the total higher than the other end of the bar.

On a dirt car, the trend has been to mount the left side much higher than the right side for added



The angle of the trailing arms is adjusted by moving the front mount up or down. The greatest effect caused by changing these angles is the creation of rear steer as the car rolls, dives and squats on exit off the corners.

sidebite on dry slick tracks. This is okay as long as it is really needed. We have experimented with running a more level bar mounted to the right side of the chassis and had good results.

A long panhard bar is mechanically and dynamically better to use. There will be less effect of rear steer and roll resistance with a longer bar. Short bars seem to work with soft rear springs, but this is only an artificial fix to a problem the soft springs cause. There are other ways to make soft rear springs work.

Short Rear Trailing Arms

In the case of a car built with short trailing arms (a three-link system), the right trailing arm should be mounted with the leading edge higher than the rear mount. The amount is dictated by the amount of rear steer you desire and the distance the front mount will travel at the point of mid-turn. To calculate, start by dividing the total distance the front end of the arm will travel by three, and raise the front mount by that distance above the rear mount. That should be the maximum height for the front of the trailing arm. This will produce a slight amount of net rear steer to the left.

For the left-side trailing arm, the front mount can be located level, or above the rear mount. The amount of angle will determine how much rear steer the car has related to the car squatting while accelerating off the corners. As the rear end squats when load transfers to the rear, the left-rear tire will be forced back causing the rear end to steer slightly to the left. The greater the angle of the trailing arm, the more the rear will steer to the left, which will increase forward bite if that is the goal.

Angle Affects Rear Steer

The angling of the trailing arms in this manner serves to enhance or reduce the effects of rear steer in the turns and may improve the effects of dynamic thrust upon acceleration. What we need to be aware of is that too much rear steer can make the car too tight.

Truck-Arm-Type Rear Trailing Arms

Many stock cars are built with rear truck arm systems, including all of the Cup cars (by rule) as well as the Busch-type cars, Craftsman Trucks and even certain short-track Late Model cars. Some teams think it is an advantage to run this type of system. Let's analyze how truck-arm systems work.

Truck-Arm Rear Steer—The truck-arm rear trailing arm system produces very little rear steer during cornering and only to the left, never to the right. The forward thrust upon acceleration is concentrated at the center of the frame about midway between the axles. There is some anti-squat inherent in this system, but it is not adjustable. The rear unsprung weight is also higher with this system.

The above characteristics can be viewed as overall positive or negative aspects of this system. There are two subtle differences that truly separate the truck-arm system from all others.

Less Roll Resistance—First, if the springs are mounted on top of the truck arms—as in the case with Cup-type cars with big springs—the spring base (i.e. the distance between the centerline of the springs) will be much narrower than the other systems where the springs can be mounted further out near the wheels. The narrower the spring base a system has, the greater the tendency for that end of the car to roll over for a given set of spring rates. This leads to an unbalanced setup.

Example: A coil-over system with the springs mounted out near the wheels will only need a pair of 175-lb springs to achieve the same roll angle as a truck-arm spring-mounted system with 250-lb springs. The system with the springs mounted on the truck arms must always be sprung heavier to resist roll and to be equal to a system whose springs are mounted further out from the centerline of the car.

Torsion Bar Effect—Second, the truck arms act somewhat like a torsional sway bar. This means that the arms themselves resist roll to some extent, just as if you had a rear sway bar mounted in the car. The wider the front mounting points of the truck arms, the more this sway bar effect must be taken into account when designing the spring layout and panhard bar height.

Because it would be difficult to predict the true amount of anti-roll rate, the front mounts of the truck arms should be as close together as possible, to minimize this effect.

Rear Leaf Springs

Another rear suspension system that warrants close analysis is the leaf spring system. The following characteristics are inherent in the design and construction of leaf spring suspensions:

1. The spring base is very wide in this system; the moment center, being the average height of the two ends of the spring, at the point of attachment to the chassis, is very high; the rear moment center is not easily adjusted.
2. There is inherent friction between the leafs in multi-leaf springs; there can be a considerable amount of rear steer depending on the height at which the front of the springs are mounted.
3. The most significant negative characteristics of this system are the extreme effect of anti-roll caused by the springs being solidly mounted to the rigid rear end housing, and the changing rate of the springs as the car rolls through the turns.

Roll Resistance—If the two ends of the leaf spring differ in distances from the axle (as in a production car), then as the car rolls, the two leaf springs will assume different vertical angles at the axle. The rear end cannot twist, so there is a considerable resistance to roll created by the uneven leaf springs.

The amount of roll resistance created from axle twist increases as the spring rates increase. As is the case of roll resistance in the truck-arm system, the exact amount of resistance created by leaf springs is very difficult to predict.

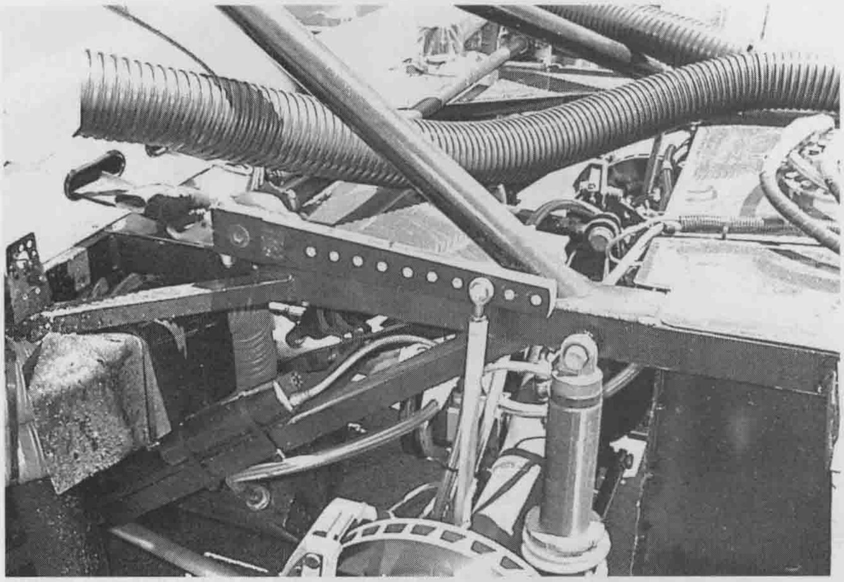
The only way to eliminate this resistance-to-roll effect would be to join the leaf spring to the rear end with a bird cage pivotal mount and add a third link or lift arm, much the same as a coil-over design system. This may not be permitted within the rules of your sanctioning body.

The other negative effect is that leaf springs have a tendency to change the effective spring rate as the car rolls. As the shackles move, they assume different angles to the chassis and spring. If the shackle is not at right angles to the chassis and spring, then a binding effect is created which causes a stiffer suspension.

The amount varies depending on what angle the shackles are mounted. This condition alone would make them very unpredictable for design of the overall spring rates.

Resistance to roll in the rear suspension system is created by:

- spring rates/splits
- rear sway bars



The use of a rear sway bar is an advantage in this GT road-racing car. These cars have a very low rear roll center and need all of the roll resistance they can get. They are usually sprung very highly and roll to a minimum degree.

- truck arm/leaf spring bind
- rear moment center height

Negative Effects—With the exception of the springs and rear moment center height, the other two in the list above are negative effects. The reason they are negative is because in order for a sway bar or truck arm/leaf spring to resist roll, they must all, to a certain extent, try to lift the left-rear tire and use the resistance of the weight of the rear end and wheel assembly to keep from doing that.

The springs cannot act independently and the suspension will be bound up. The car will not handle the normal bumps that are found in most race tracks when the suspension system is effectively locked up.

If a car works better with a rear sway bar installed (it is more neutral in handling), then something else is probably wrong and should be fixed instead. Torsional resistance to roll in the rear suspension is only an artificial fix for a car that is otherwise not designed correctly.

The problem may be that the combined overall setup is not correct and the two ends of the car want to do different things. In that case, the moment center locations, spring rates or other settings are definitely wrong and need to be changed.

Avoid Rear Sway Bars

I personally do not recommend the use of rear sway bars in most stock cars. The effect of roll resistance in a truck-arm system can be made

This team has placed the battery in the middle of the car for proper weight distribution. It is advantageous on asphalt tracks to put as much weight to the middle of the car as possible and still maintain as much left side weight as is legal. On dirt tracks, it is sometimes better to shift weight to the right side for better traction on slick surfaces.

minimal so that this system can become one of the preferred rear suspension systems.

Moving Weight Around

Any moveable weight should be placed low, left and between the axles for asphalt stock cars. For dirt cars, weight can be moved left or right in order to change the side-to-side percent distribution or up and down to raise or lower the center of gravity to compensate for slick conditions. Never mount moveable weight behind the rear axle.

Cantilever Effect

Never, ever, put weight ballast either behind the rear axle or in front of the front axle. This will create a very negative cantilever effect that would wreck your setup and possibly the car as well. As much as you think it might work, it won't.

Dirt Weight Placement

On dirt, it is sometimes an advantage to move weight to the right side and higher up for dry slick conditions. This is explained in Chapter 15.

Front-End Geometry Settings

Bump steer, steer-steer and camber change characteristics should be taken care of when the car is built. The bump steer should be measured and zeroed with the control arms moving in the range and direction as they would move on the race track.

Unequal steering angles between the two front spindles is called Ackermann or reverse Ackermann and is explained in Chapter 6.

Bump Steer Considerations

I know, everybody checks bump steer with the car at normal static ride heights and the wheel pointed straight ahead, but does that make sense? Where do we want zero bump steer—down the straightaway or in the turns where we are on the ragged edge? We really do not want the car to steer as it encounters bumps in the turns. If the car steers here, it should be the driver who is doing the steering.

Bump Steer Affected by Geometric Changes— The whole geometric layout changes when the car dives and rolls and is steered. The bump steer characteristics can be very different in the mid-turn attitude from what we may see at ride height.

If you don't have a three-dimensional geometry program and someone who knows how to use it, then set the car on the floor at the turn attitude with the steering wheel turned to simulate the car at mid-turn. Once all of the turn attitude settings have been duplicated, then check the amount of bump steer in each front wheel. This is where you need the least bump steer. See pages 60–62 for more information on bump steer.

Toe Settings—Your toe settings don't mean much either if the car loses or gains toe-out when the wheels are turned. *Ackermann* is an effect that causes a change in toe that increases toe out. *Reverse Ackermann* causes a reduction in toe-out. If the car gains or loses toe as it is steered, the steering system will need to be adjusted. It's okay to have different length steering arms when only steering to the left, but it doesn't take much difference in length to produce a big effect. For cars that steer both ways, other design changes must be made to reduce Ackermann.

If you have two holes in your steering arm, DO NOT use a different hole for the tie rod mount on each steering arm. That is not what these holes are for. They are intended to quicken or slow the steering, and approximately the same length holes are to be used on each side. The great difference in distance between the holes (one inch or more) would produce far too much steer-steer (Ackermann or reverse-Ackermann) effect.

Most cars today have one or more steering arms on the spindles with slotted holes for Ackermann adjustments. On asphalt cars the arms can be different lengths. On dirt, we need the Ackermann to be consistent with right and left turns of the wheels.