Study of Merlin Racing Kart and Tuning Characteristics

Prepared for:
MerlinUSA and Franklin Motorsports

Prepared by:
T.J. Koyen

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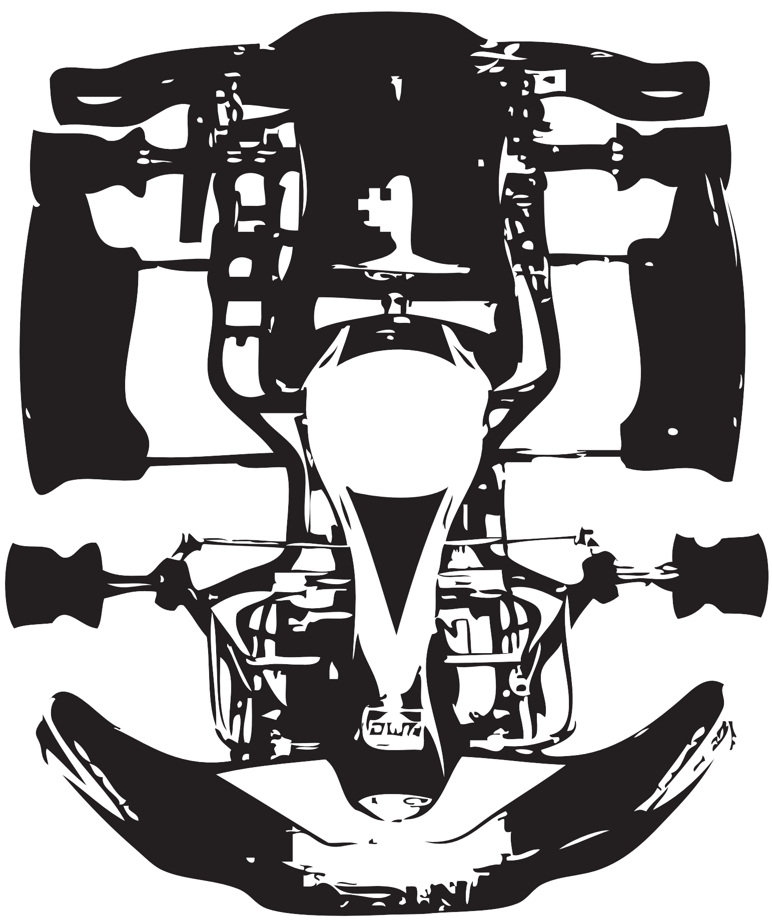

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Introduction

When competing at the highest levels of professional kart racing, chassis tuning is the most important aspect to a successful racing program. There are no “hard and fast” rules to chassis tuning; as many karts work differently than others and so different adjustments are often made between different karts to achieve the same thing. The only way to fully understand how a kart will react to adjustments is to test things and record data. A fairly strong understanding of engineering and applied physics is necessary to fully grasp the concept of what each adjustment on the kart does. Our testing and data compilation was done to help our fellow team drivers better adjust their karts so they can compete at a higher level and win more races.

Adjustments and Data

Tuning a kart chassis is an art form. The end goal is to get the kart to roll freely around a corner as quickly as possible. Since karts have a solid axle and no differential, both rear wheels turn at the same rate. With both wheels turning at the same rate, the kart does not want to go around a corner because one wheel scrubs on the track surface. This causes unwanted friction and stress on the engine, causing what is commonly referred to in karting as “bogging”. The engine has to work harder to overcome this extra friction and therefore power is sapped. In order to fully exploit the engine’s power on corner exit, we must therefore get the inside rear wheel to slip in some way. The best way to do so, and the entire goal of chassis tuning, is to get that inside rear wheel off the ground. Since karts have no suspension, all tuning is done with adjusting the flex of the chassis or the mechanical weight jacking. Getting the inside rear wheel off the ground while cornering is achieved through various adjustments that affect the stiffness, flex, and mechanical weight jacking of the chassis and its components. We’ve taken a look at 12 adjustments to the chassis and how they make the kart act on-track.

Adjustments

The adjustments on a kart chassis range from simple to complex and they often counteract or reinforce each other. The 12 adjustments we studied on the kart are as follows: rear torsion bar, 3rd axle bearing, rear hub length, axle stiffness, wheel material/stiffness, seat struts, Ackermann settings, front torsion bar, rear track width, front track width, front-end geometry (caster, camber, toe), and tire pressure (for Bridgestone YKC and MG Yellow tires).

Under the explanation of each adjustment, there are simplified notes of the overall effect of each adjustment in bold. You will notice many of them talk about the adjustment offering more or less **lift** rather than whether the adjustment offers more or less **grip**. **Do not confuse lift with grip.** Drivers often refer to karts as having “too much grip” or “not enough grip”. In reality, a kart with “too much grip” actually has a case of “not enough lift”. The feeling of “too much grip” occurs when the inside rear wheel is not lifting off the track for whatever reason. It is important to differentiate the two. In theory, it would be hard to have “too much grip” in a kart. The more grip the tires have, the faster you can go around a corner. In this manual, we will be explaining how to tune the amount of lift a kart has, not the amount of grip it has for the most part. The exception being things like tire pressure and wheel material which actually effect the “spring-rate” (or how hard the tires are pressing into the track) of a kart and alter how much the tires grip.

Rear Torsion Bar

Rear torsion bars are rarely used but can provide some valid adjustment to the kart in certain situations. The function of the rear torsion bar is to stiffen the rear of the chassis. By stiffening the chassis you are limiting the overall flex of the frame. Since the chassis must flex to an extent in order for the inside rear wheel to lift off the ground, by fitting the rear torsion bar you are limiting the flex of the chassis and limiting the amount of rear wheel lift.

Rear Torsion Bar IN = Less lift
Rear Torsion Bar OUT = More lift

3rd Axle Bearing

The 3rd axle bearing is a quick and easy adjustment that changes the amount of axle flex in the kart. By tightening the 3rd bearing, you are in effect, shortening the distance between one end of the axle and the other. This causes the axle to be stiffer. With a stiffer axle, flex within the axle is limited and you get less inside rear wheel lift. However, sometimes having the 3rd bearing tight is necessary for other reasons. In high-horsepower applications (TaG, KF), so much lateral grip is generated that the 3rd bearing must be tight to keep the axle from over-flexing and causing poor handling characteristics. The 3rd bearing will keep the rear of the kart more consistent in such instances. In these applications, it is necessary to utilize other adjustments instead of the 3rd bearing to tune the rear stiffness.

3rd Axle Bearing IN = Less lift
3rd Axle Bearing OUT = More lift

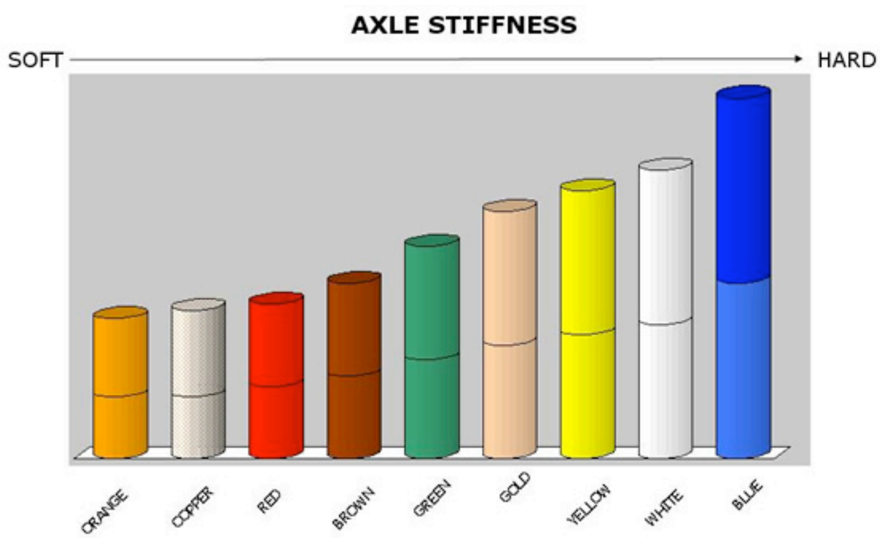
Rear Hubs

Rear hub length also affects the stiffness of the axle from the outside frame rails to the edge of the tire. A longer hub stiffens the axle and a shorter hub softens the axle. Most Merlin drivers use either the factory Merlin medium hub or the Driveline medium/short hub. The Driveline hub seems to give better rear stability while still keeping the rear free. Both these hubs offer consistent handling. A longer hub will generally add stiffness to the axle, as less of the axle is being exposed and able to flex. Shorter hubs allow more axle to be exposed and therefore allow for more flex within the axle.

Longer Rear Hubs = Less lift
Shorter Rear Hubs = More lift

Axles

Axle tuning is one of the most complex and important sectors of kart chassis tuning. Stiffer axles allow less flex and softer axles allow more flex. Although this seems simple, there are many other variables to consider. Below is the stiffness chart for Merlin axles:



With axle stiffness, you are attempting to control the amount and speed of inside rear wheel lift the kart has. There is a fine knife-edge where the kart has the perfect amount of stiffness in the rear and it is a balancing act to find that edge.

With a stiffer axle, you will have less flex in the rear, however you will also have better side bite on the outside rear wheel since the axle absorbs less of the weight transfer and you are effectively increasing the “spring-rate” and pushing the outside tire harder into the track. This can actually cause better inside rear wheel lift in certain situations as you are getting more lateral load and allowing the kart to “tip” more. Under very high-grip track conditions, a stiff axle is sometimes necessary to prevent the axle from over-flexing and rebounding, causing a “hopping” condition. A stiff axle requires very precise steering inputs, as the rear of the kart is loaded so heavily during cornering that any correction of input on the steering wheel will upset this load and the kart will either overload the outside tire and hop or slide, or it will prematurely set the inside rear wheel down before corner exit and cause the kart to be flat and bog down on exit.

With a softer axle, you are allowing more flex within the rear of the kart. This will allow the inside rear to come off the ground more, simply because the axle is flexing more. However, you effectively have less “spring-rate” on the outside rear tire because the axle absorbs some of the weight transfer and it doesn’t press into the track surface as hard. This can cause cornering issues as well. The kart may overload the outside rear tire since there is so much inside rear wheel lift and break traction. This may cause the outside tire to slide then grip then slide then grip and so on, causing a hopping condition. The outside tire may never gain traction again within the corner as well, causing the kart to lift heavily on turn-in and once the kart gets to apex, it overloads the outside rear tire and simply slides, setting the inside rear wheel down and bogging the kart down on exit.

Tuning the axle stiffness is a very conditional adjustment. There is no rule that says “a softer axle will make your kart freer on exit” or “a stiffer axle will make the kart have more rear grip”. For example, let’s say you are running a soft axle. If you go into the corner and turn, the kart lifts the inside rear wheel initially but the kart overloads the outside tire and feels like it sets the inside rear wheel down at apex and causes the kart to bog down on exit. Many would diagnose this as having “too much rear grip” because they are only feeling the bog on exit. They would then want to go to a softer axle to get more lift. This would be the wrong move in this situation. You would actually want to go to a stiffer axle to remove some of the kart’s initial rear wheel lift so that it didn’t overload the outside rear and the outside rear would “set” or plant harder in the corner, keeping the inside rear wheel off the ground through the corner and allowing the kart to roll off the exit freely.

We recommend that all drivers start out on a Merlin green (medium) axle at each race weekend, and adjust accordingly as the weekend progresses and the track conditions improve.

Stiffer Axle = Less lift
Softer Axle = More lift

Wheels

Wheel material is an important factor to consider in tuning a kart. Different alloys and metals have different chemical properties and cause different handling characteristics to the kart. Merlin karts come standard with Douglas Wheel Technologies Magnesium rims. These rims are stiffer and provide better temperature consistency. Also available are aluminum rims, which are softer.

Although many of the team drivers never vary from the stock magnesium rims, aluminum rims are a valid adjustment in some instances. The aluminum rims have been shown to take grip away, as they are softer and effectively decrease the “spring-rate” of the kart.

Magnesium Rims = More grip
Aluminum Rims = Less grip

Seat Struts

Seat struts control the weight transfer from the driver’s body in the seat to the outside rear corners of the kart. They are important to the overall weight transfer of the kart and necessary to lift the inside rear wheel effectively. The baseline setting is to have one seat strut on each side of the seat. More seat struts cause a stiffer relationship between the seat and the outside rear corners of the kart. This allows less flex within this triangular region. However, it also causes more weight transfer within the triangular region between the seat and the outside rear corners of the kart. More seat struts can cause the outside rear tire to plant harder in the corner and pull the inside rear wheel up harder, therefore causing more inside rear wheel lift.

More Seat Struts = More lift
Less Seat Struts = Less lift

Ackermann

Ackermann refers to the to front steering linkage. The Ackermann effect is visible in all karts where the tie-rods are mounted next to each other on the steering column rather than being stacked. Ackermann is necessary in karts to mechanically cause more weight jacking to the rear of the chassis. It allows the inside front wheel to turn more than the outside front wheel, pressing the inside front wheel down into the track to lift the inside rear wheel off the ground and making the kart teeter. By adding more Ackermann, you are speeding up the steering so the driver has to turn less to achieve the same amount of front wheel movement. This causes the front-end geometry to work harder and causes more weight jacking to the rear of the kart, ultimately causing more inside rear wheel lift. However, with a driver who is less precise on the wheel and tends to use many steering inputs, the sped up steering can wreak havoc on cornering. Each input will be increased in effectiveness so a driver who “saws” the wheel in the corner will have the ill effects from those inputs increased further. More Ackermann requires precise and smooth inputs from the driver.

More Ackermann = More lift
Less Ackermann = Less lift

Front Torsion Bar

Tuning with the front torsion bar is another balancing act, like so many adjustments in karting. The Merlin kart comes with one torsion bar that allows for three settings: soft, stiff, and out. The soft setting is achieved with the bar in so that the two laser-cut ovals are facing UP. The stiff setting is achieved with the bar in so that one laser-cut oval is facing UP. Taking the bar out of the kart completely allows for the softest front-end setting. The front torsion bar stiffens the front of the kart and allows for a higher “spring-rate” within the front of the kart. This leads to higher front grip on initial turn-in. However, by fitting the front bar, you are also stiffening the entire chassis to an extent. This can cause less inside rear wheel lift as well. The stiffer the front bar, the better the kart turns in but it quickens the whole lifting action and sets the inside rear wheel down after turn-in. So a stiffer front bar will help corner entry but hurt corner exit. A softer front bar (or removing the front bar altogether) will give less initial turn-in grip since the front isn’t generating as high of a “spring-rate” but it will allow the chassis to flex and roll more freely from apex to corner exit. Finding the sweet spot for this adjustment is a conditional situation and depends on the rest of your setup. For example if you feel that the kart has plenty of front grip on turn-in but isn’t rolling freely off the corner, you could try softening the front bar or removing it completely to help the kart come off the corner more freely.

Front Torsion Bar IN (Stiff) = Quicker lift, better turn-in
Front Torsion Bar IN (Soft) = Medium lift, fair turn-in/exit
Front Torsion Bar OUT = Slower lift, better roll off corner

Rear Track Width

Adjusting the overall rear track width achieves many of the same things as tuning with rear hub length, but throws in a few more variables to consider. A wider rear track width exposes more axle and thus causes more axle flex. A narrow rear track width exposes less axle and thus causes less axle flex. However, a narrow rear track width also narrows up the bottom of the rear triangular region (top of the seat to each outside rear corner) and comparatively raises the center of gravity. A narrow rear track width allows the kart to tip easier upon cornering. This can cause more inside rear wheel lift but also increases the risk of overloading the outside rear tire and causing hopping since it stiffens the rear as well. Narrow rear track width also can increase side-bite, as the kart “sets” harder into the corner. A wider rear track width will cause more flex within the axle and can offer more rear wheel lift too, but the kart will not tip as easily. We recommend setting the rear track width at a standard setting of around 54.5”, leaving it there, and tuning with other adjustments that cause less counteractive handling characteristics. If tuning rear track width is necessary, make small adjustments.

Narrower Rear Track Width = More lift

Wider Rear Track Width = Less lift

Front Track Width

Front track width is a very common and easy adjustment. By widening the front track, you are effectively increasing the amount of weight jacking the kart has. This can cause more inside rear wheel lift, as the inside front tire presses down lower and harder into the track surface. However, a wider front track also increases the amount of "scrub" in the front end. This can cause problems mid-corner and on exit by making the kart understeer. Going too wide will also cause the front to be softer, as there is more of the spindle being exposed. Generally, a wider front track will increase grip on initial turn-in. A narrow front track will help the kart rotate from mid-corner to exit but not have the initial twitchiness that a wider front end has. Sometimes it is good practice to narrow the front up for qualifying and letting the fresh tires do more of the turning work instead of trying to mechanically force the kart to turn.

Wider Front Track Width = More lift, better turn-in
Narrower Front Track Width = Less lift, better apex to exit

Front-End Geometry (Caster/Camber/Toe)

Adjusting the front geometry of the kart is one of the most effective things one can do to alter the kart's handling. Since the kart relies on mechanical weight jacking to lift the inside rear wheel off the ground, front geometry should be one of the primary adjustments you make during a race weekend. All Merlin karts come with a uni-ball eccentric/concentric "pill" system for adjusting the front geometry. This pill controls caster and camber.

Caster refers to the angle of the kingpin relative to the front and back of the kart. All karts have some amount of caster built into them, as it is necessary for a kart to corner properly. Increasing caster is done by tipping the top of the kingpin BACK towards the rear of the kart. Decreasing caster is done by tipping the top of the kingpin FORWARD toward the front of the kart. By increasing caster, you are increasing the amount that the inside front wheel pushes down into the track surface and therefore increasing the amount of weight jacking to the rear of the kart. More caster causes more inside rear wheel lift at a quicker rate and less caster causes less inside rear wheel lift at a slower rate. High amounts of caster are necessary for tight corners, where the inside rear wheel needs to come off the ground quickly and there isn't a need for a long duration of lift. More caster also causes more scrub within the front end, and can cause understeer problems on corner exit, similar to what you would experience with a very wide front track width. Less caster doesn't give the same abrupt inside rear wheel lift, but it allows the kart to roll more freely off the corner, as the inside rear wheel stays off the ground for longer.

Camber refers to the angle of the top of the tire from left to right. Negative camber is when the tops of the tire tilt in towards the center of the kart. All karts have negative camber built into the frame. Positive camber is when the tops of the tires tilt out away from the center of the kart. Less camber allows for a quicker turn-in, as less of the tire's contact patch is touching the track surface. Increasing the amount of camber will slow down initial turn-in, but can also increase weight jacking as the tire presses down into the track surface more at mid-corner.

Toe refers to the angle of the fronts of the front tires when looking down on the kart from above. Toe-in means the kart's front tires point towards each other and toe-out means the kart's front tires point away from each other. Toe-out is generally the default setting, as it provides better turn-in and more responsive steering. Toe-in is used rarely and gives the front more stability in a straight line. Excessive toe can cause increased resistance when driving in a straight line and hurt straightaway speed.

More Caster = More lift, quicker lift action
Less Caster = Less lift, longer lift duration

More Camber = Slower turn-in and lift action
Less Camber = Faster turn-in and lift action

Toe-Out = Better turn-in
Toe-In = Better stability

Tire Pressure

Tire pressure is a commonly debated topic within the karting community. There are many contradictory variables to consider when adjusting tire pressure. From our testing experience, we've found that lower tire pressure tends to increase overall grip. The tire squats more and more of the tire's surface is in contact with the track surface. Lower tire pressure also can make the sidewall of the tire flex more, and make the rear tires' sidewalls fold over and help the kart plant into the corner. However, lower pressure also causes the tire to heat up more slowly, meaning a lack of grip for the first few laps of a run until the tires get heat into them. A higher tire pressure will allow the tire to heat up faster but reduces the contact patch and therefore reduces overall grip. Higher tire pressure can also cause the kart to "fall off" at the end of the run and lose grip as the session continues when the tires overheat and start to grain. We recommend starting around 11 psi cold pressure for MG Yellows and 13 psi cold pressure for Bridgestone YKCs.

Higher Tire Pressure = Tire heats up faster, good at beginning of run, prone to falling off as run goes on, smaller contact patch provides less overall grip
Lower Tire Pressure = Tire heats up slower, larger contact patch provides more overall grip, kart tends to "set" into corner better

Conclusions and Recommendations

This section contains conclusions and recommendations based off the data we've collected in our testing. It gives tuning recommendations for several common handling issues.

Handling Issue	Possible Cause	Suggested Adjustments
Kart understeers on turn-in	Not enough inside rear wheel lift	Widen front track, increase caster, increase Ackermann, less camber, insert or stiffen front torsion bar, loosen 3rd axle bearing, insert softer axle, raise seat, narrow rear track width
Kart oversteers on turn-in	Too much inside rear wheel lift	Narrow front track, decrease caster, decrease Ackermann, more camber, remove or soften front torsion bar, tighten 3rd axle bearing, insert stiffer axle, lower seat, widen rear track width
Kart understeers from apex to exit	Inside rear wheel setting down too early, not enough lift duration	Narrow front track, decrease caster, decrease Ackermann, more camber, remove or soften front torsion bar, loosen 3rd axle bearing, insert softer axle
Kart is "hopping"	Overloading outside rear tire or not generating enough inside rear wheel lift	Change axle, softer if the kart feels like it has too much lift, stiffer if the kart feels like it isn't lifting enough
Kart oversteers from apex to exit	Overloading outside rear tire, outside rear tire not planting hard enough	Insert stiffer axle, add seat struts, tighten 3rd axle bearing

Recommendations

Although our experience has given us a vast amount of data to go off of, this tuning guide is intended to serve as a general reference. The only true way to test what adjustments work for each individual driver is to continue testing. All drivers have different styles and different body types and all tracks go through an infinite amount of changes in condition throughout the course of a race weekend. Individual testing is the best way to obtain knowledge on how your kart chassis works with your driver.

We recommend to all drivers that a factory baseline setup be the first place to start at each race weekend, and to not “chase the track” on practice days before racing. Let the track conditions improve before you begin working on your setup, since on race day the conditions will likely be very different from the first practice sessions earlier in the weekend.