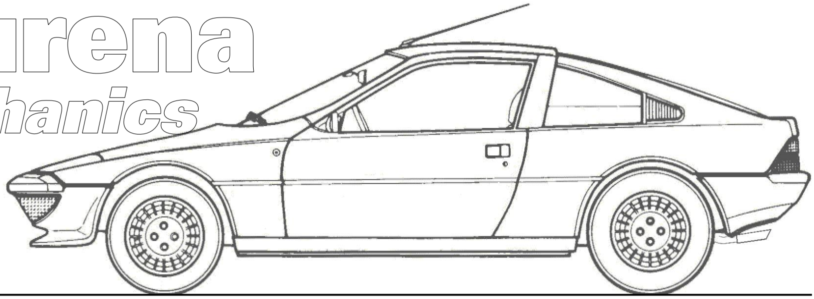
Murena mechanics



Roy Gillard

Camber, Castor and Tracking

The three major alignment parameters on a car are camber, castor and tracking, but ride height is also important as is crab. (the alignment between the front and the rear) Most enthusiasts have a fair understanding of what two or three of these settings are, but do you truly know what they all mean?

Tracking

When any axle wheels are set so that their leading edges are pointed slightly towards each other, the steering is said to have some 'toe-in'. If the leading edges point away from each other, the steering is said to have some 'toe-out'. The amount of tracking is usually expressed in degrees for the angle to which the wheels are out of parallel, but it can also be given as the difference between the track widths as measured at the leading and trailing edges of the tyres or wheels. Track settings affect the car in three ways: tyre wear, straight-line stability and corner entry handling characteristics.

For minimum tyre wear and power loss, the wheels on a given axle of a car should point directly ahead when the car is running in a straight line. Excessive toe-in or toe-out causes the tyres to scrub, since they are always turned relative to the direction of travel. Too much toe-in causes high wear at the outer tyre edges, whilst too much toe-out causes wear at the inner edges.

If minimum tyre wear and power loss are achieved with zero track, why have any toe angles at all? The answer is that the type of drive affects the wheels and tyres differently. With any suspension and all its various joints there will always be some allowable movement in the whole set up even when new. All wheels will naturally try to move to a slight toe-out setting as it is being driven along, so you need to start with a slight toe-in at rest to counter this. The wheels should then come straight whilst driving in a straight line.

However, whilst this is true for a rear drive car, where the front suspension only has to cope with suspension and steering, once you add front wheel drive, this changes things. With a front wheel drive car, the wheels get pulled in to a toe-in setting by the torque, and this is more than the natural toe-out movement as you drive along, so for a front wheel drive car you need to start with a slight toe-out setting and the wheels will get pulled back to parallel.

The tyres are affected equally so any tracking misalignment will cause tyre wear on **both** tyres. If you have bad tyre wear on only one side or it is much worse on one side, then that shows there is another fault. Owners often see one front tyre worn on the outer edge and think that re-tracking the car will cure it. It won't. If only one tyre is getting worn badly it is because there is some other misalignment and since most road cars only have adjustable tracking, the usual cause is either the chassis or some part of the suspension is worn, damaged or something has broken. See the diagram opposite for some samples of tyre wear patterns and their causes.

Usually in these situations it should also be noticeable in other things, such as the steering wheel is now turned slightly when driving in a straight line. Often the car will pull to one side all the time, or it may pull badly to one side under braking. Or you may have a combination of these faults.

You then need to find out what is causing it, and if it is something broken or bent, replace it, but if it is a kink to the chassis then that will need to be pulled straight again on a bodyshop jig. How did it get that kink? On newer vehicles this can be due to the latest cars having deformable structures to absorb impacts in an accident. Unfortunately this also makes some items bend easier! If you hit something at speed, say something has been dropped onto the motorway surface and you can't avoid hitting it with one front wheel, the impact forces can be enough to bend a suspension arm or kink the chassis at the suspension mounting point.

With the current poor state of our roads even hitting a large pot hole is enough to do some damage, and if it does you should claim against the council for things like damaged tyres, bent alloy wheels, or damage to suspension or chassis. The more people did that the quicker they would see that letting the roads deteriorate like they have is more expensive than keeping them properly maintained.

How does the tracking affect the stability of a car? Consider this example. A particular car should have a slight toe-in on the front and rear suspension, which brings them parallel during running. One wheel hits a bump or is disturbed in some way, so its grip is reduced or lost for a brief period of time. Since the opposite wheel should be running straight, the car should hardly deviate from the steered direction.

Now consider the effect if one of the axles is badly tracked owing to some fault. The wheels are toeing out but each side counter acts the other until one side momentarily loses its grip and allows the other wheel to pull the car away from the direction of travel and you have a steering effect. If this is during a corner taken as speed, the car could suddenly under or over steer and hit a kerb or a car coming the other way.

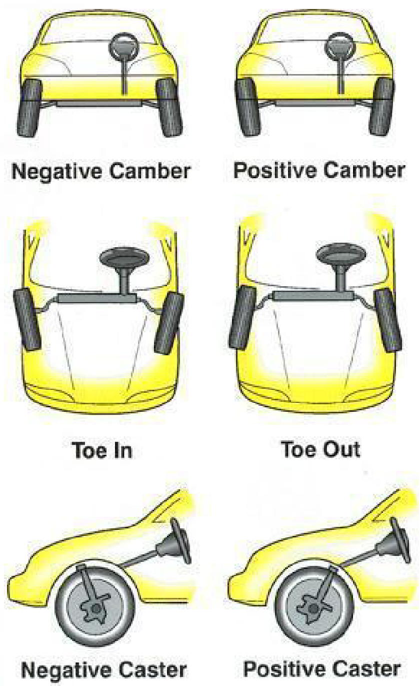
Parallel track or very slight toe-in at both front and rear axles keeps a car going straight naturally and you don't have to keep correcting the direction with the steering. If the car keeps wandering to the left and right, and you have to keep using the steering just to drive in a straight line, it will be annoying, as well as tire you through the extra concentration required.

The amount of toe-in or toe-out dialled into a given car is dependent on the compliance of the suspension and the desired handling characteristics. To improve ride quality, road cars are equipped with relatively soft rubber bushes at their suspension links, and thus the links move a fair amount when they are loaded. Race cars, in contrast, are fitted with steel spherical bearings or very hard urethane, metal or plastic bushes to provide optimum rigidity and control of suspension links. Beware then of replacing your standard suspension bushes with something much harder, such as those polyurethane bushes, as this will not only make the ride harder, but will alter the handling as it controls the settings much tighter and you should as a minimum reset things like tracking since they will need to be different.

Often manufacturers will actually use the compliance in the rubber suspension bushes to control the suspension, in a predefined way. In a straight line when the bushes are unstressed, the car drives correctly, but under cornering the amount of distortion of those bushes are taken into consideration to give the correct angles, handling and stability. If you now change to much harder bushes you will undo all their hours of work to make the car handle correctly, and probably cause problems.

Camber

Camber is the angle of the wheel relative to vertical, as viewed from the front or the rear of the car. If the wheel top leans in towards the chassis, it has negative camber; if it leans out from the car, it has positive camber. The cornering force that a tyre can develop is highly dependent on its angle relative to the road surface, and so wheel camber has a major effect on the road holding of a car. It's interesting to note that a tyre develops its maximum cornering force at a small negative camber angle, typically around half a degree negative. This fact is due to the contribution of camber thrust, which is an additional lateral force generated by elastic deformation as the tread rubber pulls through the tyre/road interface (the contact patch).



To optimize a tyre's performance in a corner, it's the job of the suspension designer to assume that the tyre is always operating at a slightly negative camber angle. This can be a very difficult task, since, as the chassis rolls in a corner, the suspension must deflect vertically some distance. Since the wheel is connected to the chassis by several links which must rotate to allow for the wheel deflection, the wheel can be subject to large camber changes as the suspension moves up and down. For this reason, the more the wheel must deflect from its static position, the more difficult it is to maintain an ideal camber angle. Thus, the relatively large wheel travel and soft roll stiffness needed to provide a smooth ride in passenger cars presents a difficult design challenge, while the small wheel travel and high roll stiffness inherent in racing cars reduces the engineer's problems.

It's important to draw the distinction between camber relative to the road, and camber relative to the chassis. To maintain the ideal camber relative to the road, the suspension must be designed so that wheel camber relative to the chassis becomes increasingly negative as the suspension deflects upward. If the suspension were designed so as to maintain no camber change relative to the chassis, then body roll would induce positive camber of the wheel relative to the road. Thus, to negate the effect of body roll, the suspension must be designed so that it pulls in the top of the wheel (i.e. gains negative camber) as it is deflected upwards. This can be achieved by things such as shorter radius top wishbones compared to the lower ones.

While maintaining the ideal camber angle throughout the suspension travel assures that the tyre is operating at peak efficiency, designers often configure the front suspensions of passenger cars so that the wheels gain slight positive camber as they are deflected upward. The purpose of such a design is to reduce the cornering power of the front end relative to the rear end, so that the car will understeer in steadily greater amounts up to the limit of adhesion. Understeer is considered inherently a much safer and more stable condition than oversteer, and thus is preferable for cars intended for the public.

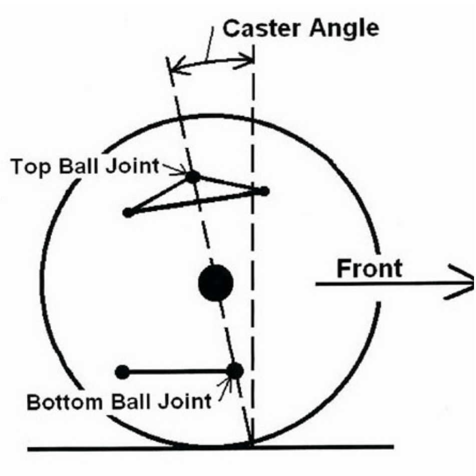
Since the arrival of the low profile tyre, keeping their flat tread vertical on the road is more important than when we had the older rounded shoulder 82% profile tyres. This is one reason you should never fit low profile tyres on an older car not designed for them. The deeper sidewall flexibility was also taken into account as part of the springing, which you will not get from the more rigid low profile sidewall.

The Bagheera suspension was not designed for these low profile flat tread tyres that have become the norm, yet because the only source of the older 82% profile tyres is through vintage tyre supplies, and they are more costly, many fit these low profile tyres instead. If you do, then be aware it will not ride, handle or grip like it was originally designed to do.

Castor angle

Castor is the angle to which the steering pivot axis is tilted forward or rearward from vertical, as viewed from the side. If the pivot axis is tilted backward (i.e. the top pivot is positioned farther rearward than the bottom pivot) then the castor is positive; if it's tilted forward, then the castor is negative.

Positive castor tends to straighten the wheel when the vehicle is travelling forward, and thus is used to enhance straight-line stability. The mechanism that causes this tendency is clearly illustrated by the castoring front wheels of a shopping trolley. The steering axis of a shopping trolley wheel is set forward of where the wheel contacts the ground. As it is pushed forward, the steering axis pulls the wheel along, and since the wheel drags along the ground, it falls directly in line behind the steering axis. The force that causes the wheel to follow the steering axis is proportional to the distance between the steering axis and the wheel-to-ground contact patch - the greater the distance, the greater the force. This distance is referred to as 'trail'.



Owing to many design considerations, it is desirable to have the steering axis of a car's wheel right at the wheel hub. If the steering axis were to be set vertical with this layout, the axis would be coincident with the tyre contact patch. The trail would be zero, and no castoring would be generated. The wheel would be essentially free to spin about the contact patch (actually, the tyre itself generates a bit of a castoring effect due to a phenomenon known as 'pneumatic trail', but this effect is much smaller than that created by the mechanical castoring, so we'll ignore it here).

Fortunately, it is possible to create castoring by tilting the steering axis in the positive direction. With such an arrangement, the steering axis line intersects the ground at a point in front of the tyre contact patch, and thus with the same effect as seen in the shopping trolley, castor and trail is achieved.

The tilted steering axis has another important effect on suspension geometry. Since the wheel rotates about a tilted axis, the wheel changes camber as it is turned. This effect is best visualized by imagining the unrealistically extreme case where the steering axis would be horizontal-as the steering wheel is turned, the road wheel would simply change camber rather than direction. This effect causes the outside wheel in a turn to gain negative camber, while the inside wheel gains positive camber. These camber changes are generally favourable for cornering, although it is possible to overdo it.

Most cars are not particularly sensitive to castor settings. Nevertheless, it is important to ensure that the castor is the same on both sides of the car to avoid the tendency to pull to one side. While greater castor angles serve to improve straight-line stability, they also cause an increase in steering effort. Three to five degrees of positive castor is the typical range of settings, with lower angles being used on heavier vehicles to keep the steering effort reasonable.

Like a shopping trolley wheel, the trail created by the castoring of the steering axis pulls the wheels in line.

Crab (or thrust angle)

Crab is the alignment of the front and rear axles. The axles can be parallel to one another but offset one side or the other. But you could also have the axles superficially in line but at an angle to one another. Either or both will cause problems. Axles at an angle to one another will mean the car is permanently trying to go around to the left or right depending on which way the angle goes.

This used to happen on rigid rear axle cars when the leaf spring pin broke and the axle moved forward or backward on one side relative to the spring mountings. It is not so common on fully independent suspensions. However, you can check for this condition by measuring the wheelbase on either side, which should of course be the same. (Unless you have one of those odd cars where the left and right rear axles are mounted one in front of the other! So you must refer to the manual in such cases.)

To check for parallel but offset rear suspension, you need to check the centre position of front and rear axle and the line between those centres should be in line with the centre line of the car.

Ride Height

The ride height is important because it will affect the centre of gravity, and angle of attack of the car, as well as all the suspension settings. Normally, like all the angles except tracking, this is not adjustable on most cars except by changing the wheels, tyres or tyre profiles; but on a car with torsion bar suspension it often does have a small range of adjustment at one end of the torsion bar which will allow you to alter the ride height slightly.

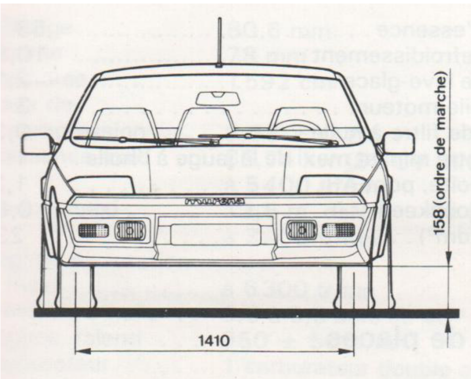
The Bagheera and Murena have torsion bar suspension, the Bagheera all round, the Murena only at the front.

With the Bagheera the original rear tyres (185x13 where the actual profile was 82%) are no longer available except through vintage tyre suppliers and they are expensive, so many fit an alternative wider lower profile tyre, such as a 205/70x13 but those will lower the rear ride height, so as well as the tyre strictly being too wide for the 5.5" wheel rim, you will alter the angle of attack negatively putting the nose of the car higher relative to the rear and make the aerodynamics and probably the handling worse. You could alter the angle of attack by adjusting the torsion bars to bring it back to the correct front to rear setting, but I bet it is rarely done.

With the Murena, the car was designed and originally set up with 13" steel wheels and 70 profile tyres which gave a certain ride height and angle of attack. When they fitted alternative 14" alloy wheels with 60 profile tyres, again the rear dropped in comparison to the front and did the same as with the Bagheera. However, they never gave any alternative setting for the front torsion bars to bring that ride height setting back correct, which they should have done.

Some few years after the Murena had been out, a new 55 profile tyre became available, and with these 185/55x14 tyres on the front this brought the correct front to rear ride heights back. The small reduction in profile from 60 to 55% improves the steering as well as correcting the ride height, yet is so small a difference that it does not negatively impact on the speedo reading, so it is a win-win situation. I have used and recommended them for many years and would no longer go back to 60 profile front tyres, which make the car worse.

However, if you don't or can't change to the 55 profile front tyres, you should at least alter the front torsion bar settings to correct the cars ride height. Beware though that the figure of 158mm to the bottom of the front spoiler in the handbook is wrong. (see below) I'm sure it should be no less than 185mm. It appears they transposed two of the digits by mistake.



Testing
Car manufacturers will always have recommended camber, caster, tracking, crab and ride height settings. They arrived at these numbers through exhaustive testing. The goals of the manufacturer are always aimed at their use on the road of course. It is different for a competitor. What works best at one race track may even be wrong at another. So the 'proper' alignment settings in those situations are best determined by you - it all boils down to experimentation and testing.

Even on a road car though, if you change something you must only do one thing at a time and test it thoroughly. When I tried the 55 profile tyres which the dimensions suggested should be more correct, that was all I changed and after extensive mileage I knew they were better and right. If you make several changes at once, how can you ever know what has done what, and which improves things or which makes it worse?

Tyres and pressures
One final point about tyres. If you alter the widths of the tyres from the recommended ones, beware that the pressures may need to alter, and not always the way some think.

Tyre pressures are mainly about the weight on them as much as anything. Think about the way you increase the tyre pressures if you have a fully laden car. If you increase the tyre size a lot some think the pressures must be increased too. But you have to consider the change in the contact patch area, because pressures are related to area!

Pressure is stated in pounds **per square inch** for instance, so if the area is increased the poundage to support a given weight is lowered. A wider low profile tyre with a flatter tread will most likely have an increased contact patch compared to the original tyre. Therefore the pressures in each tyre to support the same weight as previously, will be proportionately lower. You need to know what the new contact patch size is and how it relates to the original.

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