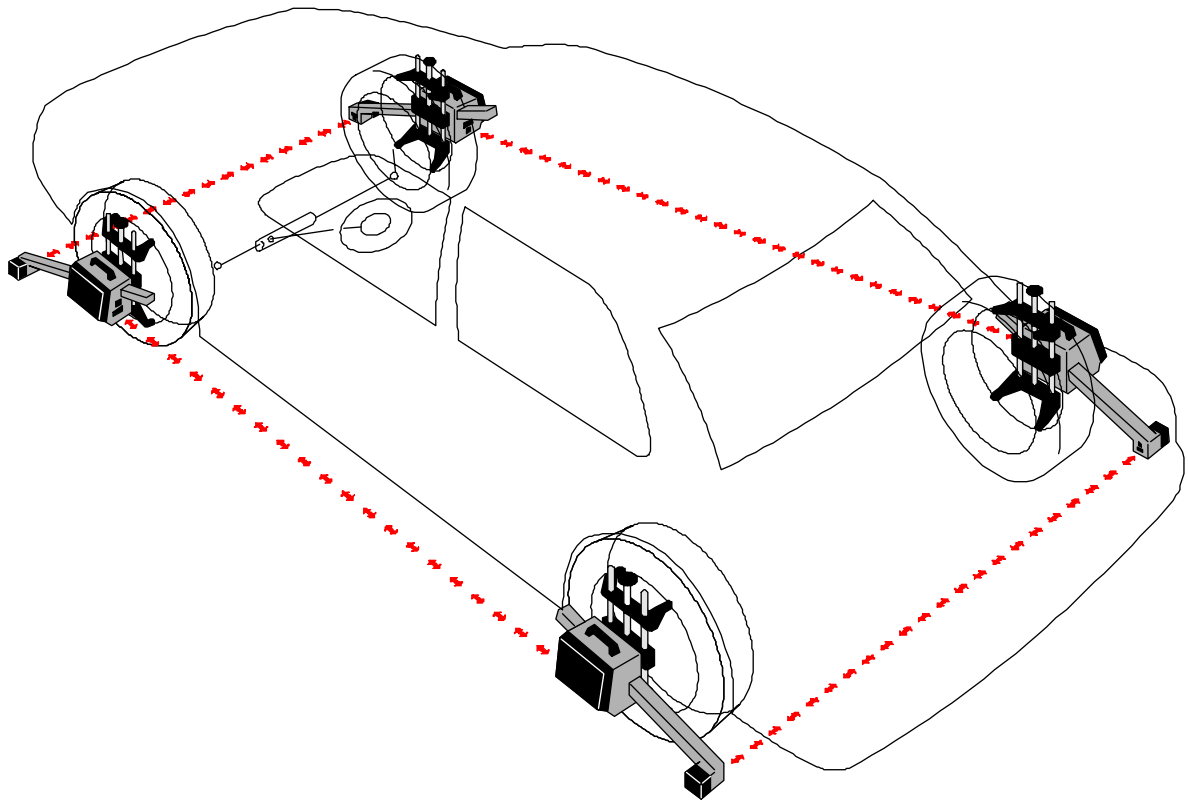
OPTO-PLUS

Principles of Steering Geometry



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Conditions for correct measurement of wheel angles

It is important to eliminate the different sources of inaccuracy in the measurement of the wheel angles.

Before measuring

1. The lift shall be level including the turntables and roller plates. A difference left/right of 5mm on the level of a typical vehicle gives a fault of 10' on the Camber value.

2. For the same reason the tyre pattern shall have the same height on all 4 wheels, and of course the tyres shall be of the same type.

3. Tyre pressure shall be correct and the loading of the vehicle according to manufacturer specifications.

4. Turntables and roller plates shall move easily and freely to avoid that the suspension is blocked.

5. Check that the rims are undamaged and meet the specifications from the manufacturer.

6. Check ball joints and bearings for play. Check for broken springs, worn bushings and improper shock absorbers.

7. Check that the suspension height is correct and that the steering gear is correctly mounted.

8. In case the measured values are severely out of tolerance look for chassis damage.

Before performing Wheel Alignment all mechanical faults should be corrected.

During measurement

1. Perform run-out compensation carefully.

2. Bump the vehicle.

Correct Toe and Camber values are measured with the front wheels in straight ahead position.

Before Printout the front wheels shall be in straight ahead position and the measuring units in level.

Norm for measuring Wheel Angles

In 1992, a German norm was established, the DIN 70028. This norm specifies the measuring conditions and the data for the wheel angles that must be provided, and the norm has also been translated into a draft for an ISO/TC norm.

Accuracy

All above mentioned points are important to observe in order to do the measurement with optimal accuracy.

The equipment manufacturer often specifies the accuracy of the equipment, but to find the accuracy of the performed measurement, one must add the contribution from the above mentioned sources.

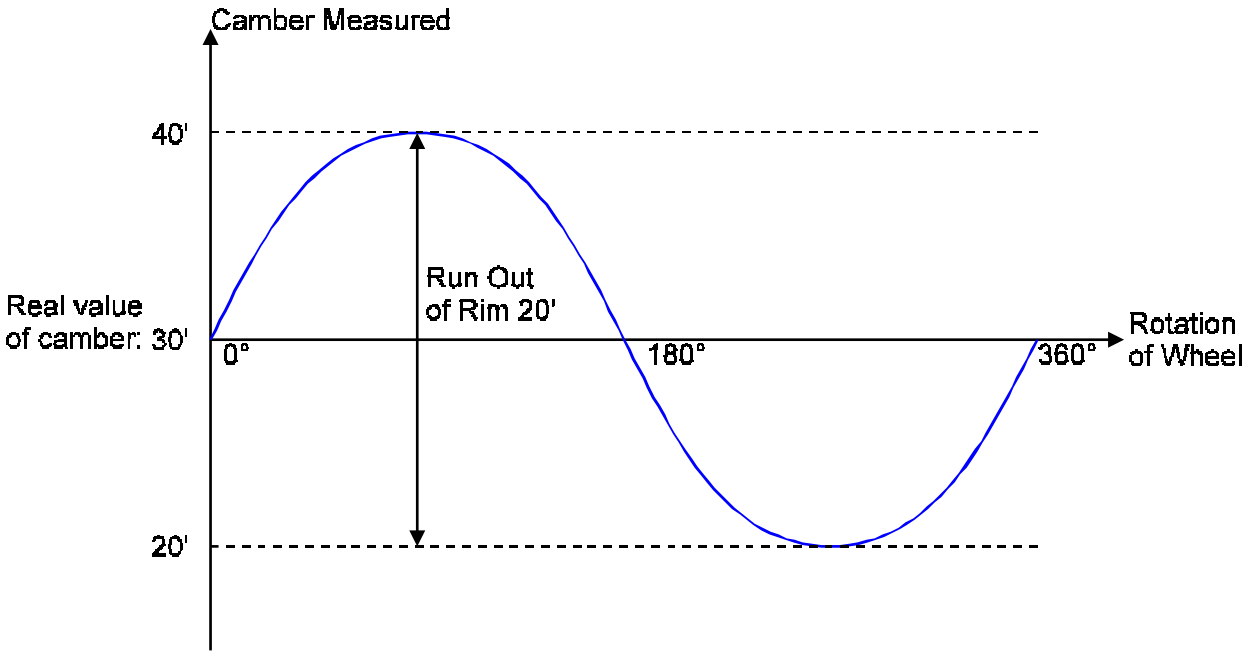
Run Out Compensation

One source of inaccuracy is the Run Out of the wheels.

The Toe and Camber angles are related to a plane which is perpendicular to the rotational axle of the individual wheel. The measuring heads, however, are normally clamped to the wheel rim. To compensate for the Run Out of the rim, the so-called Run Out Compensation must be performed.

Typical Run Out values even for good rims are 20'. It is therefore important that the operator perform the Run Out procedure to eliminate this source of inaccuracy. The measured Camber value varies between 20' and 40' because of the Run Out of the Rim.

In some cases a Quick Clamp is used for convenience. However, this method is not different from the normal clamping method. To avoid that the wheel Run Out influences the measuring result, Run Out Compensation must be performed.



Only in the case where the clamp is fixed against the brake disc through holes in the rim, can Run Out be left out without loss of accuracy.

Measured camber value varies because of Run Out. The real value is 30', but the measured value varies between 40' and 20'.

Convincing the Customer

6 important facts about wheel alignment

1. Extend tyre life

It's happened to almost everyone: buy a set of tyres, and before long one or two tyres are wearing out before the others. On today's cars, this applies to the rear tyres as well as the front tyres. The most common cause of unusual tyre wear is improper alignment. Over the years, a properly aligned vehicle can save hundreds of dollars in tyre wear.

2. Spot problems early

A suspension system inspection is an inherent part of the wheel alignment operation. This gives the mechanic a chance to spot worn parts that would affect vehicle alignment. It also gives him an opportunity to spot small problems before they become big, costly ones.

3. Ensure safe driving

A periodic four wheel alignment makes sure your car handles properly and, more important, provides an opportunity for inspecting the suspension system for defective parts. In some ways, the safe driving aspect may be the most important benefit of wheel alignment.

4. Stretch fuel mileage

Fuel mileage increases as rolling resistance decreases. Proper wheel alignment sets all four wheels parallel which, in turn, assures minimum rolling resistance. This plus proper tyre inflation provide top efficiency for maximum mileage.

5. Improve handling

Does your car pull to one side, does the steering wheel vibrate, do you have to constantly move the steering wheel to keep your car travelling straight ahead? These and other handling problems can generally be corrected by four wheel alignment.

6. Get a better ride

Proper alignment helps the front and rear suspension system do their job. With all the system components in proper relation, road shock is efficiently absorbed, so the vehicle is more stable, and you get a smoother ride.

4-Wheel Alignment as a Service Offer

At times like these, all workshops should take into consideration new service fields to offer to the customers. This could make a considerable contribution to the workshop's profit thereby compensating for the general decrease in vehicle repair work.

4-wheel alignment with wheel adjustment is such a field. Another is shock absorber testing. Everybody knows, of course, that a car has 4 wheels, but many workshops nevertheless treat the car as though it only had 2 front wheels. It is a matter of being updated on developments in modern vehicle techniques coordinating wheel suspension, tyres, and spring suspension to achieve the best possible ride as regards comfort, safety, and economy.

Selling wheel alignment and wheel adjustment is not difficult at all. There are many obvious arguments for it. In return for this service, the customer gets longer tyre life, reduced fuel consumption, and increased safety and comfort. In short: the customer saves money and is therefore prepared to pay for the service.

Many car models have independent suspension with a tendency to get out of adjustment over a period of time. The suspension consists of a set of arms and springs ensuring a specific change of the wheel angles when loaded and when going round corners. The arms are connected to the chassis by rubber bushes to absorb the forces generated during driving thereby keeping the wheel angles under control.

The rubber bushes wear, and their elastic qualities change as they grow old. The alignment therefore changes or the following rear axle begins to steer awry. The suspension arms or their pivot points are easily damaged e.g. by hitting a curb. The result is changed wheel angles and possibly excessive tyre wear, reduced comfort, and maybe even reduction of the vehicle safety.

There are therefore evident arguments for recommending 4-Wheel alignment as a regular service. Computer-Controlled equipment is available to carry out the alignment easily and with great accuracy. OPTO-PLUS 614 is such a unit, which can, moreover, be used for other jobs. There is a program available which can, after having received information on the undercarriage cross measurements, calculate the effect of wheel suspension adjustment on the wheel angles. This ensures that all factors affecting the wheel angles are taken into consideration when evaluating the test results.

In Workshops with this equipment it is now possible to solve problems which could not be solved by the old type of equipment which only concentrated on the function of the front wheels. The customers complaining that their car wears the tyres too much or that the steering pulls to one side when driving straight ahead are all gone!

Even if only few wheel alignments are made every day, the investment in a 4-wheel aligner pays off. Add to this that still more motor manufacturers demand the 4-wheel alignment facility in the workshops.

At first, the workshops should convince the customers that this service is indispensable. The demand for it already exists, and further arguments are: increased road safety, better economy, and better driving comfort.

Influence of the chassis measurement on the wheel angles

Sometimes we are faced with the problem that it is impossible to adjust the wheel angles within the tolerances recommended by the manufacturer. If it is a new car with no sign of damage or even a car fresh from the factory, the question naturally arises what the cause of this deviation is.

One explanation can be incorrect installation of the suspension due to damage or excessive tolerances in installation hole positions. If the chassis attachment points are offset, an alteration of Camber, KPI, and Caster will be the result. Looking at concrete cases it is truly surprising, how small measurement changes can result in changed wheel angles larger than the tolerances stipulated.

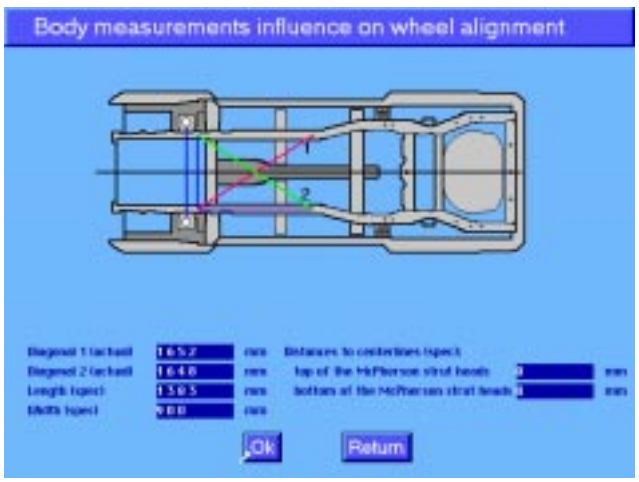
In connection with steering alignment courses, the Danish Technological Institute has taken up this problem and made a systematic basis on which to calculate this situation. In order to simplify the use of this equipment and place it at the disposal of our customers, Autek has made a PC-based program with a graphic interface to make it easy for the user to establish how much a chassis misalignment influences the wheel angles.

The procedure is as follows:

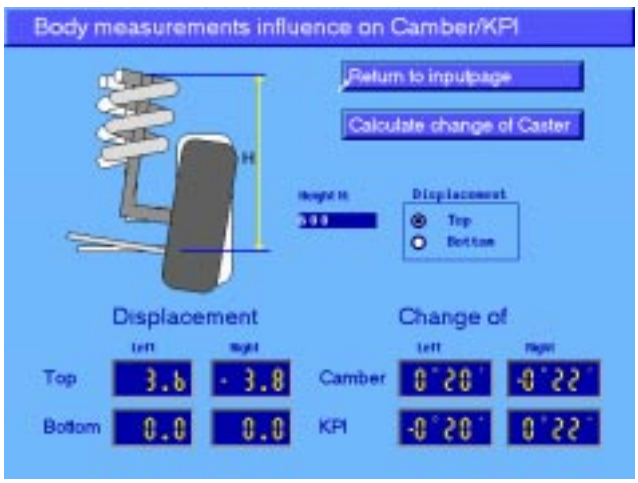
A square is measured including the misaligned chassis part and the suspension installation holes. The screen shows how to insert a couple of cross measurements in the digit sections and combining with dimensions from the manufacturer's dimension data sheet. Based on this, the program calculates the suspension installation point displacements, and this combined with the suspension height gives the relevant angle alterations.

In the case shown, a 4 mm difference in cross measurement gives a 22' alteration in Camber and KPI. The suspension height is set at 600mm. It is also possible to calculate Caster alterations by inserting figures in dimension sections as shown on the last screen picture.

The program helps by indicating the influence of misalignment on the wheel angles but it does not show the factual causes of misalignment. This is still in the responsibility of an experienced panel beater.



The difference in the diagonals results in 22' alteration in the Camber and KPI.

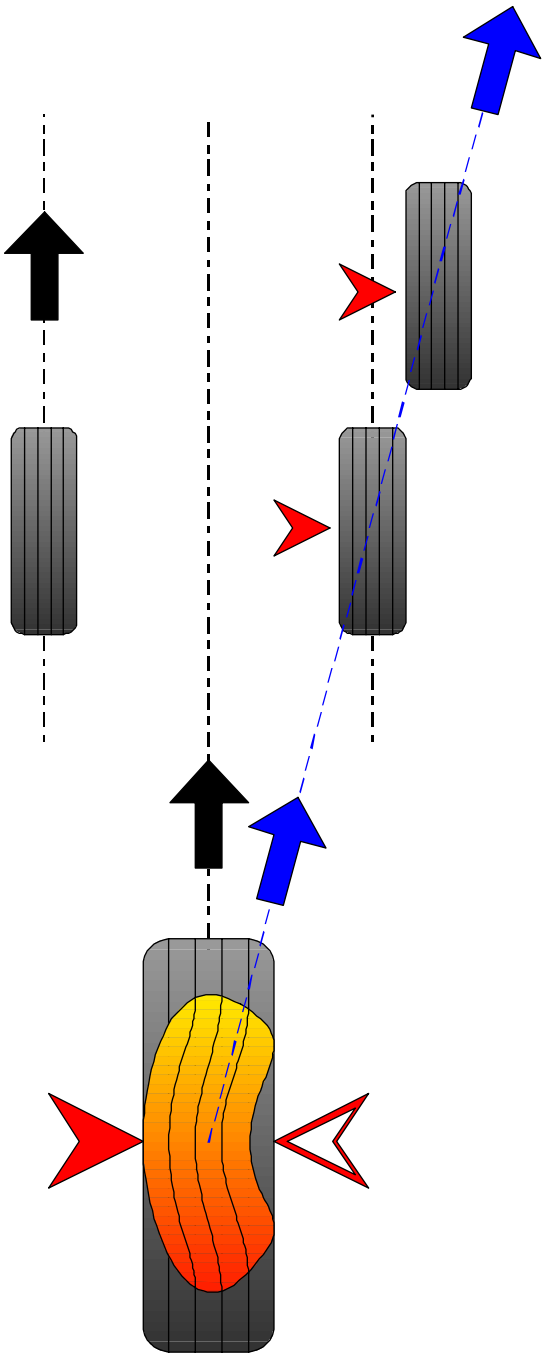


In this case, there is a difference of 4mm between diagonal 1 and 2.

Slip angle

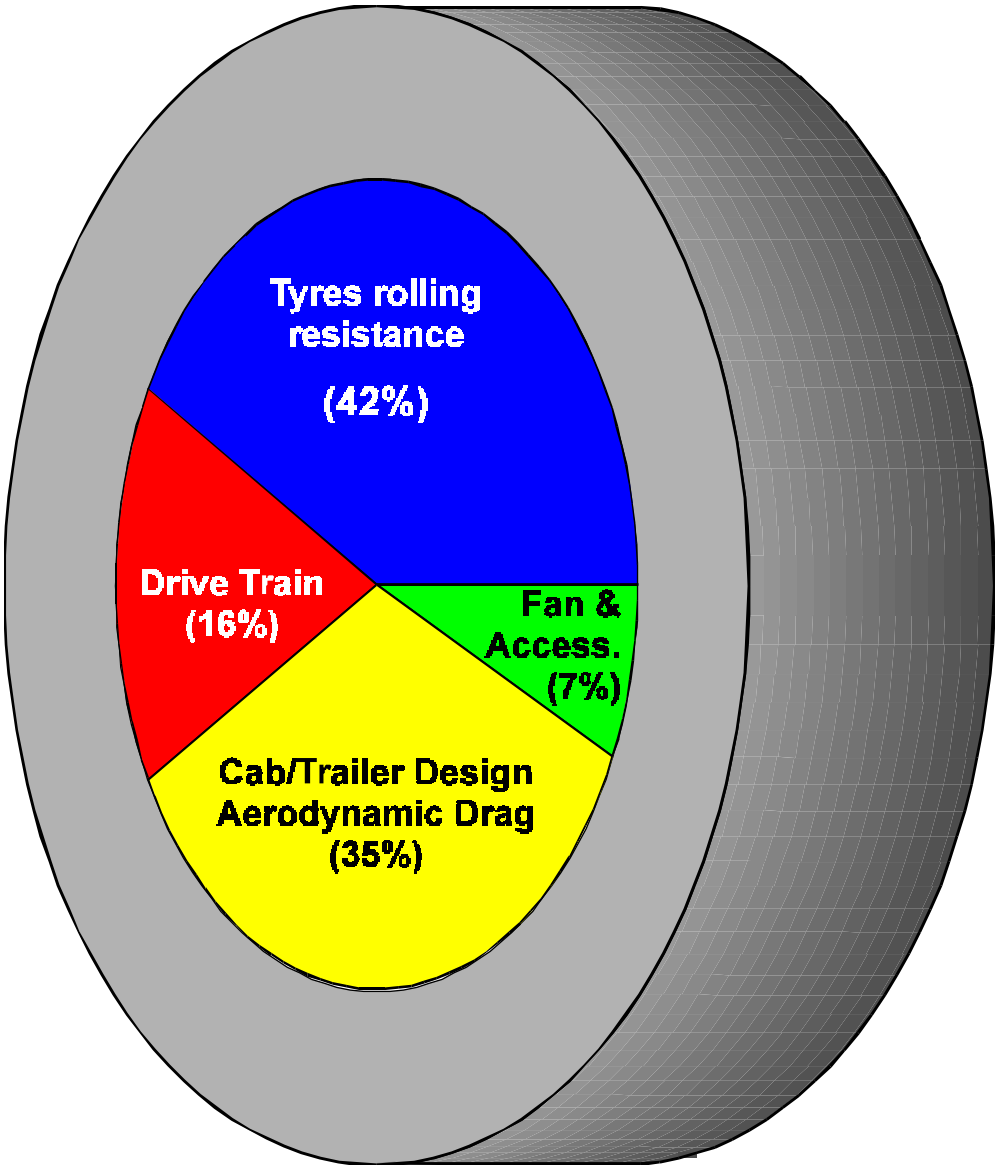
The whole force acting on the car body must be carried to the road by the tyres. Side ways forces acting on a car when cornering causes the tyres to distort, so that the tyre tread and consequently the car, follow slightly different paths than the direction the wheel is pointing. The forces and distortion is absorbed in the thread of the tyre as illustrated on the figure.

The difference between the direction of travel and the wheel is called the slip angle. A slip angle will always exist when sideways forces are acting on the tyre e.g. when the vehicle turns in a curve. Intuitively one can see that an improper slip angle causes the rolling resistance to increase causing excess tyre wear. The figure on the next page shows how the fuel energy is consumed in a typical vehicle. More than 40% is typically used to overcome tyre rolling resistance. It follows that even a modest increase in rolling resistance increases fuel consumption. The Slip Angle increases through low tyre pressure.



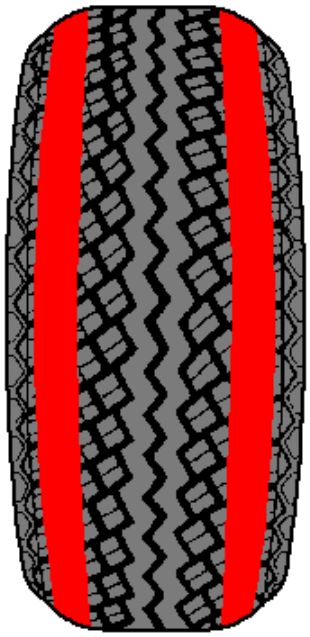
Tyre rolling resistance has a major effect on fuel consumption.

Misalignment adds rolling resistance to the wheels and that in turn means increased fuel consumption. This relationship is obvious looking at the distortion of the tyre tread pattern when the wheels are tracking incorrectly. The graph shows a typical representation of how the fuel is consumed.



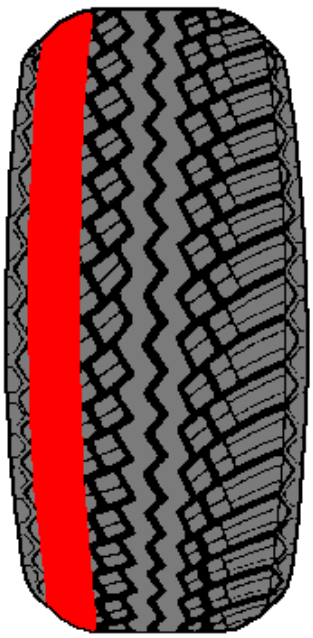
Common causes of tyre wear

Tyre pressure too high



Tyre pressure too low

Shock absorber faulty

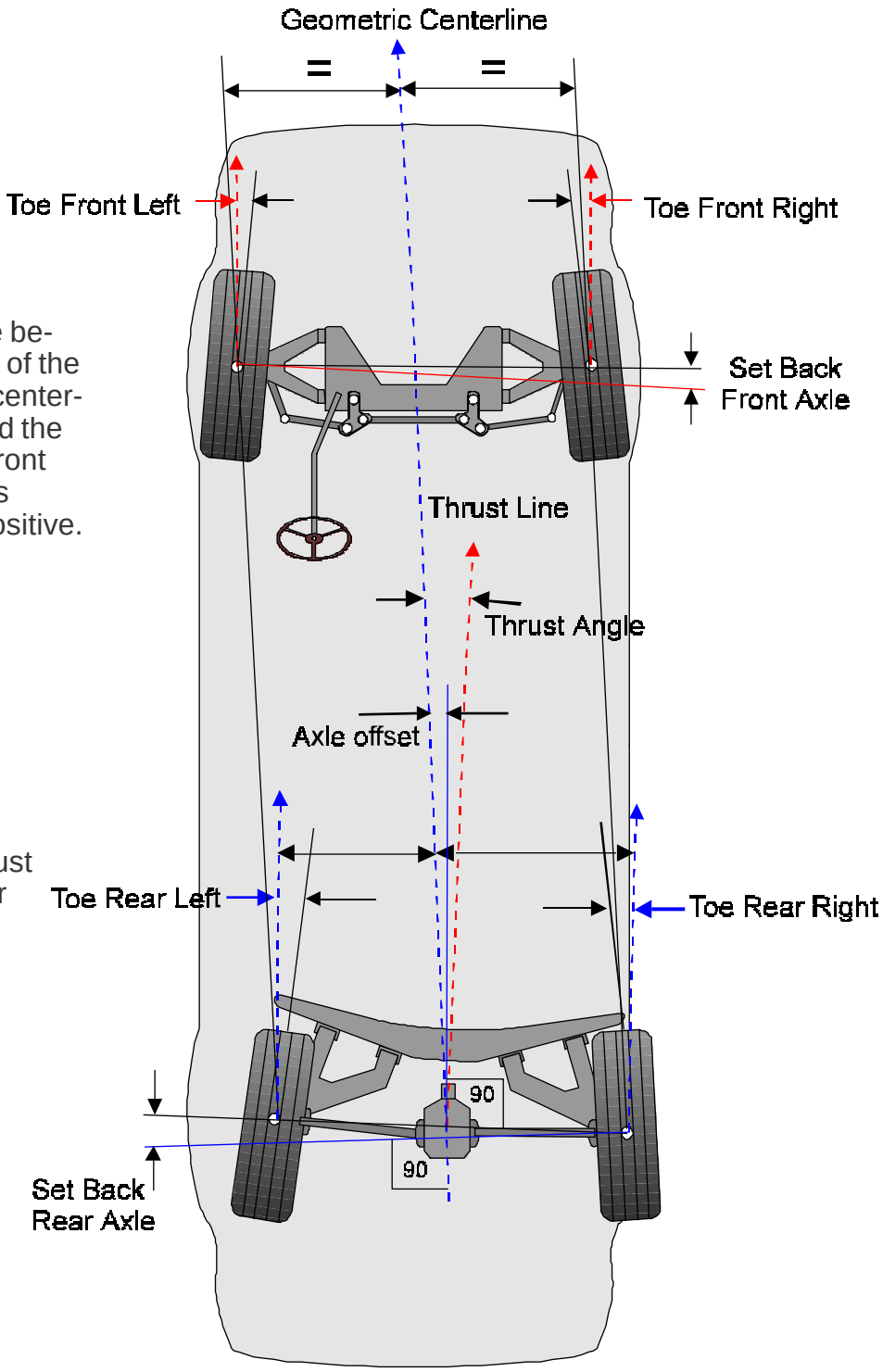


Suspension faulty

Alignment incorrect

The Toe Angles

On the figure the different alignment angles in the horizontal plane are demonstrated. The Geometric center line is intersecting the middle of the front and rear axle. The Thrust line is the symmetry line of the rear wheels in relation to the Geometric centerline. The Thrust Angle is therefore the angle between the center line and the thrust line.



Individual Toe

Individual Toe is the angle between the rotational plane of the wheel and the geometric centerline for the rear wheels and the vehicle thrust line for the front wheels. When the wheel is turned inside the Toe is positive.

Set Back

Set back is the front axle angle in relation to the thrust line. A difference in Caster will cause Setback.

Alignment of Toe

The wheels are aligned with respect to some reference line. The question is then which reference line. There is the vehicle center line, the geometric center line and the rear axle thrust line. The vehicle center line is not relevant as it refers to the vehicle body, and as the wheels can't think, they don't know where the car body is in relation to themselves.

They are influenced by each other and together they decide in which direction to go. Therefore in alignment the geometric centerline and the thrust line are used as reference, whereas the vehicle centerline is a concern of the body repair.

Geometric Centerline Alignment

Toe on each front wheel is measured and adjusted using the geometric centerline as a reference. This type of alignment is referred to as 2-wheel alignment, as only the front wheels are aligned and one forgets about the rear wheels. In the case where the rear wheel create a thrust line that is not in coincidence with the geometric centerline, the front and rear wheels are not tracking, unless the steering wheel is cocked to get the vehicle to move in a straight direction.

4 -Wheel Alignment

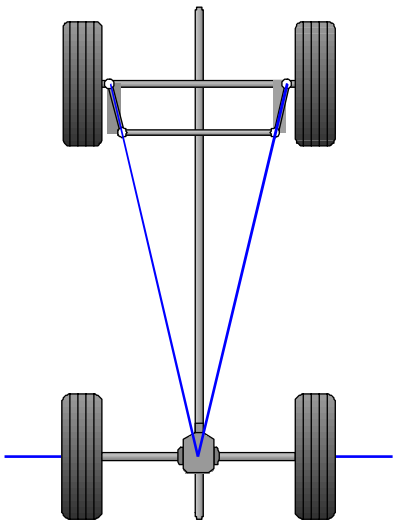
This is the correct Toe alignment for a car, ensuring that all four wheels runs in parallel in a straight direction, with the steering geometry being centered. For vehicles with adjustable rear wheel suspension, the rear wheels are adjusted so the Thrust Line coincides with the Geometric Centerline. The front wheels are then aligned relative to the Thrust Line/ Centerline. This sets all wheels straight ahead and parallel, and centers the steering wheel.

For vehicles with non-adjustable rear suspension, the rear wheel angles are measured to determine the Thrust Line. The front wheels are the aligned relative to the Thrust Line. This also sets all wheel parallel and centers the steering wheel.

The Toe is the most critical tyre wear angle. Improper Toe will create a variety of wear pattern which will differ because of the many different types of tyres available today. The Toe add to the directional stability of the vehicle. However a correct Toe value is trade-off between the desire for good directional stability and tyre wear. Excessive Toe makes the wheel roll based on the angular direction. However, the vehicle forces the tyre to roll straight ahead, creating a scruffing action across the thread. In effect this is similar to dragging the tyre sideways. On a modern Wheel Aligner all the Toe angles are measured according to the rules of 4-Wheel Alignment.

Turning Angle. Toe Out on Turns

Turning angle is the steering angle that controls the amount of angle each individual wheel turns while cornering. During cornering, the inside wheel must turn at a greater angle since it is turning at a smaller radius. This is accomplished by the angles built into the steering linkage.

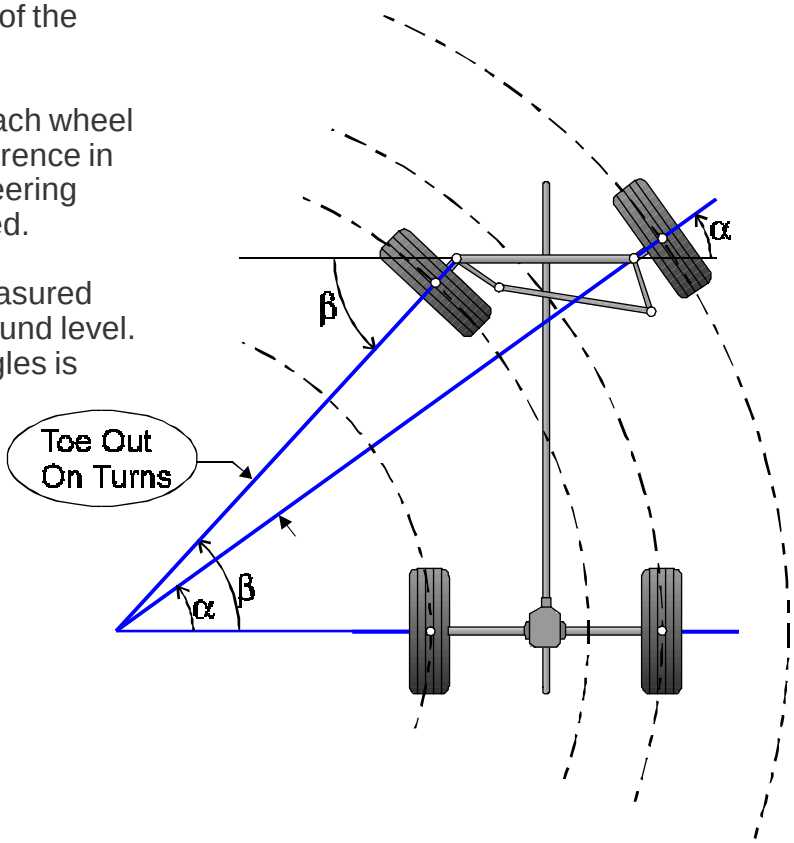


The linkage trapezoid with the steering arm and tie rod, is designed so that the center lines of the inner and outer wheels are intersecting at a point on a line through the rear axle. This will give an ideal track for each wheel when turning. Because of the slip angles when the vehicle must overcome centrifugal forces this situation only exists with the vehicle in a static situation. However the correct designed angles help to reduce the tyre scruff while cornering.

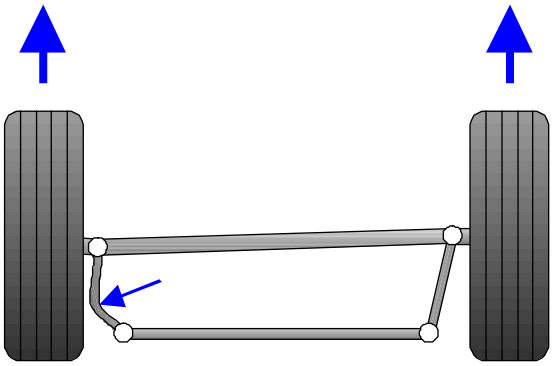
The difference in turning angle is called Toe Out on Turns. It is measured with the inner wheel at an angle of 20°. An incorrect Toe Out on Turns indicates that parts of the steering linkage is damaged.

The maximum turning angle for each wheel is normally also measured. A difference in the values will indicate that the steering linkage is not centered or damaged.

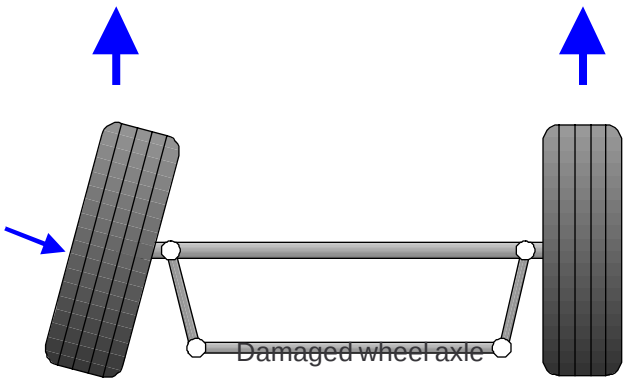
The turning angle can only be measured correctly when referring to the ground level. The measurement of all these angles is done very easily and accurately using electronic turntables.



On the figures below are shown examples with a damaged wheel axle and a damaged steering arm. In both cases, it is possible to turn the wheels straight ahead and adjust the Toe. The asymmetric steering trapezoid will cause an incorrect Toe out on turns and abnormal tyre wear.



Damaged steering arm



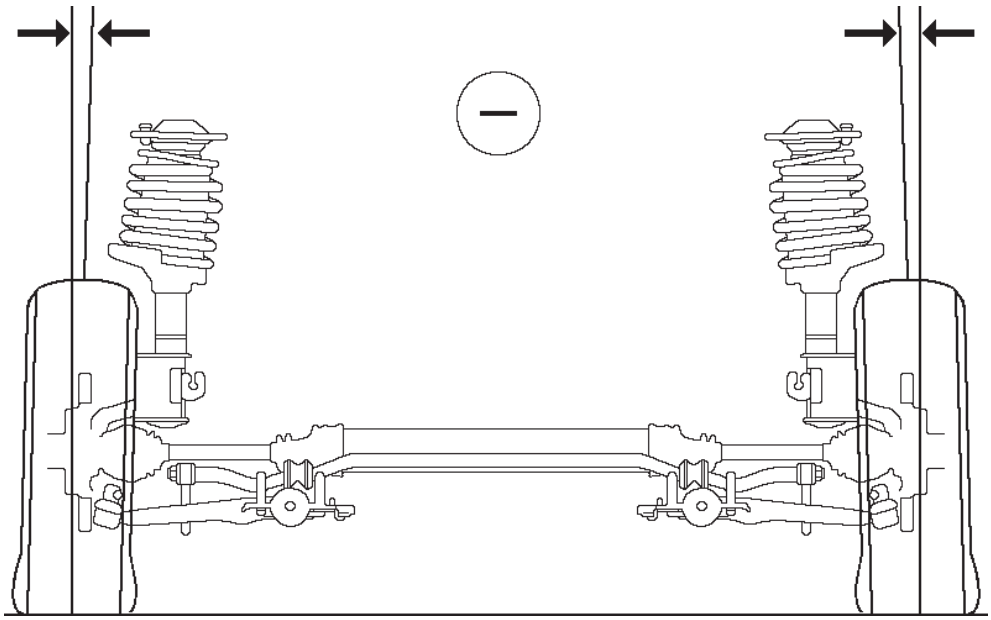
Damaged wheel axle

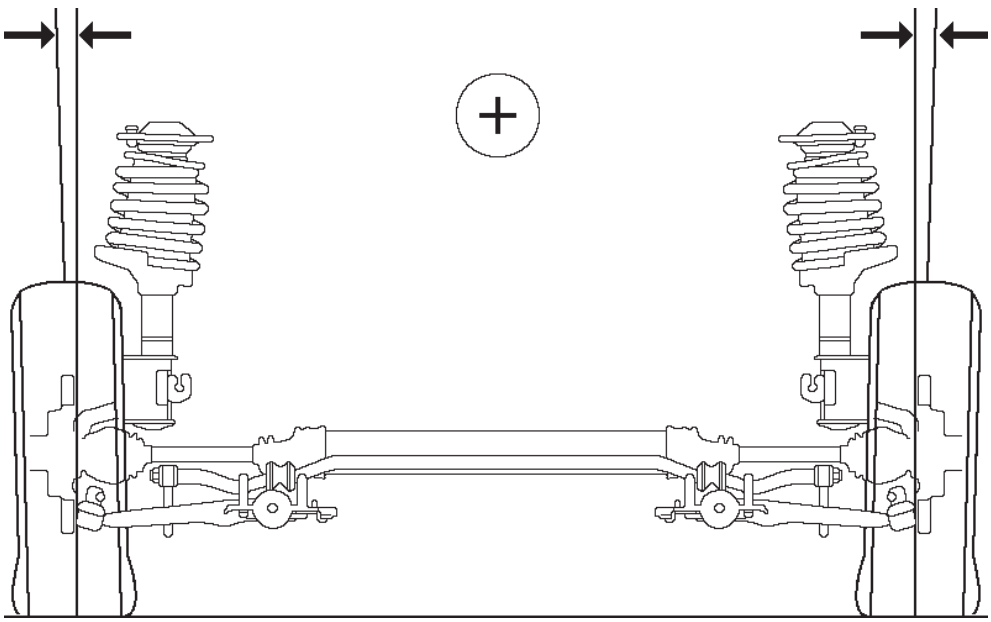
The diagnostics of this situation can only be performed by measuring the Toe out on turns using turntables.

Camber Angle

This angle is measured from the gravity vertical line to the wheel plane. When the wheel is tilted outwards the Camber is positive when tilted inwards the camber is negative.

The correct value depends on the actual design of the suspension system. Generally the Camber helps straight ahead stability and to maintain optimum tyre life. The Camber values left-right must be the same to avoid that the car pulls sidewards. An improper Camber value often cause excess tyre wear on the edge.

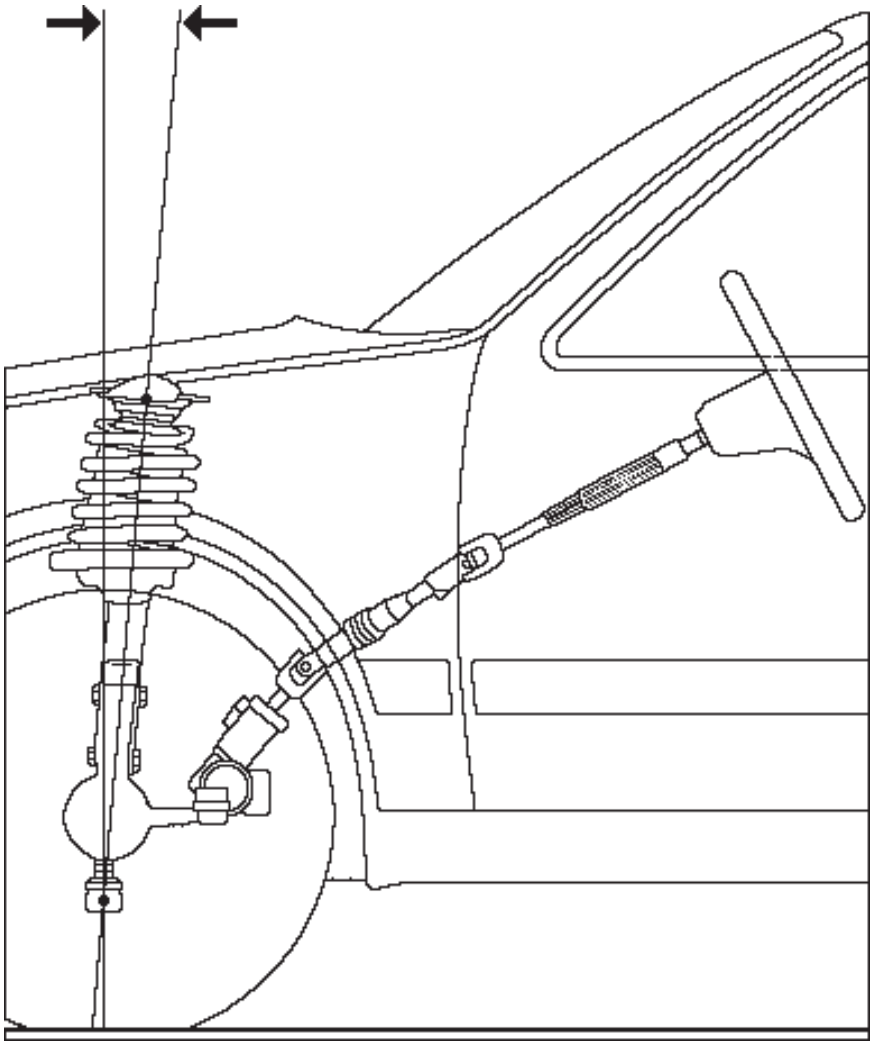




Caster Angle

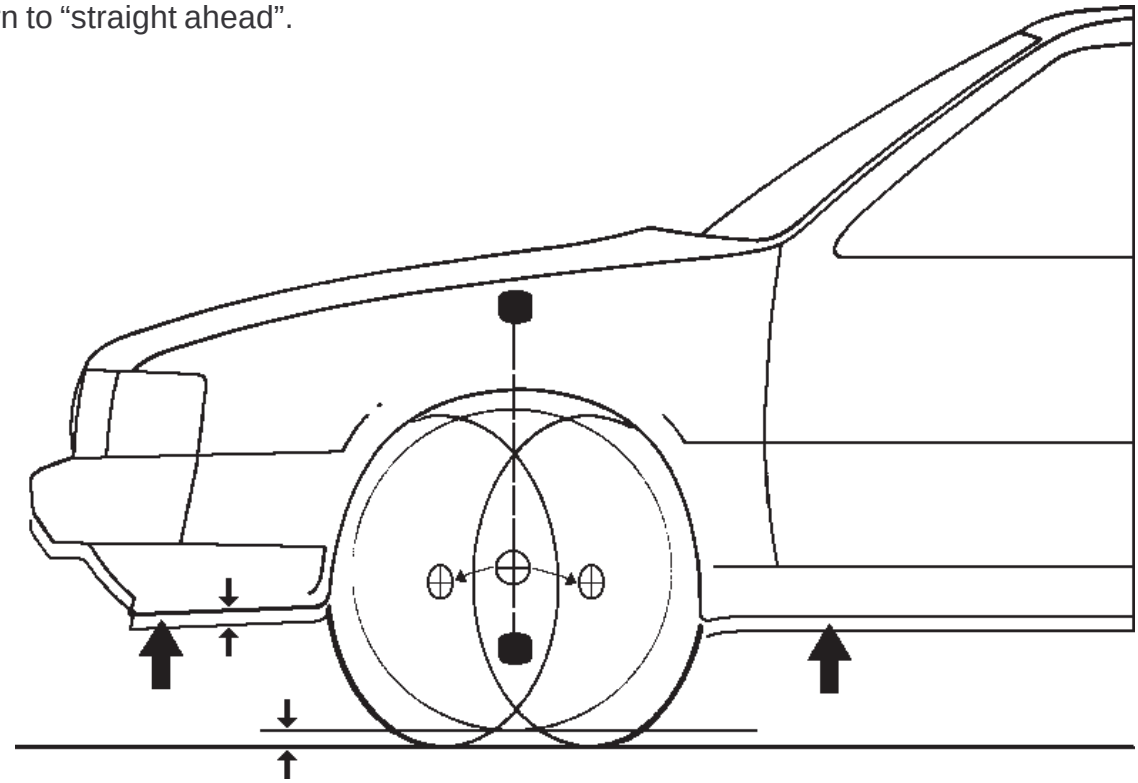
The Caster angle positions the pivot point on which the wheel turns ahead of the tyre contact patch. This gives the wheel an inherent self centering effect as the wheel is drawn ahead instead of being pushed.

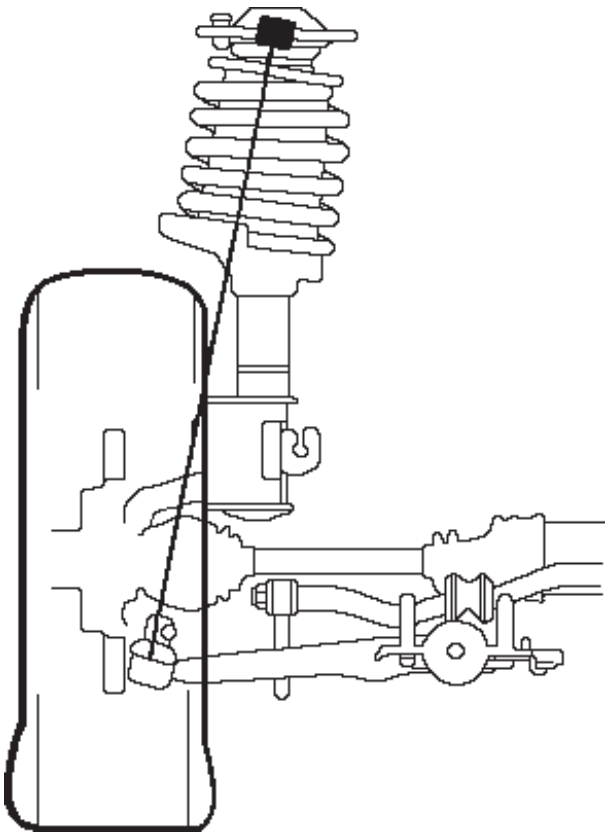
It is important that the Caster angles on both front wheels are the same to avoid unstable steering on bumpy roads and when braking.

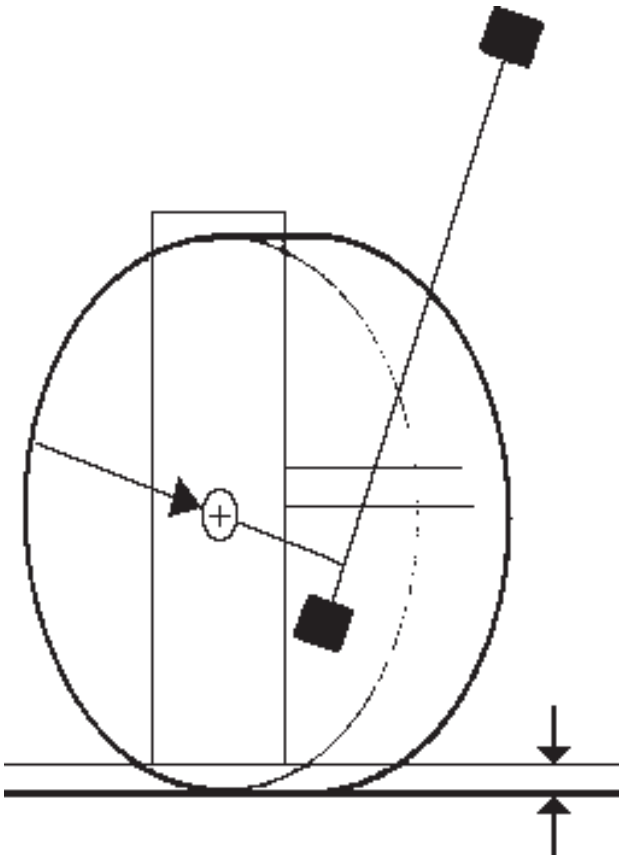


King Pin Inclination - KPI

This angle is also known under the name Swivel Axle Inclination (SAI). The angle is determined by the line through the swivel points to the vertical. The purpose is to position the Pivot point in the tyre contact patch to obtain the desired slip radius. Also this angle will cause the car body to be lifted when the wheels are turned giving a tendency for the steering to return to “straight ahead”.

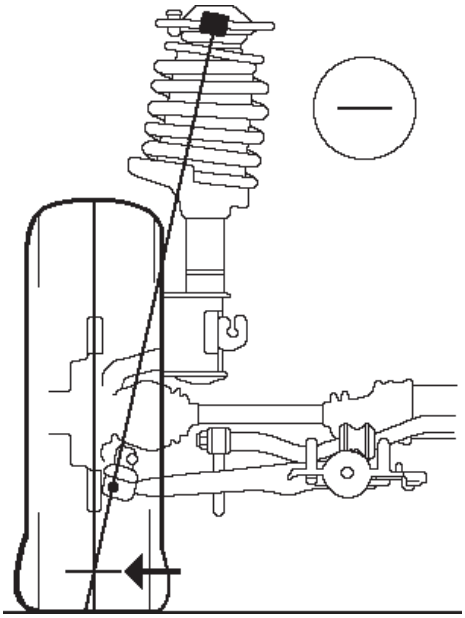


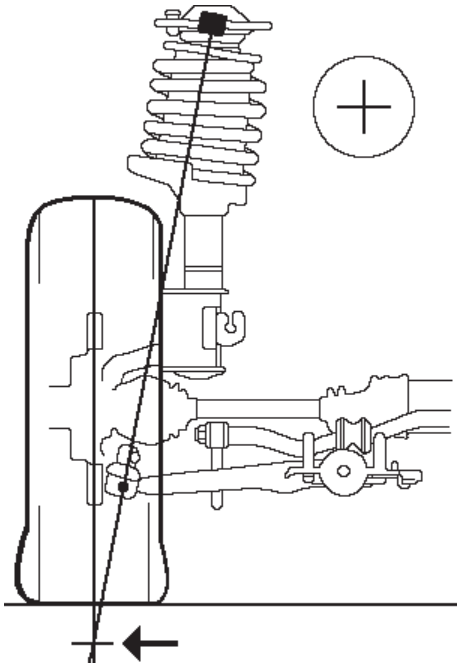


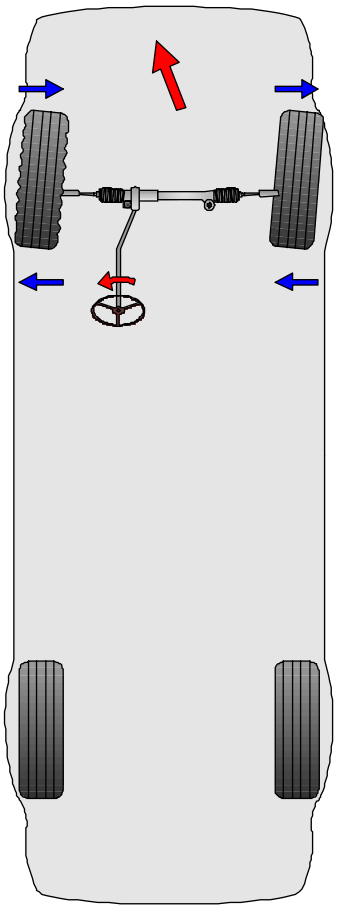


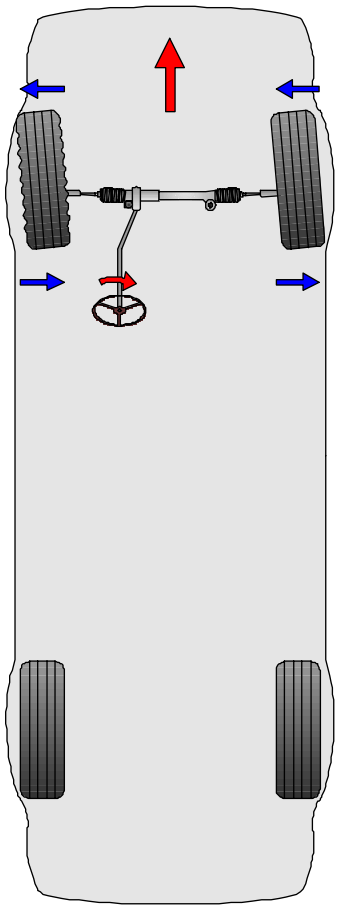
Slip radius

The distance between the centerline of the tyre and the line drawn through the steering swivel is called the wheel slip radius. Giving the wheel a small positive or negative slip radius makes the wheel roll easier when turning.



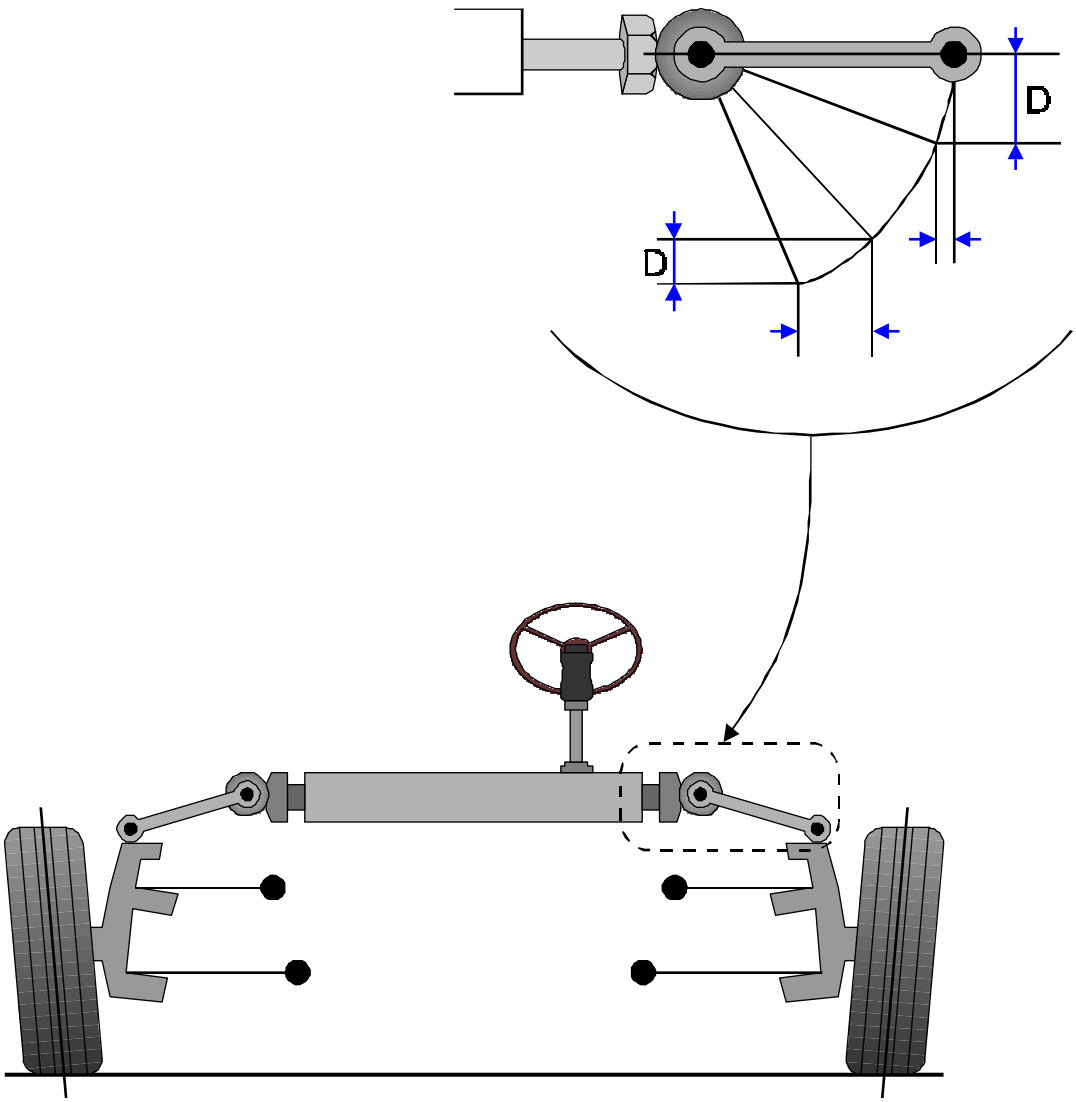






Steering Linkage Height

Another value which often is important is the steering linkage height. If the steering linkage has not the same height on each side of the vehicle, a handling condition sometimes called “Bump Steer” may result. This means that while the vehicle is moving along a bumpy road, Toe can change in such a manner that it will cause the vehicle steering to become unstable.



When the distance, D, is not the same on the left and right side, the Toe will change more on the one side than the other.

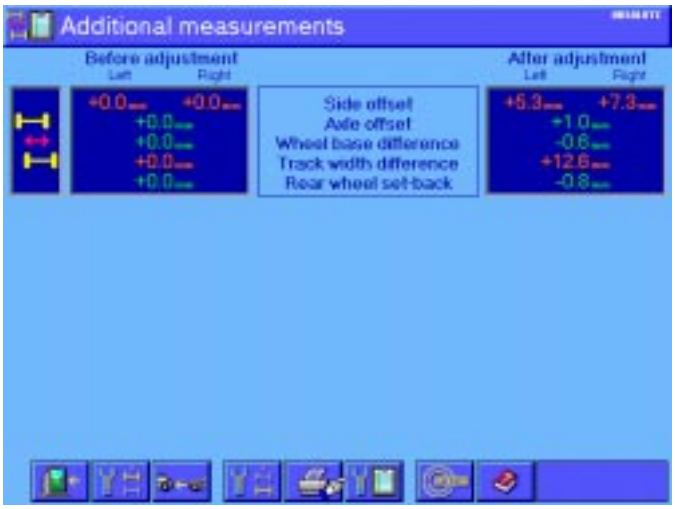
To check for bump steer, Toe should be at the factory preferred Toe setting, the steering linkage centered and the steering wheel locked. Pulling down the chassis the change in Toe value on each wheel is measured. If the change is not symmetric or excessive there probably is a fault in the mounting of the steering linkage.

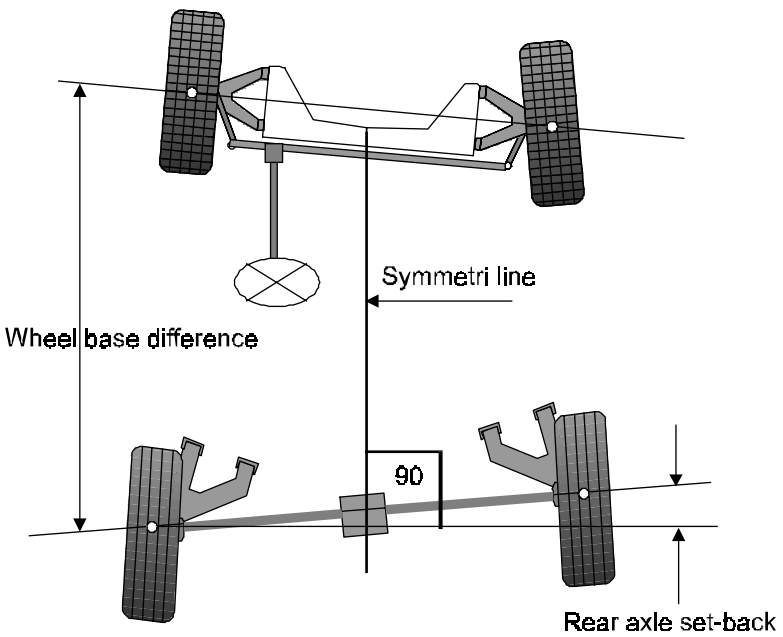
Additional Angles

The OPTO-PLUS 618 models has 8 toe sensors. This establishes a rectangle around the vehicle, which makes it possible to measure some important angles that cannot be measured with only 6 toe sensors.

Basicly the angles is measured, but if information about wheel base and track width is available in the database, the angles can be converted to distances in mm.

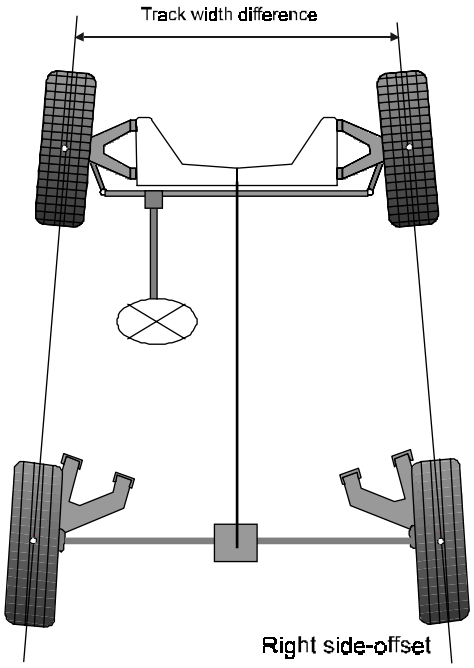
On the screen the 5 different values are displayed as shown on the figure.



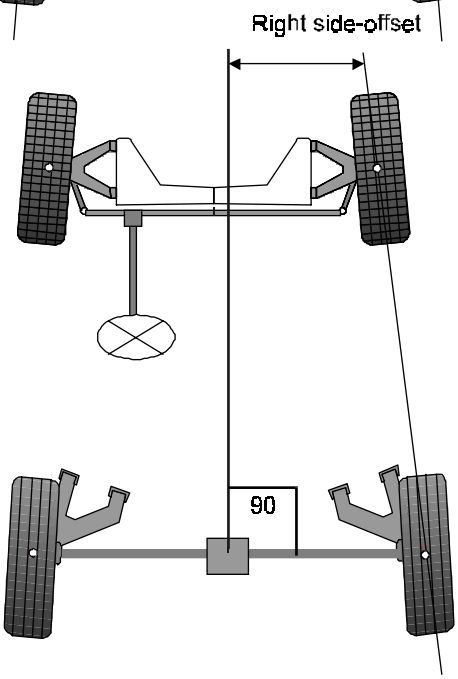


Wheel base difference is measured as the angle between lines through the rear and the front wheel centres

Rear axle set -back is measured as the angle between a line perpendicular to the symmetri line and a line through the rear wheel centres

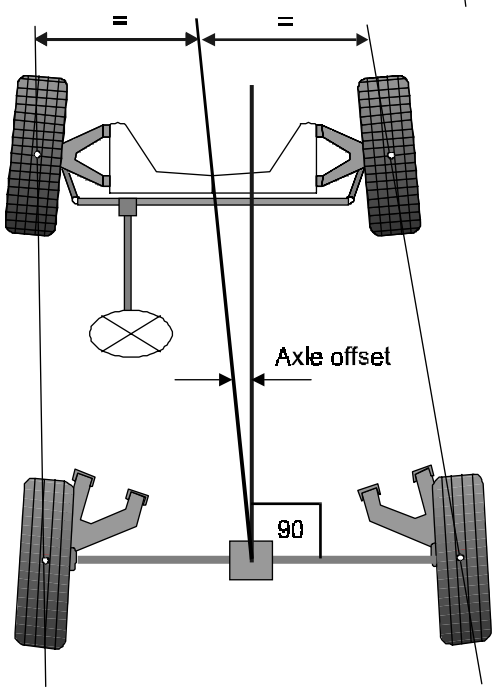


Track width difference is measured as the angle between two line througt the centres of the right and the left wheels



Right side offset is measured as an angle between a line perpendicular on the a line through the rear wheel centres ans a line through the right wheel centres.

Left side offset is measured as an angle between a line perpendicular on the a line through the rear wheel centres and a line through the left wheel centres.



Axle offset is measured as an angle between a line perpendicular to a line through the the rear wheel centres and the geometric centerline.