Wheel Alignment

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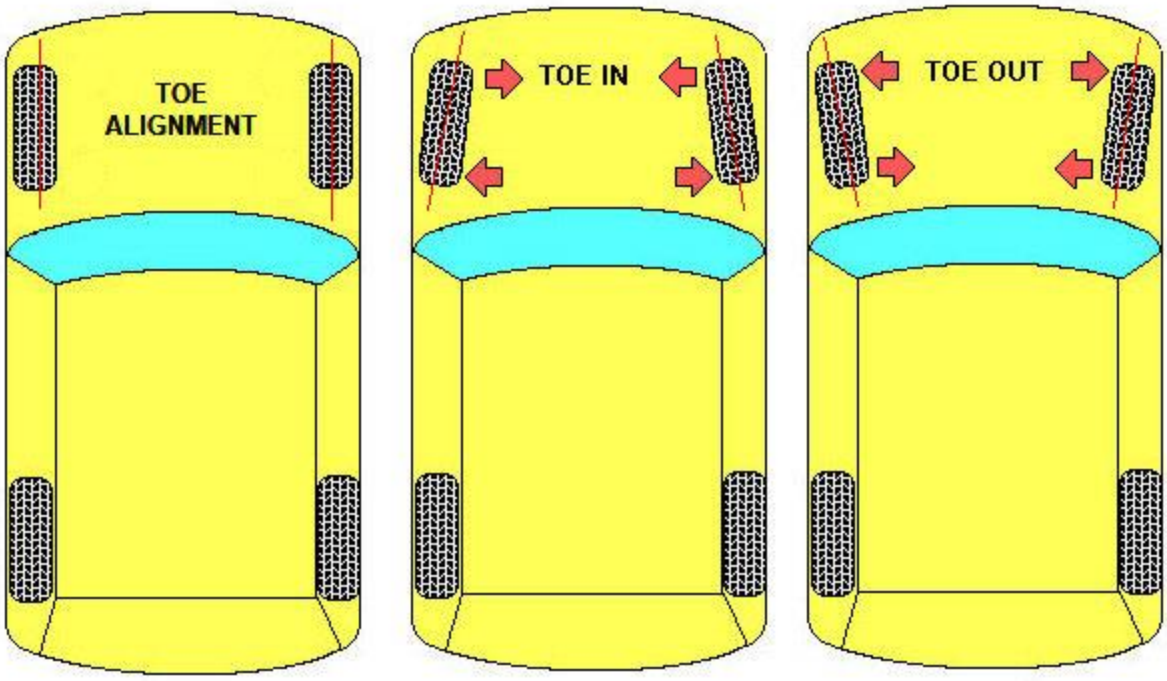
Wheel alignment refers to the geometrical relationship of the wheels to the vehicle itself, to each other and to the road. Ideally, all four wheels should be aimed straight ahead, parallel to each other, perpendicular to the road and perpendicular to their respective axles. This will produce the least amount of rolling resistance, the least amount of friction, the least amount of tire wear and the greatest traction. The basic alignment angles we're talking about here are **TOE, CAMBER** and **CASTER**.

TOE WHEEL ALIGNMENT

Toe is the most important wheel alignment angle because it has the greatest effect on tire wear.

Toe refers to the parallelism between the wheels as viewed from above and is usually measured in inches or millimeters.

When both front wheels are aimed straight ahead and the distance between the leading edges of both front tires is exactly the same as the distance between the trailing edges, the wheels have **ZERO TOE**" and are theoretically aligned. We say in theory because toe alignment changes when the vehicle is being driven.



The joints and sockets in the suspension and steering linkage all have a little play, which when added together can allow wheel alignment to change depending on how the steering and suspension are loaded. Likewise, the rubber bushings in the control arms have some compliance and deflect slightly when the vehicle accelerates, brakes, turns and cruises. This too can allow toe alignment to change. To compensate, a little bit of "toe-in" or "toe-out" may be added when the wheels are aligned depending on whether the vehicle has front- or rear-wheel drive.

TOE-IN means the front edges of the tires are closer together than the rear edges. Most rear-wheel drive cars and trucks have alignment specifications that call for a little bit of toe-in (say 1/16th of an inch or so). This will produce zero rolling toe as the vehicle is being driven down the road because the natural tendency for the front and rear wheels is to toe-out due to rolling resistance and compliance in the steering and suspension.

TOE-OUT is when the front edges of the tires are farther apart than the rear edges. This may occur if the tie rod ends are worn, or if the control arm bushings have collapsed. Toe-out is a bad condition to have because it causes the tires to scrub as they roll along.

Only 1/8th inch of toe-out will scrub the tires sideways 28 feet for every mile driven. At this rate, it doesn't take long to wear down the tread.

Uneven wear on the inner area of the tread caused by toe-out misalignment.

A classic symptom of toe misalignment is a feathered wear pattern across both front tires. The direction of the feathering tells you if the tires are toed-in or toed-out (rough edges towards the inside signal toe-in while rough edges to the outside indicate toe-out). But on radial tires, toe misalignment tends to roll the shoulder of the tire under as it scrubs producing wear on the inner or outer ribs only. **Toe-in** will wear the **outer** area of the tread while **toe-out** will cause wear on the **inner** area of the tread. In both instances, wear can be aggravated even more if the tires are underinflated.

Replacing worn tires may replace the worn rubber, but it won't eliminate the tire wear problem. The new tires will suffer the same fate unless the cause of the misalignment is identified and toe is reset to specifications. So anytime the tires show toe wear, toe alignment should be checked to see if it is out of range. Also, the steering should be inspected for worn or bent parts. In addition to checking for loose or worn tie rod ends, look for bent steering arms or tie rods because either can cause toe wear, too.

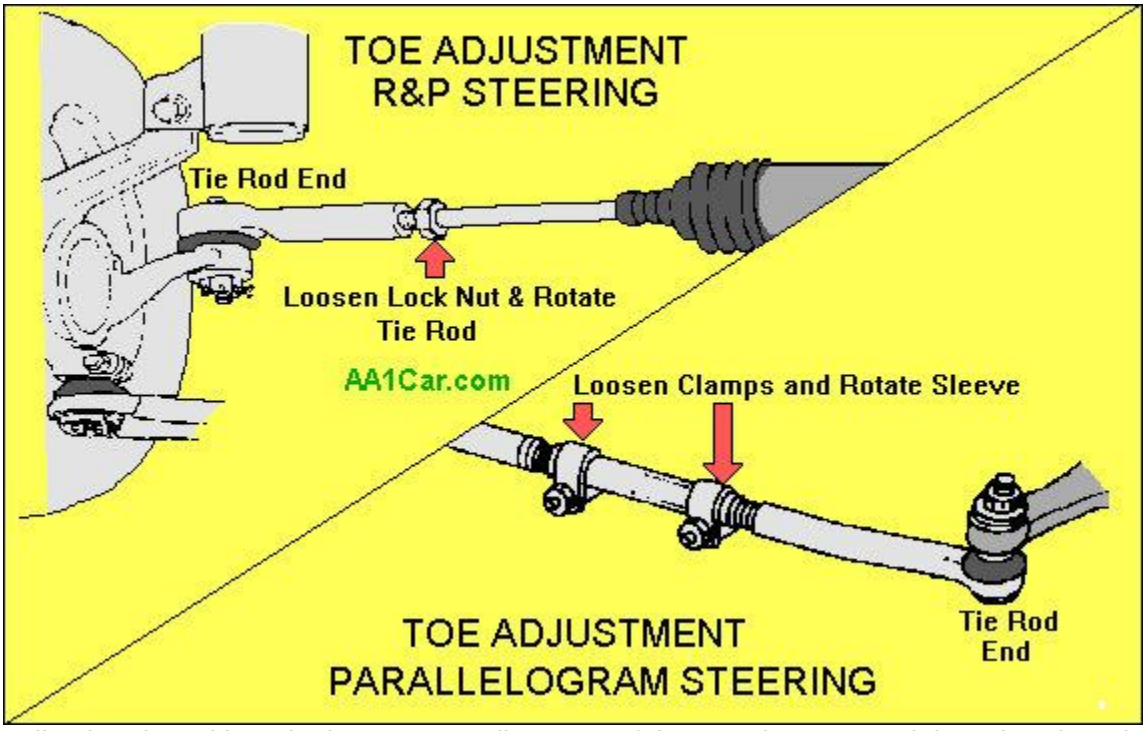
Strange as it may seem, on some front-wheel drive cars and minivans, a slight amount of toe-out (up to about 1/16th inch) may be specified when aligning the wheels to compensate for toe-in that occurs as the front wheels pull the vehicle down the road. Drive torque more than offsets the compliance in the steering and suspension allowing both front wheels to toe-in slightly when accelerating. This is also what causes "torque steer" (a sudden steering pull) in some FWD cars that have unequal length halfshafts. Under hard acceleration, the left wheel with the shorter halfshaft experiences more toe-in than the right wheel with the longer halfshaft. The result is unequal toe changes and a steering pull to the right. Vehicle manufacturers have reduced or eliminated torque steer in many FWD cars by using equal length halfshafts and/or stiffer control arm bushings.

HOW WORN PARTS AFFECT TOE ALIGNMENT

Worn **TIE ROD ENDS** are the most common cause of uneven tire wear (usually toe-out wear on the inner area of the tread). Worn or loose tie rod ends should always be replaced. But new tie rod ends won't necessarily cure a tire wear problem unless the tie rods are properly adjusted after the new parts have been installed.

Changing the tie rod ends, tie rods or a steering rack will change the distance between the steering arms, which changes toe. So after the parts have been installed, some type of alignment equipment must be used to measure toe. Then and only then can the tie rods be adjusted to set toe within the vehicle manufacturer's specifications (always use the specs listed in an alignment reference manual or service manual, never "rule of thumb" settings, because every vehicle is unique).

One old mechanic's trick when replacing tie rod ends is to count the number of turns it takes to unscrew a tie rod end, then to use the same number of turns when screwing it back on. This only works if the same tie rod end is being reinstalled because the length of the tie rod end and threading may be different on a new part. What's more, there's no way to know if the original alignment setting was correct or not. That's why toe should always be measured and readjusted as needed after parts have been replaced.



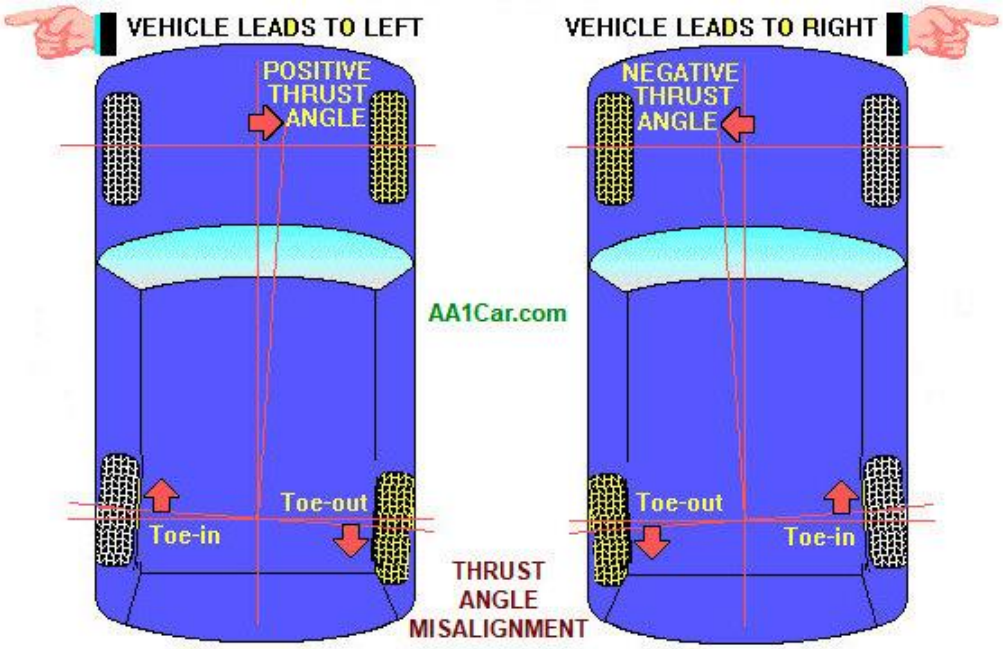
Adjusting tie rod length changes toe alignment. If the steering arm and tie rod end are behind the steering knuckle, as is the arrangement in most vehicles, INCREASING the length of the tie rod will add TOE-IN. SHORTENING the length of the tie rod will add TOE-OUT.

REAR TOE AND REAR WHEEL ALIGNMENT

Something else to keep in mind about toe is that rear toe is just as important on front toe -- especially if a vehicle has an independent rear suspension or rear toe adjustments. This includes most front-wheel drive cars and minivans as well as some rear-wheel drive cars. Rear toe misalignment can cause toe wear on both the front and rear tires by creating a steering pull to one side. Unlike front toe which is self-centering because of the steering linkage, a difference in rear toe angles side-to-side creates something called a **THRUST ANGLE.** The result is the same as rear axle misalignment that causes the vehicle to pull or lead to one side.

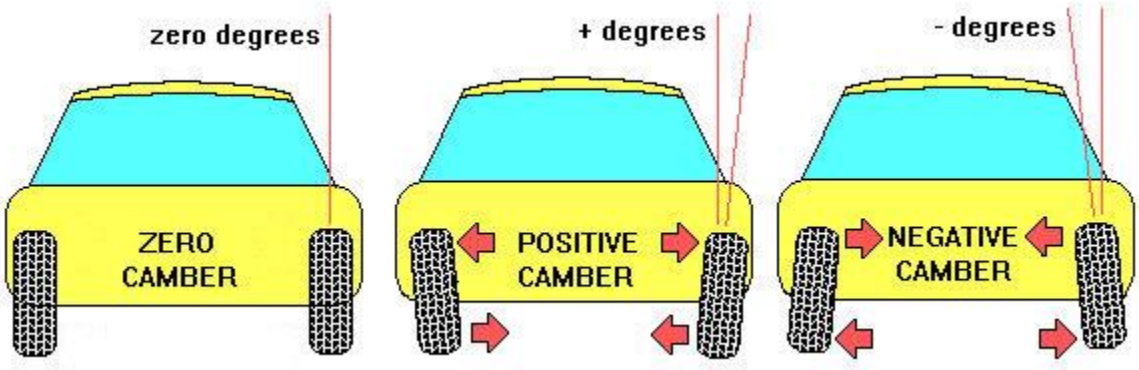
So how does rear toe-misalignment and/or the presence of a thrust angle cause wear on the front tires? Because front toe changes slightly when the wheels are steered to either side. This is called **TOE OUT ON TURNS**. Because the inside wheel follows a shorter arc than the outside wheel, the steering arms have a built-in angle (sometimes referred to as **ACKERMAN STEERING**) . This causes the wheels toe-out slightly with respect to one another when the wheels are turned to one side. The amount of toe-out is only a couple of degrees, but it helps to minimize scuffing and tire wear.

If the rear wheels are misaligned, though, and the driver has to constantly steer off-center to keep the vehicle going straight, it means the front wheels are constantly in a toe-out condition. Over a period of time, this will cause toe wear on the inner tread of the front tires. The cure? Check and realign rear toe as needed.



Toe misalignment at one or both rear wheels will create a THRUST ANGLE problem. If the rear wheels are aligned correctly, there will be zero thrust angle and no effect on steering or tire wear. But when a thrust angle exists, it causes the vehicle to lead or pull to one side. This puts the steering wheel slightly off center, which changes toe alignment (toe-out on turns, remember?), which can cause toe wear on the front tires..

Rear-wheel drive cars and trucks that do not have independent rear suspensions have fixed rear toe settings, so no adjustments are possible. But on most other vehicles, rear toe can be adjusted either by using factory adjustments (where available) or by installing aftermarket alignment aids such as toe/camber shims, offset bushings, etc.



CAMBER WHEEL ALIGNMENT

The next important wheel alignment angle you should know something about is camber. Camber refers to the tilt of the wheels as viewed from the front or rear. Camber is the inward (negative) or outward (positive) tilt of the wheels. It is usually measured in degrees.

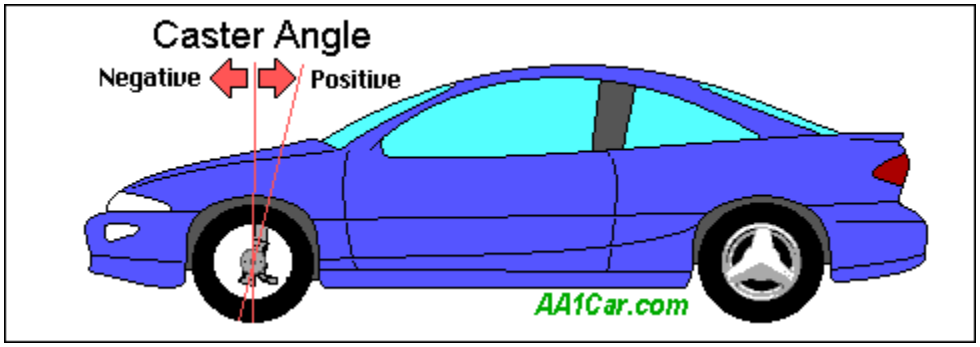
As with toe, zero camber (perfectly perpendicular to the road) is the ideal alignment setting. But like toe, camber changes as the vehicle is being loaded and every time the vehicle encounters a bump or dip in the road. The up and down motions of the suspension change the geometry of the control arms and struts, which causes camber to change. So many static camber alignment specifications may allow up to a degree of more of positive or negative camber depending on the design of the suspension. As a rule, camber settings should usually be within half a degree side-to-side.

If camber is out of specs, a tire will wear unevenly on one shoulder and the vehicle may pull toward the side with the most camber. Camber usually only affects one wheel, so if only one tire shows unusual shoulder wear it is usually a symptom of camber misalignment.

Keep in mind that camber applies to both front and rear wheels, though only vehicles with independent rear suspensions typically have rear camber alignment specifications. Most rear-wheel drive cars and trucks with solid axles do not have rear camber specifications because there's no way to change it (even so, a bent rear axle can cause a camber problem!).

Excessive camber can be caused by a bent spindle, mislocated strut tower, bent strut, worn or collapsed control arm bushing, bent control arm or a weak or broken spring. If any of these parts are replaced, camber should be checked and adjusted as needed

after the parts have been installed. And of vehicles that do not have camber adjustments on the struts or control arms, or provide only a limited amount of adjustment, there are aftermarket camber adjustment aids that can help.



CASTER WHEEL ALIGNMENT

The third most important wheel alignment angle is caster, which is the forward (negative) or rearward (positive) tilt of the steering axis as viewed from the side. Caster is usually measured in degrees, and only applies to the front wheels because they are the only ones that steer (except for the few oddball Japanese cars that had four-wheel steering).

Caster is a weird angle because it doesn't affect tire wear directly. It's greatest effect is on steering stability, steering effort and steering return. So it is often the most ignored angle.

Most vehicles have a small amount of positive caster to provide quick steering return and high speed stability. This happens because caster forces the spindle to angle down slightly as the wheels turn. This lifts the chassis and brings more weight to bear on the wheels as they turns. The net effect is that caster helps keep the wheels aimed straight ahead for improved steering stability, and helps the wheels return to the straight ahead position after turning. Many European luxury sedans have a lot of caster for this very reason because it provides a more stable feel at highway speeds. The downside is that it increases steering effort and steering feedback to the driver.

What happens if caster is out of specifications? If there is too much difference in caster side-to-side, it can cause a vehicle to drift or lead to one side. Some alignment specs call for a slight difference in caster to compensate for road crown. But as a rule, caster should usually be within half a degree side-to-side.

The same kind of problems that can cause camber misalignment can cause caster misalignment: a bent spindle, mislocated strut tower, bent strut, worn or collapsed control arm bushing, bent control arm or a weak or broken spring. So if any of these parts are replaced, caster should be checked and readjusted as necessary after the parts have been installed.

Ride height can also affect caster. Spring sag or overloading a vehicle can alter ride height up to several inches, which can change caster readings by up to a degree or more. This may contribute to steering instability or change steering effort. So checking ride height is also an important element of aligning the wheels. If ride height is below specifications, weak springs should be replaced. Upgrade opportunities here include installing variable rate springs, air springs, overload shocks or air-assist shocks on a vehicle that is used for towing or hauling heavier than normal loads.

CHECKING WHEEL ALIGNMENT

The only way to make sure the wheels are properly aligned is to check wheel alignment periodically. Once set wheel alignment should not change unless parts become worn or damaged. Likewise, it makes no sense to attempt to realign the wheels until worn or damaged parts have been replaced. Worn parts will not hold an accurate alignment because they have too much play. There's also the danger that a component failure could result in the collapse of the suspension and/or loss of steering control (a broken ball joint or tie rod end, for example).

Most experts recommend an annual alignment check, or to check wheel alignment when the tires are replaced. Even new vehicles can benefit from an alignment check if the wheels were not properly adjusted at the factory. Some factory specifications allow a rather wide range of settings, which may provide less than ideal tire wear and handling characteristics. Setting the wheels to the "preferred" or mid-range settings often gives the best results.

Most shops today promote four-wheel alignments as opposed to two-wheel (front only) alignments. Why? Because all four wheels influence directional stability, steering and handling. Four-wheel alignments are more expensive, take a little longer and require more sophisticated equipment, but should be considered a must for most front-wheel drive cars and minivans as well as rear-wheel drive cars with independent rear suspensions.

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