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Basic Suspension Geometry

Model: All

OBJECTIVES

After completion of this module you will be able to:

- Understand basic suspension geometry.
- Understand the relationship between alignment angles and ride quality.
- Understand the effect of alignment angles on tire wear.

Introduction

The safety, stability, handling and performance of a vehicle depends on many factors. One of the most important aspects of these characteristics is the design of suspension and steering systems. BMW vehicles are known for their superior handling and road holding performance.

The design of the BMW suspension systems is a key factor in achieving these goals. Suspension geometry is defined as: "The angular relationship between the suspension, the steering linkage and the wheels - relative to the road surface."

There are several alignment geometry angles which relate to the suspension components and steering linkages including:

- Caster
- Camber
- Toe-In/Toe-Out
- Steering Roll Radius (steering offset)
- Steering Axis Inclination (SAI) and Included Angle (IA)
- Toe Out on Turns
- Thrust Line and Thrust Angle

All of these angles influence:

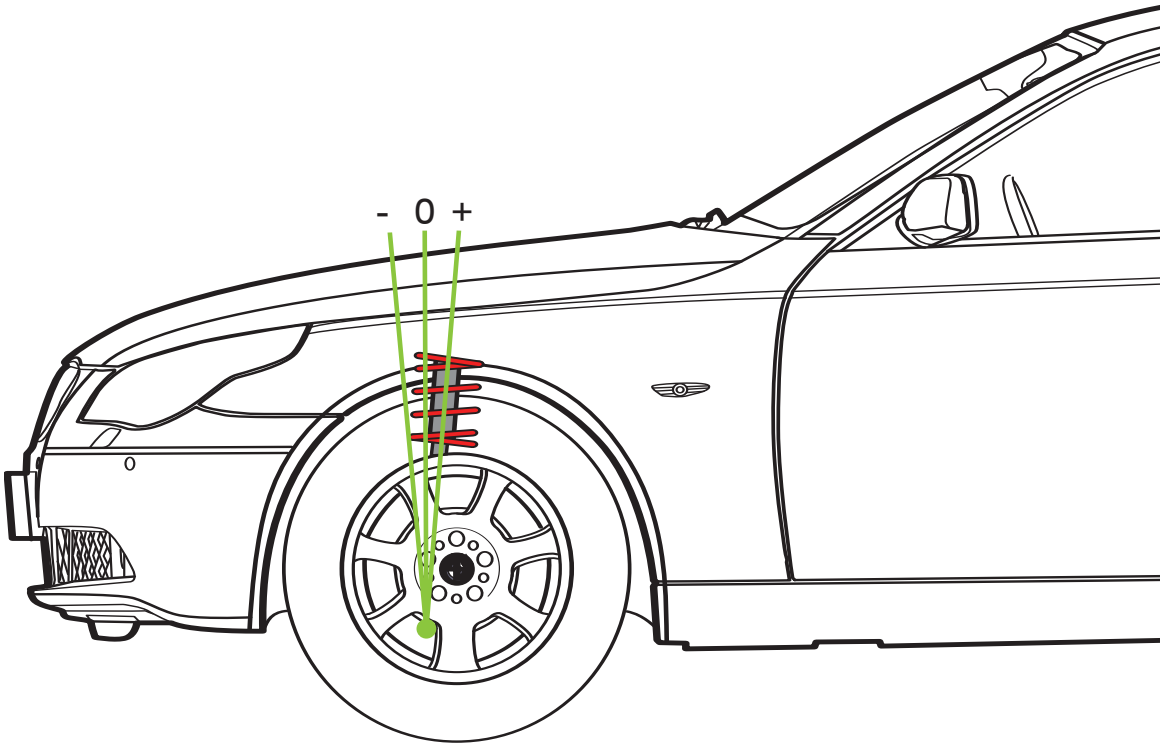
- The ease with which the vehicle can be steered
- The overall vehicle stability (handling, tracking and safety)
- Tire wear

The suspension geometry for any given vehicle is a result of the design engineers development of the vehicle and the design criteria for that particular vehicle.

Alignment Angles

Caster

Caster is the forward or rearward tilt of the steering axis centerline, as viewed from the side of the vehicle, and is measured in degrees. When the steering axis centerline is exactly perpendicular to the road surface, the Caster is considered to be at zero degrees.



When the top of the steering axis centerline is tilted rearward (toward the bulkhead), the caster is considered to be “positive”. When the top of the steering axis centerline is tilted forwards, the caster is considered to be negative.

Most vehicles have a caster angle from zero degrees to a positive angle. Negative caster is not very desirable because is reduces the vehicle stability especially at high speeds. BMW vehicle always have a positive caster angle. Positive caster promotes high speed stability and provides feedback to the driver.

Positive caster also promotes “steering return” which increases driver comfort and safety. Caster angles which are more negative (or not very positive) can increase the effect of wheel “shimmy”, create sensitivity to high winds and creates poor steering return.

When the caster angle differs greatly from side to side, the vehicle may “pull” to the side which has the “least positive” caster.

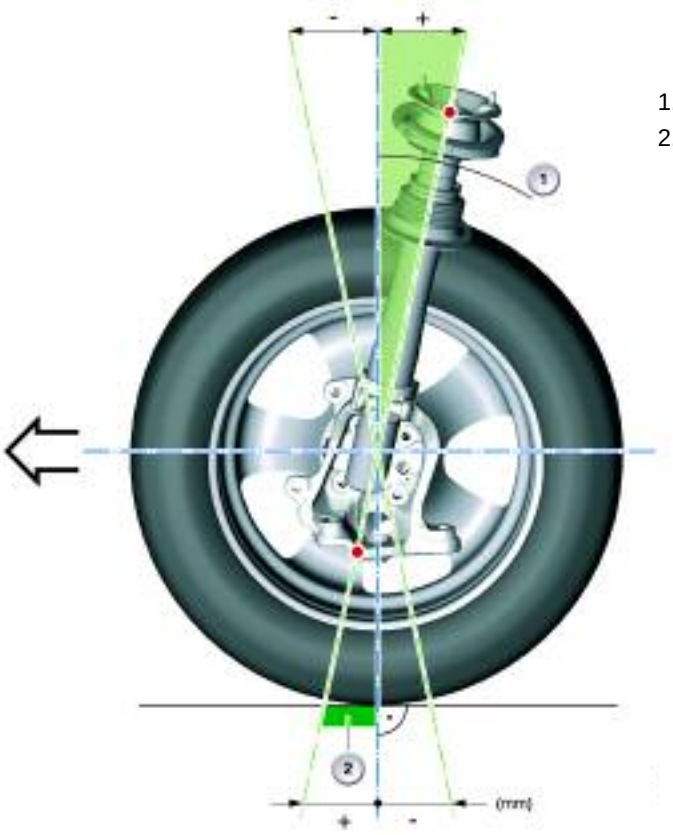
One of the main characteristics of positive caster is the positive effect on high speed steering stability. However, low speed steering effort is increased. This characteristic is counteracted by the power steering system and in particular the Servotronic system. Servotronic will be discussed in later training modules.

Caster is not a directly measured angle. It can only be measured by sweeping the steering through an angle of 20 degrees in both directions. This is important to know during the alignment procedure.

On BMW vehicles, caster can only be measured, there is no adjustment. However, caster measurement can be used to detect and diagnose alignment concerns. Caster which is out of specification could indicate damaged or worn components.

Caster Offset

Caster offset is the distance between the centerline of the wheel contact point and the intersection point of the extended pivot axis. This greater the offset, the more effort required to turn a moving wheel. The negative effects of more increased offset are counter-acted by the BMW double pivot suspension system and the Servotronic steering system (if equipped).

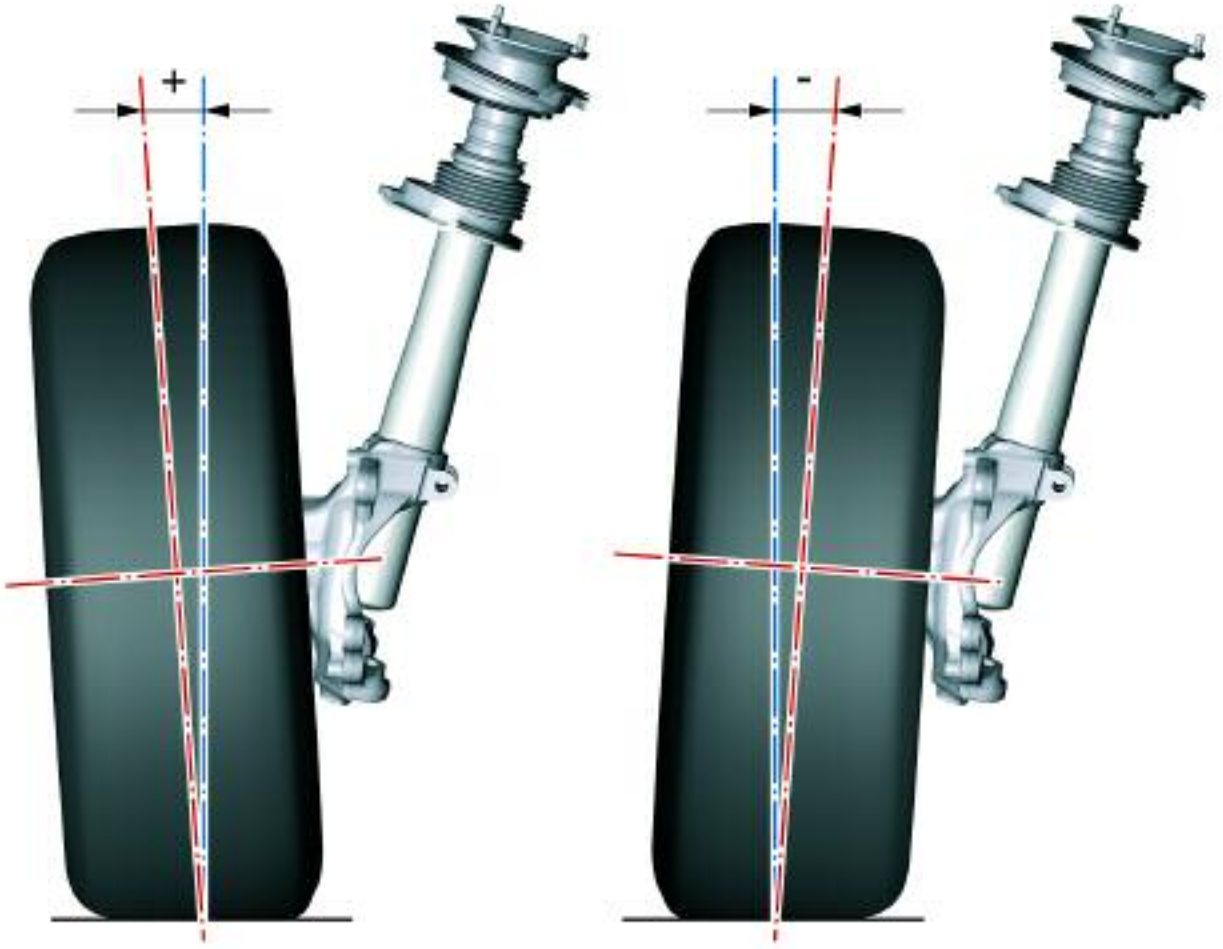


1. Caster Angle
2. Caster Offset

Camber

Camber is the inward or outward tilt of the wheels when viewed from the front of the vehicle. The amount of tilt is measured in degrees from the vertical and is called the camber angle.

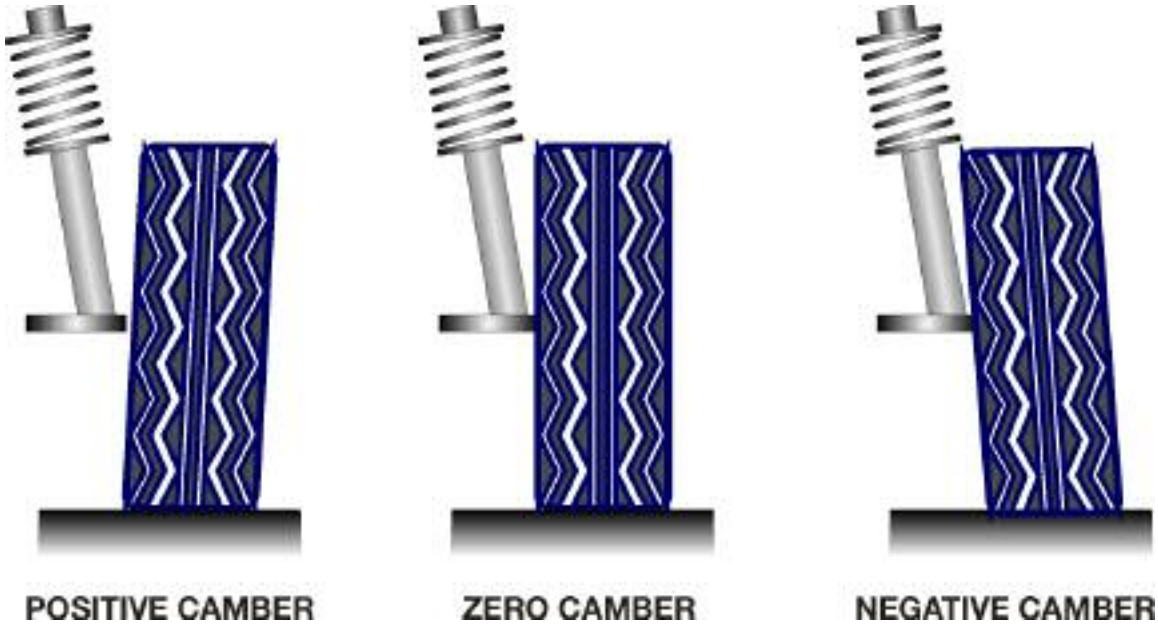
The camber angle is the angle between the wheel center point and a perpendicular line (in the wheel contact point) with respect to the road surface. Camber angle is considered positive (+) if the upper part of the wheel is angled outward from the wheel center point and negative (-) if it is angled inward.



Wheels running at a camber want to follow a circular path, like an overturned cone. Therefore, vehicles which have excessive camber angles will tend to pull to one side. As a general rule, the vehicle will tend to pull to the side of the vehicle which has the most positive camber.

Front camber angle on most current BMW vehicles is set at a slightly negative value. This promotes good straight line stability. This is due to the fact that slight negative camber causes the wheels to “track inward”. As long as the side-to-side camber is roughly equal, the vehicle will track in a straight line.

Camber angle also has an effect on component wear. For instance, the wheel bearings will perform well and last longer as long as the camber is within specification. Camber which is out of specification will cause undue load on the wheel bearings. Excessive camber angle also causes wear on the outer edges of the tire. The outside of the tire will wear if the camber is too positive and the reverse is true with excessive negative camber. The same holds true for the rear camber angle.



Positive Camber

Older vehicles often had a positive camber on the front axle. The design made this necessary, as the tapered roller bearings would not withstand any other type of load. In a steering maneuver, the front axle wheel on the outside of the turn is shifted to the negative camber range by the caster angle and the spread. The desired cornering stability is achieved in this way. When cornering, no positive camber should arise at the outer wheel of the steered axle.

Negative Camber

On modern BMW chassis, it is possible to set a negative camber for the straight-ahead position on the front axle as well. This has been made possible by using two rows of ball bearings. The rear wheels on BMW vehicles have always had a negative camber.

This is a compromise. The wheels on the rear axle cannot be shifted to the negative camber range by steering movements. To improve cornering stability, a negative camber has to be pre-set.

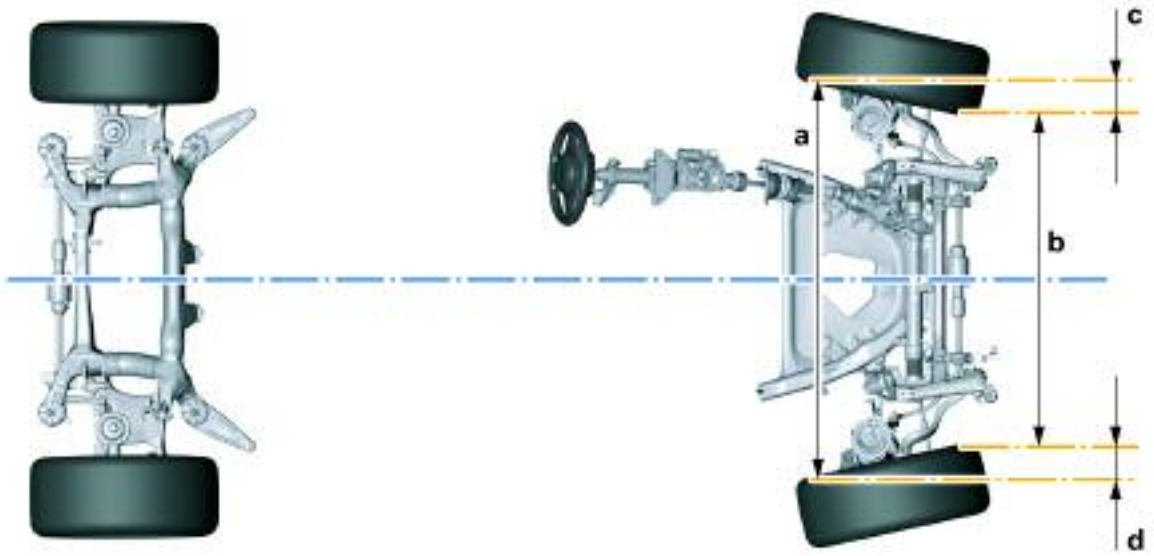
Toe

The total toe of an axle is the difference in the distance between the front of the wheels and the rear of the wheels on the same axle.

Toe is measured at the center of the wheels from one wheel rim to the other. When the distance is greater at the rear of the wheels, it is called toe-in. When the distance is greater at the front of the wheels, it is called toe-out.

Rear wheel drive vehicles generally will have a small amount of toe-in at the front wheels. This will allow the wheels to toe out when rolling to achieve a zero running toe.

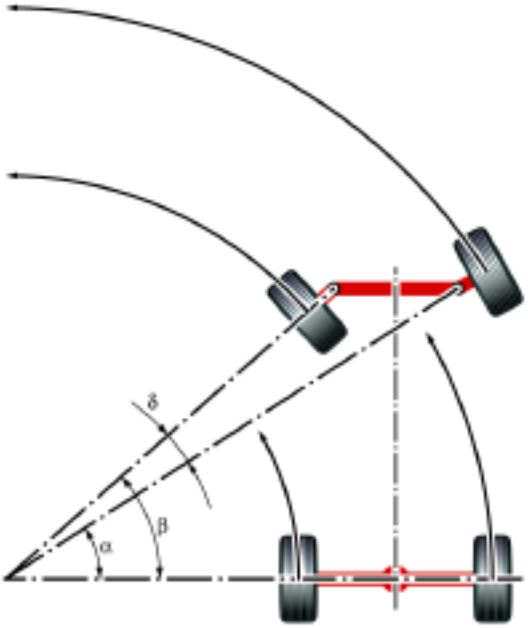
Toe is measured in Degrees when using BMW specifications. Front toe is adjustable on all BMW vehicles. Rear toe is only adjustable on some models.



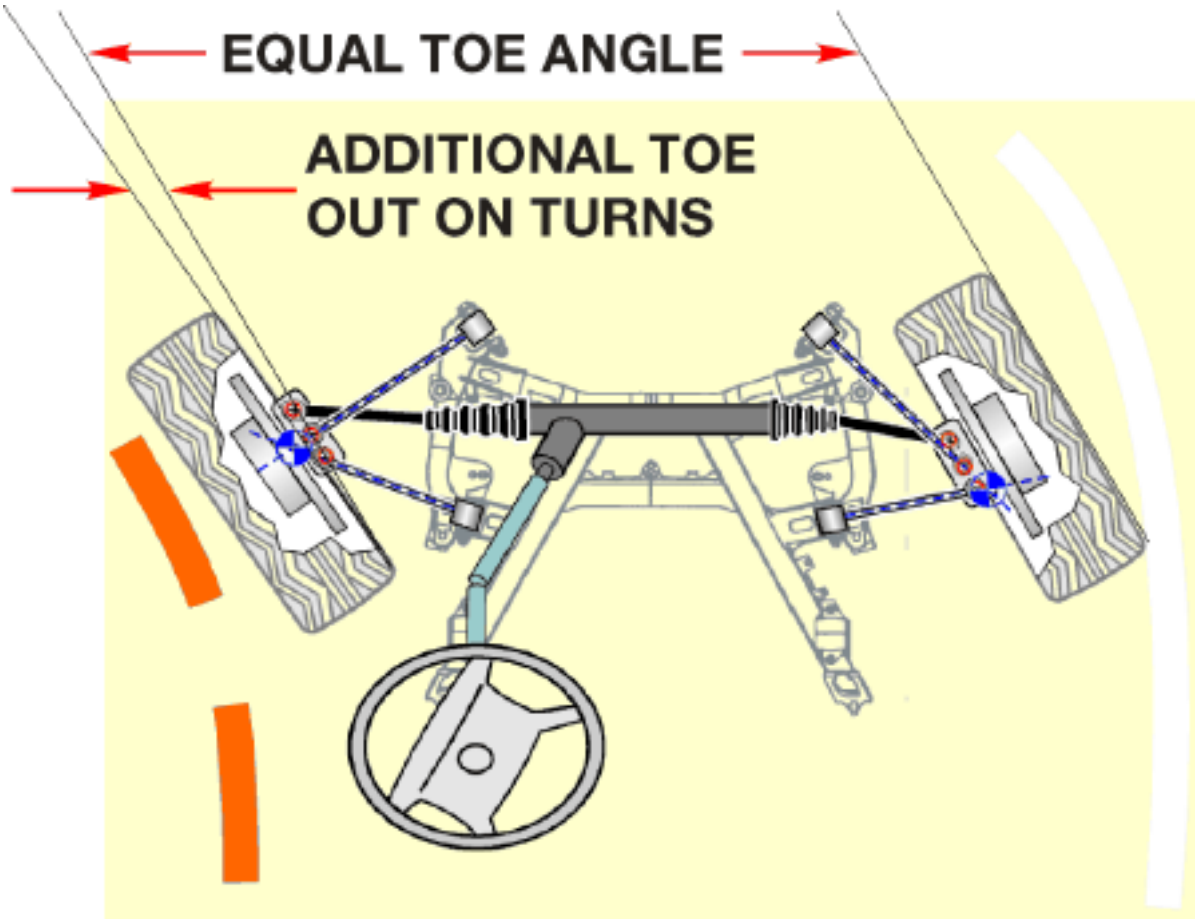
Toe has a major influence on vehicle handling, straight line stability and the position of the steering wheel. An incorrect toe setting will have a negative effect on tire wear. A toe angle which is out of specification will cause the tires to wear in a relatively short time.

Toe Out on Turns

Also referred to as “Turning Angle” or “Toe differential angle”. Toe out on turns results from the different angles (arcs) taken by the front wheels when driving through a corner. When turning a corner, the outside wheel must travel a greater distance than the inside wheel. The additional toe angle is determined by the steering arm design.



Deviations from the specified value could indicate possible bent steering linkage.
A typical complaint that would be associated with this condition would be excessive tire squeal or “scrubbing” on turns. When looking for this specification in TIS, look for the “Track Differential Angle” specification.

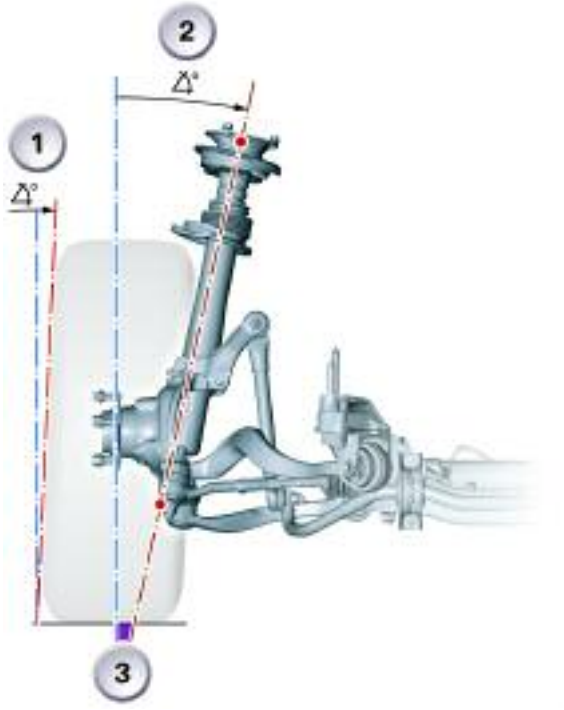


Steering Roll Radius (Steering Offset)

The steering roll radius is the distance between the point of contact of the projected line drawn through the steering axis to the road surface and the center point of the tire contact area (foot print). The roll radius is the distance between these two lines.

The roll radius can be positive or negative:

- A positive roll radius exists when the steering axis line is inside the center line of the tire (in other words, the imaginary intersection of these two lines is below the road surface).
- A negative roll radius exists when the steering axis line is outside of the tire center line (in other words, the imaginary intersection of these two lines is above the road surface).



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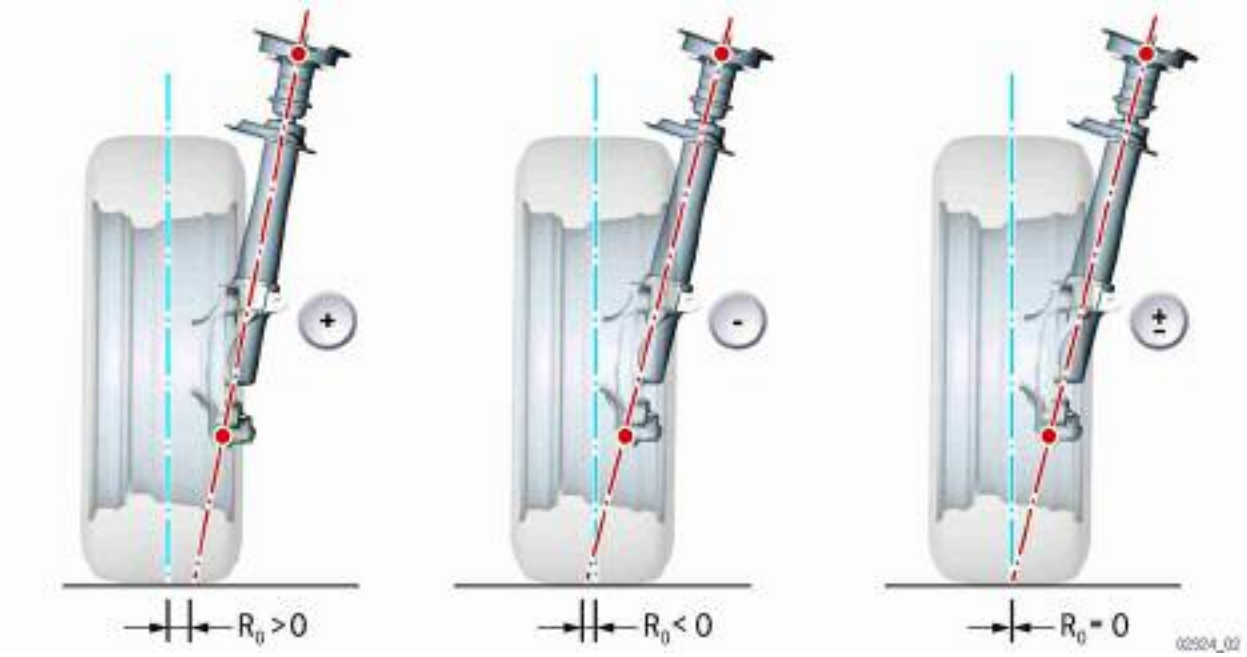
2	Steering Axis Inclination		

The steering roll radius influences the steering by means of a “torque effect”. During braking, uneven brake forces will influence the steering towards the side with the most braking force. This becomes more evident when the roll radius is excessively positive. A positive roll radius also provides more feedback to the driver regarding road surface conditions.

A steering roll radius which is excessively positive, reduces vehicle stability during braking. However, when roll radius is excessively negative, the directional stability is reduced (when not braking) and there is reduced feedback to the driver through the steering wheel. This is why BMW vehicles are designed with a steering roll radius which is slightly positive. This gives the driver a better “road feel” without compromising braking stability.

Steering Roll Radius is not adjustable, but can be influenced by camber, SAI and rim offset. This can become evident by installing improper tire and wheel combinations. Wheels with incorrect offsets can compromise handling characteristics.



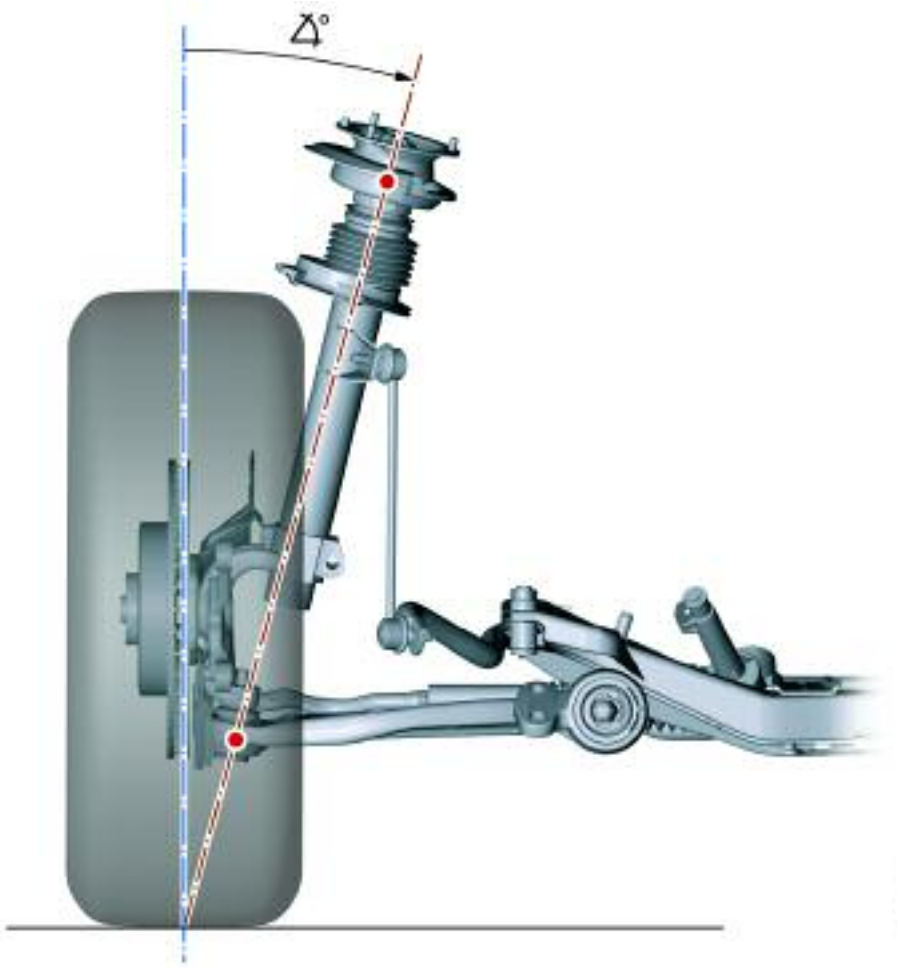
Note: The term “Steering Roll Radius” is also known as Scrub Radius, Steering Offset or King Pin Offset.

Steering Axis Inclination (SAI)

Steering Axis Inclination is the inward tilt (angle) of the strut assembly with respect to a vertical line to the road surface. SAI raises the vehicle when the steering wheel is turned, which results in the self-correcting forces that cause the front wheels and steering wheel to return to a straight ahead position after cornering.

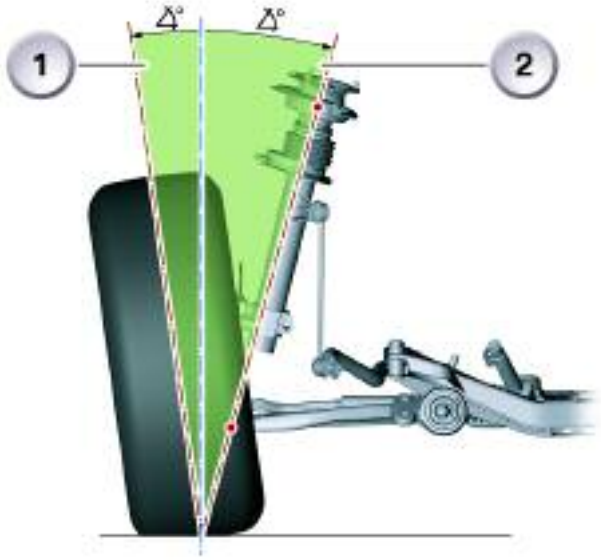
SAI is not adjustable, but is affected by damaged suspension components.

Most current alignment equipment can measure SAI and can aid in the diagnosis of damaged parts. Bent strut or spindle assemblies are common causes of incorrect SAI readings.



Included Angle (IA)

Included angle is the Camber angle and SAI combined. IA is also helpful when trying to diagnose bent suspension components. Knowing the IA and SAI is helpful when adjusting Camber. If the desired Camber angle cannot be achieved, then looking at SAI and IA could help determine the cause.



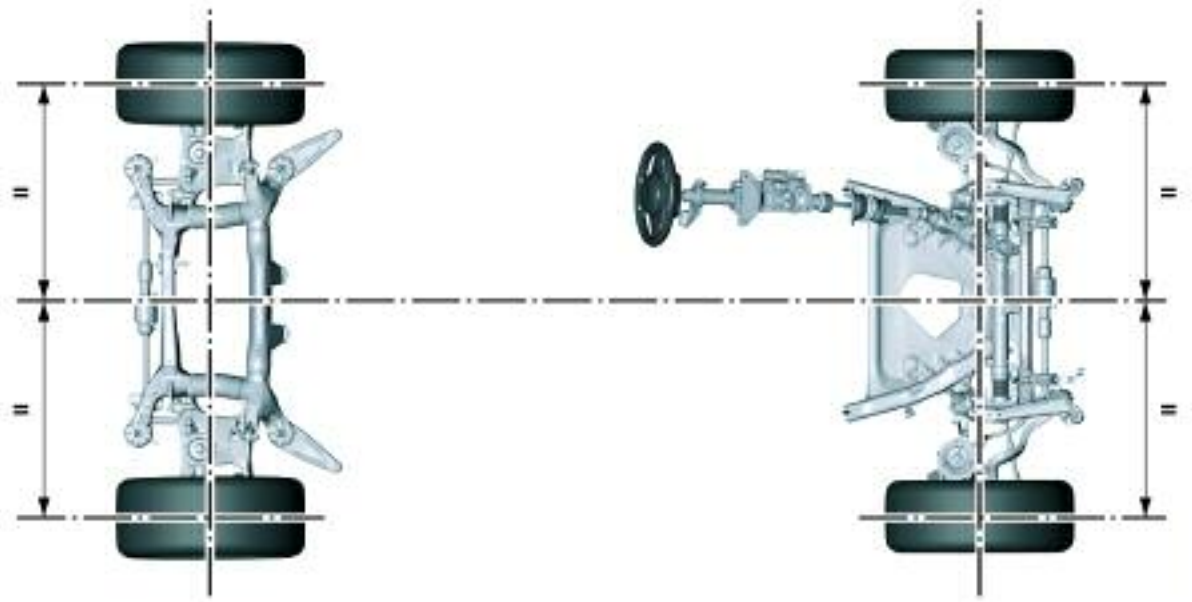
1. Camber
2. S.A.I.

1 + 2 = Included Angle

Depending on the type of alignment equipment used, S.A.I. and I.A. can be measured by raising the vehicle. Look for any excessive deviations from side to side. This could indicate possible chassis (frame) damage or bent components (strut/spindle).

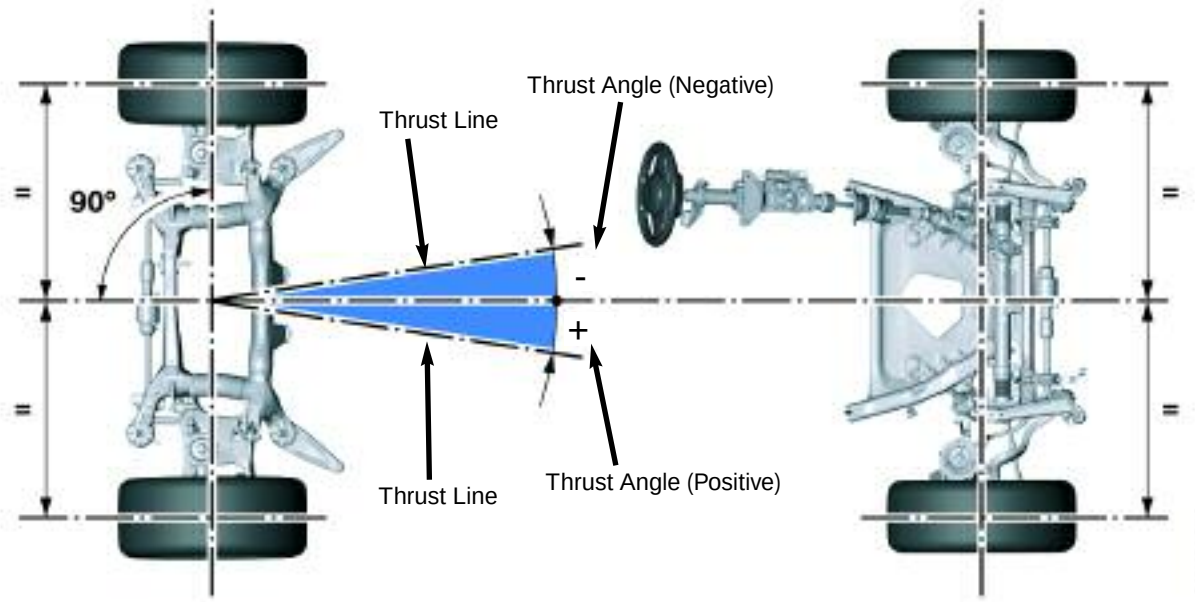
Geometric Axis

The Geometric Axis (Centerline) is an imaginary line that is drawn between the midpoints of both front and rear wheels. The Axis is perpendicular to the axis of the front and rear axles at 90 degrees. This is an imaginary angle that is not adjustable.



Thrust Line/Thrust Angle

The Thrust Line is represented by an imaginary line that bisects the rear toe angle. This angle represents the overall “direction” in which the rear wheels are pointing. The thrust angle is the difference between the Geometric Axis and the Thrust Line. The optimum Thrust Angle is Zero Degrees, any deviation from this will affect the position of the steering wheel.



Positive Thrust Angle

A positive thrust angle is formed when the thrust line is to the right of the Geometric Axis (Centerline). When this situation occurs, the steering wheel position will be off to the right as well. The rear of the vehicle will tend to move to the right which will cause the front of the vehicle to steer left, the driver will move the steering wheel to the right to compensate.

Negative Thrust Angle

A negative thrust angle is formed when the thrust line is to the left of the Geometric Axis (Centerline). When this situation occurs, the steering wheel position will be off to the left as well. The rear of the vehicle will tend to move to the left which will cause the front of the vehicle to steer right, the driver will steer the vehicle by moving the steering wheel to the left to compensate.

Alignment Procedures

When performing a wheel alignment, make sure that the thrust angle is as close to zero as possible. Failure to do so can result in a steering wheel that is not centered.

Wheelbase

Wheelbase (1) is the distance between the centerline of the two wheels on the same side of the vehicle. This is a static measurement which will change when the suspension travels on a moving vehicle.

A vehicle with a long wheelbase is of course larger and more spacious. The ride comfort is improved due to less “pitching” motion. In contrast, a vehicle with a shorter wheelbase is capable of tighter “cornering”.

Track Width

Track Width (1) is the distance between the centerline (wheel contact point) of two wheels on the same axle. This is also a static measurement which will change during vehicle movement.

A vehicle with an increased “track width” can corner at higher speeds.

NOTES PAGE

Classroom Exercise - Review Questions

1. What is the main benefit of positive caster?

2. How is Caster angle measured?

3. What influence does Camber angle have on tire wear?

4. Why are Toe angles different on turns?

5. How does steering roll radius affect directional stability?

Classroom Exercise - Review Questions

6. How is the Included Angle (IA) helpful in diagnosis?

7. What is the difference between SAI and Camber angle?

8. What influence will a positive thrust angle have on steering wheel position?

9. What effect does excessive positive Camber have on directional stability?

10. What is the toe setting on a rear wheel drive vehicle and why?