Basic Alignment Geometry
Quick Training Guide – QL411C

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Primary Wheel Alignment Angles

Wheel alignment geometry describes the positioning of the wheels, tires, and suspension components in relation to each other and to the vehicle as a whole. Proper relationships between these elements are necessary for safe, responsive handling, and maximum tire life. Listed below are the primary elements that comprise a vehicle’s wheel alignment geometry.

The Effects of Alignment Geometry on Handling, Ride, Steering, and Tire Wear

Incorrect wheel alignment geometry can be the cause or a contributing factor to nearly every type of handling complaint. Wheel alignment inspection reveals not only adjustment errors, but also verifies the condition of suspension components and the relationship of the suspension and steering components to the vehicle structure.

Alignment geometry may not be the most likely cause of every type of handling complaint. Individual wheel alignment elements deserve particular attention because they influence handling, ride, steering and tire wear.
Camber describes the inward or outward tilt of the top of the tire compared to a vertical reference viewed from the front or rear. The camber angle is the angle formed by a vertical line and the tire's centerline. This value is measured in degrees.

Camber Is Measured With the Vehicle At Rest
Vehicle loading and suspension reactions to road irregularities result in a camber value that changes as the vehicle is in motion. A tire's static camber value is specified to achieve a balance between tire wear and handling performance when the vehicle is moving.

Camber Spread
Camber spread (or cross camber) is the difference in camber values between the left and right side of the vehicle. This difference is normally specified as a maximum of 30' (0.5°) or 45' (0.75°) depending upon the model.

Diagnosing Pulling Complaints
Remember that camber values may be within specification and still cause a pulling complaint from excessive camber spread. The diagnostic rule is:
- Camber Pulls Positive - The vehicle pulls in the direction of the tire with the most positive camber value.
Caster describes the forward or rearward tilt of the steering axis compared to a vertical reference viewed from the side. The caster angle is the angle formed by the intersection of the steering axis and a vertical line through the wheel’s centerline.

**Purpose of Caster**
Caster is designed into the front suspension geometry of a vehicle for two reasons:
1. Directional control
2. Steering returnability

**Steering Axis**
The steering axis is an imaginary line that the spindle pivots around.
- The upper and lower ball joints define the steering axis on a double wishbone suspended vehicle.
- The upper strut bearing and the lower ball joint define the steering axis on a MacPherson strut suspended vehicle.

**Caster Spread**
Caster spread (or cross caster) is the difference in caster values between the left and right side of the vehicle. Tweaked subframe positioning may also affect cross caster.

**Diagnosing Pulling Complaints**
Remember that caster values may be within specification and still cause a pulling complaint from excessive caster spread. The diagnostic rule is:
- **Caster Pulls Negative** - The vehicle pulls in the direction of the tire with the most negative caster value.
Ride Height Affect on Caster

A caster value deviating from specification may have several causes. Caster error at both front wheels can often be traced to the relationship between caster and the attitude or level of the vehicle.

- A change in the height of either the front or the rear of the vehicle alters the caster at a rate of approximately one degree of caster for each one degree change in vehicle attitude.
- By lowering the rear of the vehicle (sagging springs or an overloaded condition) caster is moved positive.
- Large individual caster errors suggest possible bent or worn suspension components or even structural damage.

Measuring Caster

Caster is typically calculated by measuring the amount of camber change through a 40° turn of the wheels and multiplying the result by a constant value. Electronic measurement systems perform this function and determine the direction and degree of the turn.

If the vehicle being measured has excessive toe error, the toe value should be adjusted close to specification before measuring and adjusting caster.
Purpose of Toe

The primary purpose of a static toe angle is to keep the front wheels operating at nearly zero toe when the vehicle is in motion.

- Toe provides compensation for the various forces acting on the steering linkage while the vehicle is moving.

Toe Specifications

Differences in suspension and powertrain design determine the static toe specification.

- Most vehicles operate with a slight amount of toe-in.
- Some front-wheel-drive designs may specify zero toe or even slight toe-out.
When measuring toe, both individual and total toe must be inspected.

- Both are measured with the wheels steered straight ahead and the vehicle at its correct ride height.

**Effect of Toe on Steering Wheel Alignment**

- Individual toe values determine the position of the steering wheel.
- When individual toe values are equal and the rear wheels are in proper alignment, the steering wheel is centered when the vehicle is traveling straight down the road.

**Ride Height Effect on Toe**

The correct ride height is important since the toe values change as the suspension travels through compression and rebound.

- Bump steer is caused when the right and left steering linkage and suspension travel in different paths or arcs.

**Caster & Camber Effect on Toe**

Any changes in wheel or tire position (such as caster or camber adjustments) change the toe value.

- For this reason, the front wheel toe is measured and adjusted after all other alignment adjustments have been made.

**Steering Linkage Effect on Toe**

Changes in the length of the steering linkage by either damage or adjustment error, or a change in overall tire/wheel diameter can also affect toe adjustment.

The Repair Manual specifies total toe and requires tie rod length to be equal from side to side.

- To accomplish equal individual toe, one-half the total toe value is applied to each wheel.
Thrust Line & Thrust Angle

The **thrust line** is the average direction of the rear wheels. The thrust line divides or bisects the vehicle’s rear total toe value. The intersection of the vehicle’s geometric centerline and the thrust line form the **thrust angle**. The **geometric centerline** is an imaginary line extending through the midpoint of both the front and rear axles.

**Thrust angle** directly affects steering wheel position (steering wheel off center).
Sequence of Adjustments

The process of correcting wheel alignment geometry is determined by the relationships between the individual alignment angles, vehicle, and the type of alignment being performed.

Before setting the front wheel toe, make all other adjustments first because the positioning of each wheel influences the front toe value. Specific details of the alignment sequence may be dictated by the electronic alignment equipment being used.

The actual adjustment process should generally occur in the following order:

1. Rear Camber
2. Rear Toe – Thrust
3. Front Caster
4. Front Camber
5. Re-sweep Caster
6. Front Toe
7. Verify All Values

This adjustment sequence is one of the final components of a complete diagnostic process.

- Proper wheel alignment diagnosis and correction must follow all of the diagnostic steps.
- Always ensure proper ride height and tire pressure.
- Simply adjusting the alignment geometry without proper inspection of the suspension, steering, and other related systems may not correct and could even mask the root cause of the customer complaint.