Form 1572-DIAG-VT, 11-11

Diagnostics Alignment Angles

Training Supplement
Technician Reference Guide

Table of Contents

Diagnostic Process

The first step in a diagnostic process is collecting information

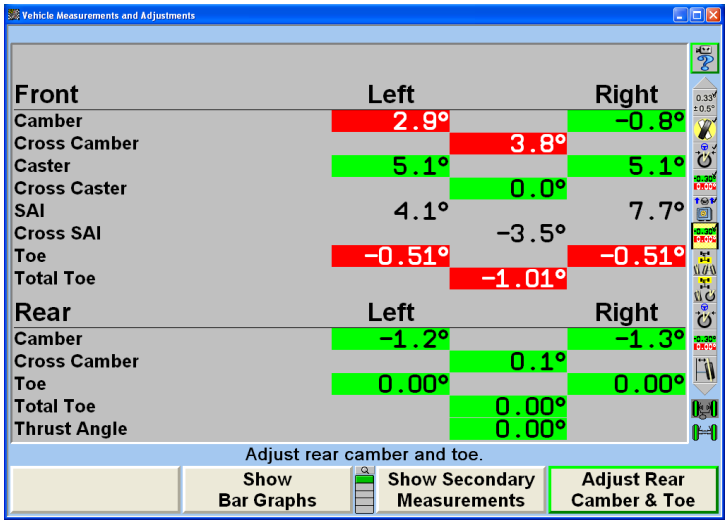
Sources of Information

- Customer interview
- Diagnostic road testing
- Vehicle inspection
- Alignment Measurements

Basic Angles

The following angles should be made with every alignment:

- Camber
- Cross camber
- Caster
- Cross caster
- Total toe front and rear
- Individual toe front and rear
- Thrust angle



Diagnostic Angles

Check these additional measurements when a vehicle has been involved in an accident, exhibits unusual handling problems, or abnormal tire wear.

Steering Axis Inclination

Used to diagnose structural damage:

- Control arms
- Frame / Uni-body
- Axle

Included angle

Used to diagnose parts damage:

- Steering knuckle
- Spindle
- Strut
- Ball joint studs

Front wheel setback

Use to diagnosis damaged control arms and diamond frames. Low caster and high set back is usually bent lower arm.

Maximum steering measurement (steering lock-to-lock)

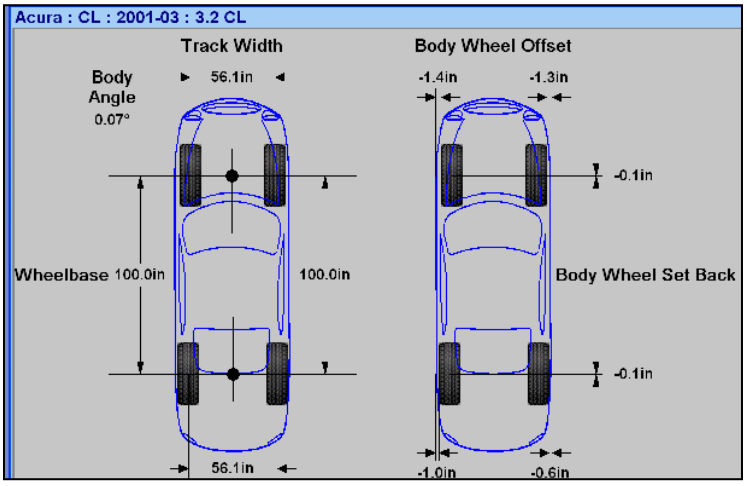
- Use to verify steering wheel-to-gear alignment. Checks for:
- Jumped rack teeth
- Bent pitman arm
- Lateral movement of gearbox at frame mounting
- Steering stop adjustment

Turning angle

Use to diagnose bent steering arms.
A bent steering arm may cause tire wear and drivability problems when turning.

Wheelbase

Useful in diagnosing excessive thrust angle problems.



SAMPLE QUESTIONAIRE

Name: _____ Vehicle: _____

Indicate the problem:

Pull ☐ Drift ☐ Tire wear ☐ Vibration ☐ Shimmy ☐

Which way does the vehicle pull or drift? Left ☐ Right ☐ Doesn't pull ☐

Check the box or boxes which best describe the tire wear problem.

Center tread wear ☐ Inner and outer shoulder wear ☐ other ☐

Outside shoulder wear ☐ Inside shoulder wear ☐ Diagonal tread wear ☐

When does the vibration or pull problem occur?

When the vehicle is at highway speeds. ☐ When the vehicle is at lower speeds. ☐

During cruising ☐

During acceleration hard ☐ medium ☐ light ☐

During braking hard ☐ medium ☐ light ☐

During deceleration hard ☐ medium ☐ light ☐

During or after turning the vehicle. ☐

What speed does the problem occur? _____ to _____ mph doesn't matter ☐

What accessories are being used when the vibration occurs? A/C ☐ 4WD ☐ doesn't matter ☐

Does it occur in a certain gear? Yes ☐ No ☐ if yes, what gear? _____

Does the problem occur with certain loads? Number of people ____ Pounds in trunk _____

Road Conditions

Paved road (smooth) ☐ Paved roads (rough) ☐ 2-lane highways ☐ Bumps ☐

How often does it occur?

Always ☐ Sometimes ☐ Rarely ☐ Just started ☐ Since new ☐ Only in morning ☐

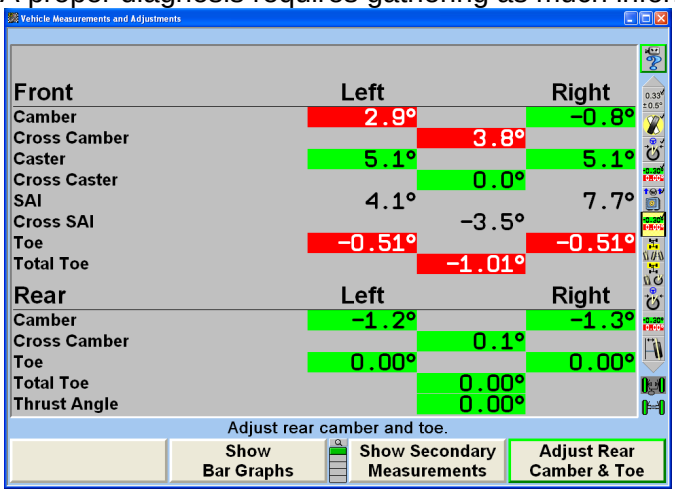
Has any mechanical work been done to the vehicle recently? Yes ☐ No ☐

If yes, what was done? _____

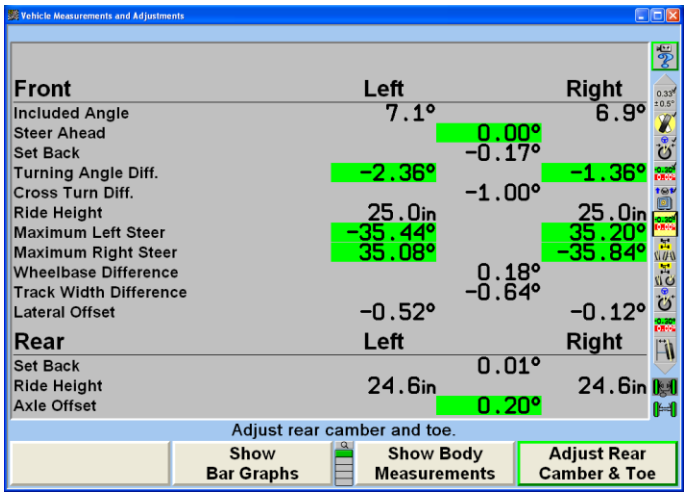
Have the tires been recently rotated or replaced? Yes ☐ No ☐

Diagnostic Measurements

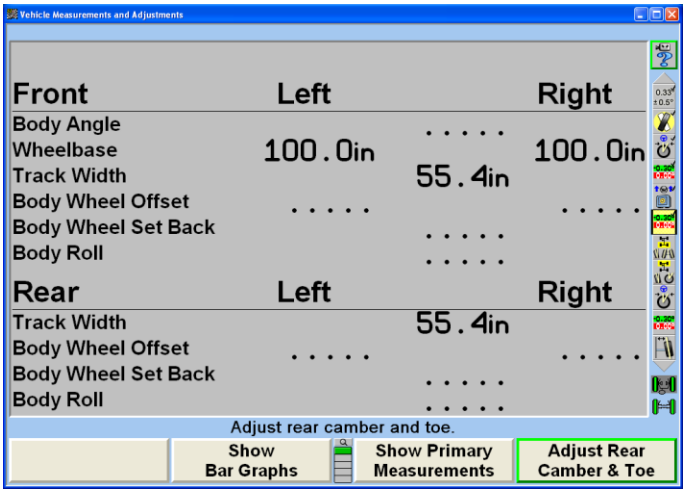
A proper diagnosis requires gathering as much information as possible.



"Primary Alignment Measurements"



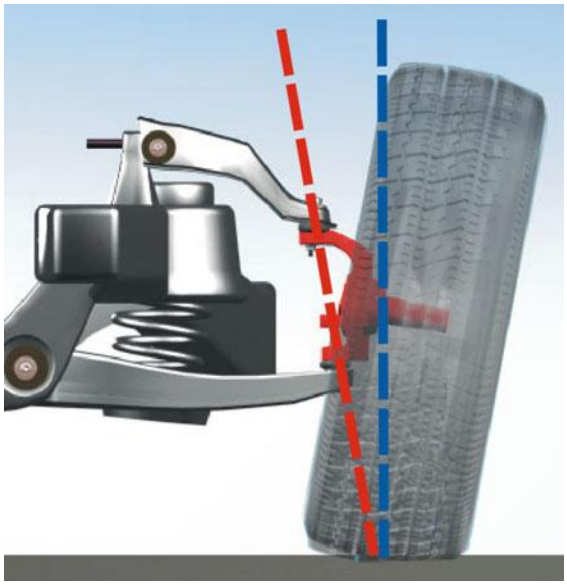
"Secondary Alignment Measurements"



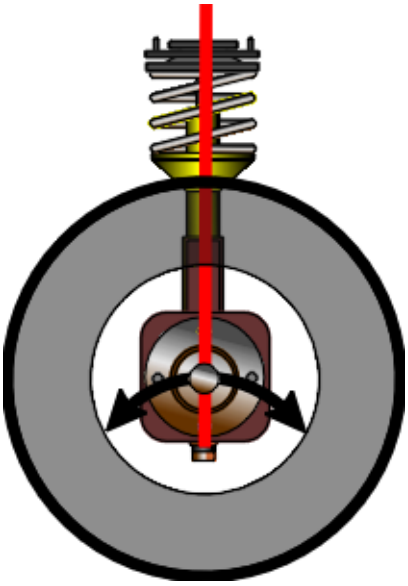
"Body Measurements"

Steering Axis Inclination and Included Angle

Steering Axis Inclination or **SAI** for short is the angle formed by a line drawn through the upper and lower pivot points of the spindle and a vertical line drawn from the lower pivot point.



Steering Axis Inclination (SAI)



SAI Spindle Arc

Steering Axis Inclination's primary function is to:

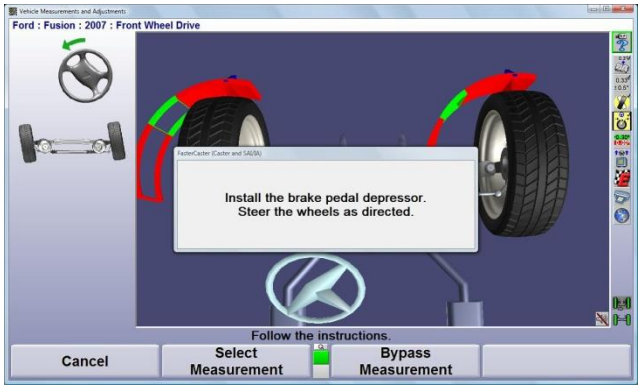
- Enhance directional stability
  - ⇒ Spindle travels in an upside down arc causing vehicle weight to be lifted when the knuckle is steered an either direction.
  - ⇒ S.A.I. doesn't need the opposing side to balance forces
  - ⇒ S.A.I. is not known to cause a pull

- Enhanced returnability is created because vehicle weight helps return the spindle to the straight ahead position when steering wheel pressure is released.

- Reduce the need for positive camber by moving weight inboard on the spindle.

S.A.I. and caster combine to supply high speed directional stability and returnability of the front wheels back to equal front toe. S.A.I. and I.A. measurements are useful diagnostics tools.

Measuring S.A.I. and Included Angle



Press “Measure Caster” on the “Vehicle Measurements and Adjustments” primary screen. The “Caster Measurement” popup screen will appear.

Press “Select Measurement,” to access “Measurement Selection”.

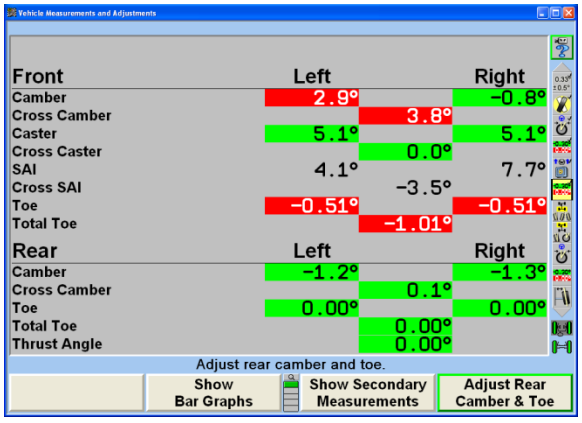
Measuring “SAI / IA Only”

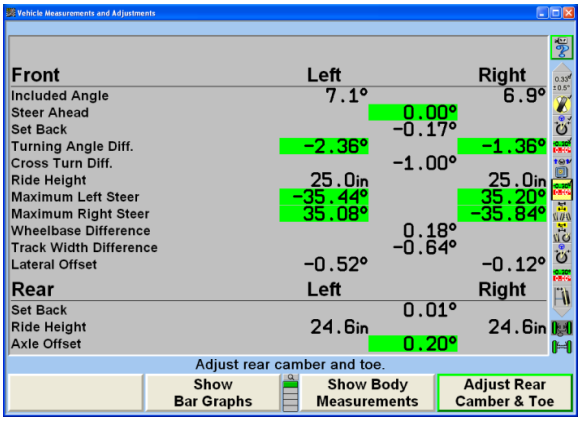
This selection asks for the front wheels to be lifted, sensors to be locked and the brakes to be locked. The measurement is complete once the vehicle is lowered.

Measuring Faster Caster (Caster and SAI/IA)

This selection asks for the front wheels to stay on the turn plates. Lock the front brakes using a brake pedal depressor and level and lock sensors.

The SAI/IA measurement relies on the front brakes holding the wheel from rotating as they are steered. Should the front brakes slip, the measurement will be falsified.





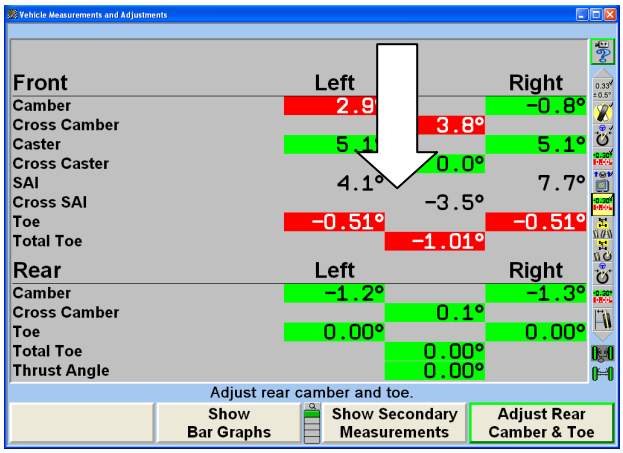
S.A.I. measurements are displayed on the “Primary Measurement” display.

Included Angle is displayed on the “Secondary Measurement” display.

S.A.I. Diagnosis

Cross S.A.I. equal to or greater than 1.5º may indicate a:

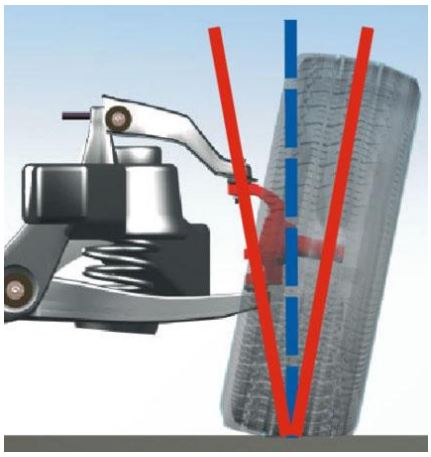
- Bent control arm
- Damaged strut tower
- Damaged frame or sub-frame
- Bent axle

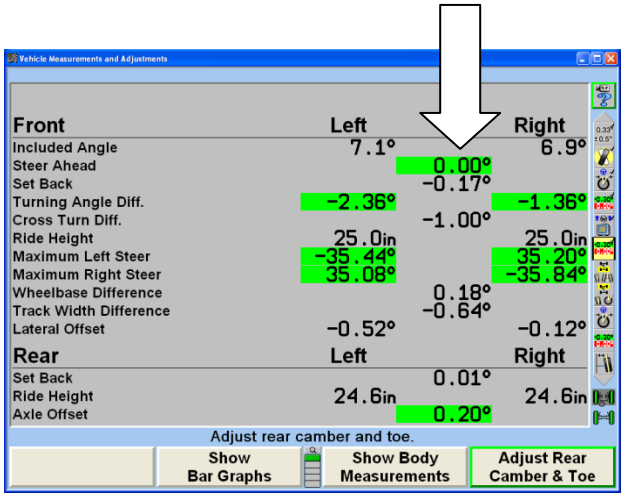


Included Angle

Included angle, or **I.A.** for short, is the combination of S.A.I and camber.

SAI + Camber = Included Angle





Cross Included Angle = Left IA – Right IA

Included angle diagnosis

Cross Included Angle equal to or greater than 1.5º generally may indicate a:

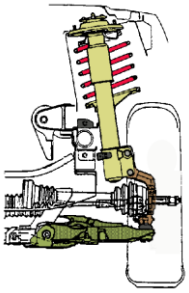
- Bent spindle
- Bent knuckle
- Bent ball joint stud

S.A.I. and I.A. Diagnostic Example

- Left camber is within specifications.
- Right camber is -1.8º low of specifications
- Cross S.A.I is only 0.2º.
- Cross Included Angle is 1.6°

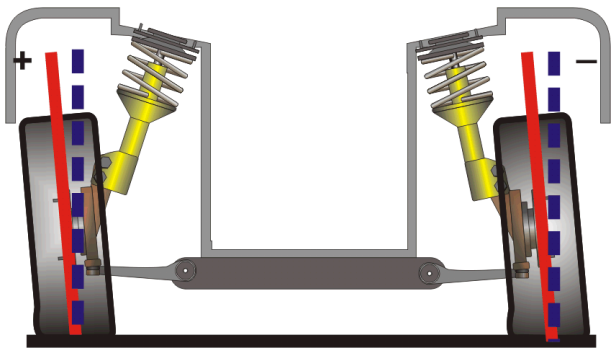
Camber spec is 0.30°	Left	Right	Compare damaged side to good side
Camber	0.3°	-1.8°	Low
S.A.I.	12.0°	12.2°	OK
Included Angle	12.3°	10.4°	Low

Use the table below to find the combination of low camber, OK S.A.I. and low IA.

	Camber	SAI	IA	Check
	High	Low	OK	Bent lower control arm or frame.
	Low	High	OK	Strut tower in at top
	High	OK	High	Bent strut, knuckle, or ball joint
	Low	OK	Low	Bent strut, knuckle or ball joint
	High	Low	High	Bent lower control arm or frame and Bent strut, knuckle or ball joint
	Low	High	Low	Strut tower in at top and Bent strut, knuckle or ball joint

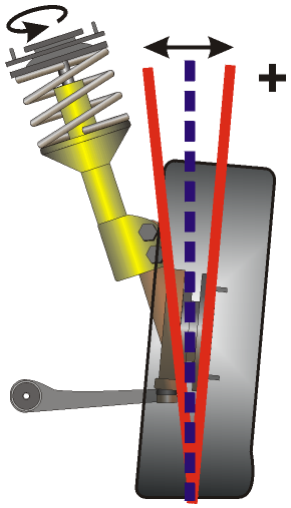
S.A.I. / I.A. Diagnostic Chart for a Strut Suspension

More tests may be needed now that the damaged are is isolated.



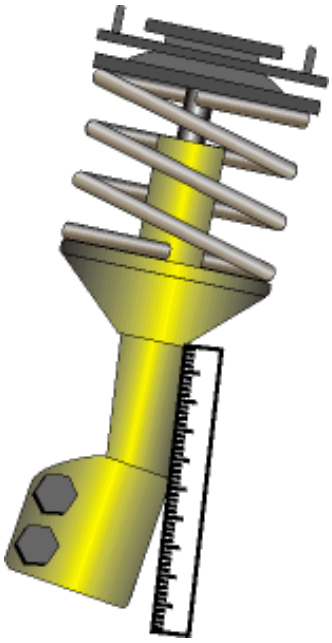
Check for a bent strut piston rod

Loosen the strut piston rod nut. The strut piston rod is bent if camber changes as you rotate the strut piston rod 360º.



Check for a bent strut housing

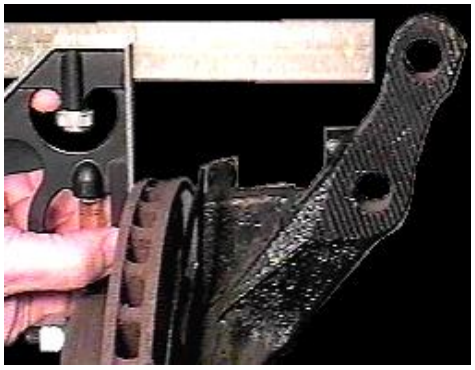
Place a straight edge against the strut housing. Check for distortion near the bottom of the housing. Look for paint cracks where the strut tube enters the collar.

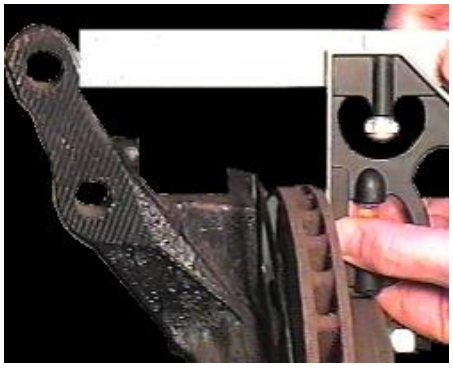


Check for a bent knuckle

Use a carpenter's square to check for a bent knuckle.

Set the base against the brake rotor or hub and slide the ruler until it touches the top of the knuckle. Compare one side to the other.





Be sure to check the bottom of the knuckle as well. Set the carpenter's square's base against the bottom of the knuckle and slide the ruler until it touches the brake rotor. Compare one side to the other.

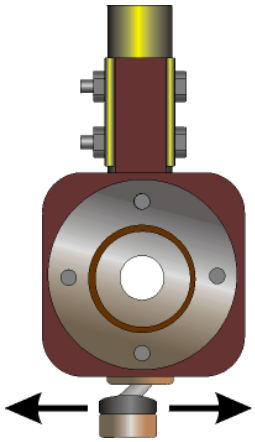
Check for bent ball joint stud

Disconnect the outer tie rod end from the steering arm.

Steer the wheels left and right. Look for back and forth movement between the ball joint and the steering knuckle.

If you find a bent stud, carefully inspect the knuckle. If the hole is tapered to fit the stud, damage to the stud may have distorted the hole, also. Industry standard is to replace both the and the knuckle.

Note: Pinch bolt type knuckles are not machine fitted, so generally damage to one doesn't necessarily affect other."



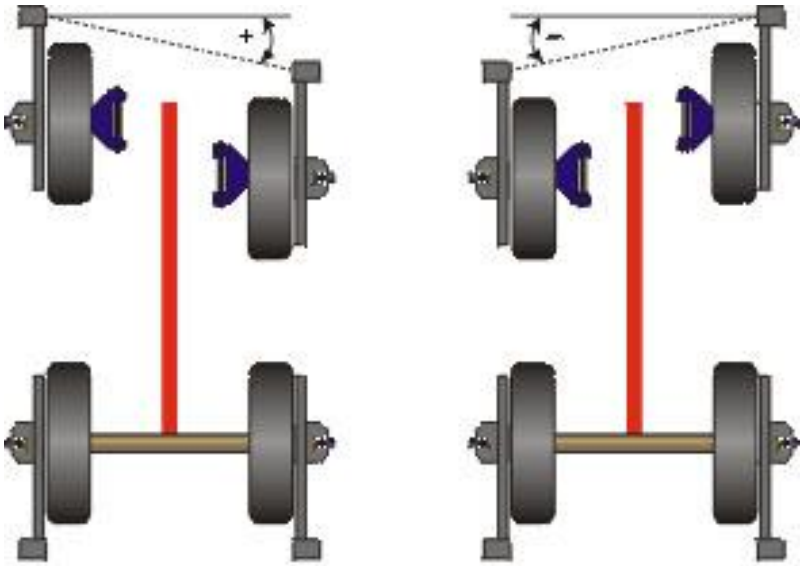
knuckle

stud

NOTES:

Setback

Front setback

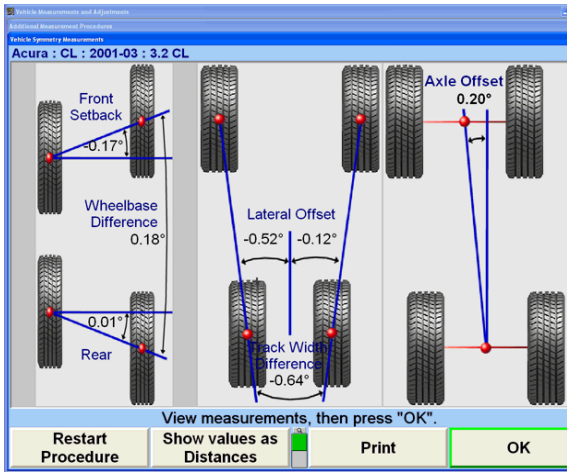


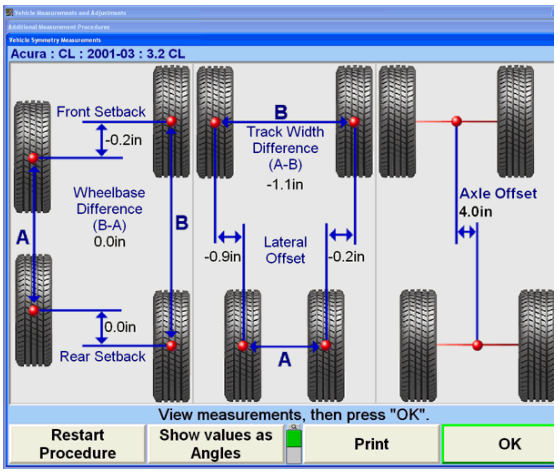
Front setback is an angle formed by a line drawn perpendicular to the centerline and a line connecting the centers of the front wheels.

Positive setback indicates the right front wheel is behind the left front wheel.

Negative setback indicates the left front wheel is behind the right front wheel.

Setback is measured as an angle but can be displayed in inches or millimeters if front track width is available in the vehicle specifications.





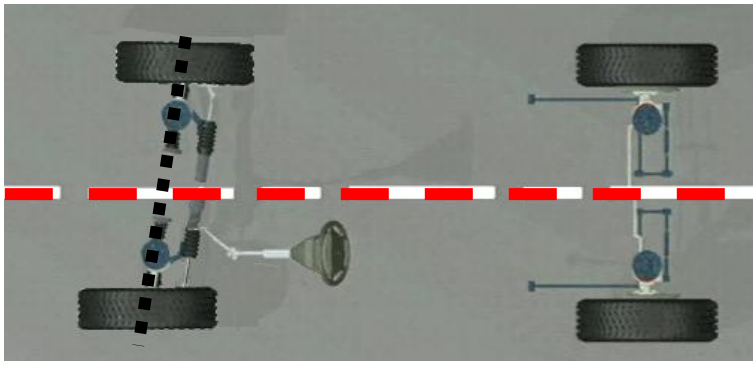
The preferred setback measurement is assumed to be zero.

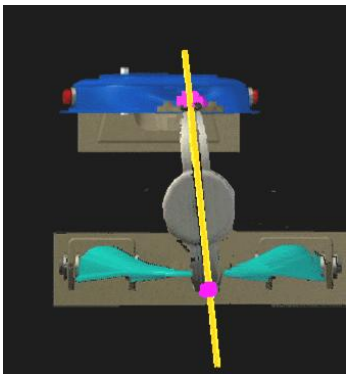
Setback may exist because of manufacturing tolerances, collision, frame repair or parts installation.

Use setback to help determine the cause of side-to-side caster differences and turning radius problems.

Cross caster measurements exceeding ±0.5º may be caused by a setback condition.

If a lower control arm has been moved rearward, caster is changed in a negative direction.





Low caster and high setback may indicate a bent lower control arm.

Compare the setback measurement to the caster measurement to determine if the lower control arm may be moved to reduce cross caster and setback measurements.

Extreme setback conditions may affect turning angle due to the repositioning of the steering arm when the lower control arm is moved forward or rearward.

Setback is not known to cause a vehicle to pull.

Setback diagnostic example

A FWD vehicle pulls left after the vehicle struck a curb. The caster specification is 3.3°. Right front caster is -3.0º low of specification and front setback is -1.01°.

	Left	Right
Caster	0.3°	3.2°
Setback	-1.01°	

Low caster and high setback may indicate a bent control arm

Many technicians check for accident damage by comparing the distance between the front and rear of the tire to the wheel opening.

Verify the left control arm is bent with a tape measure.

Rule of thumb for front setback:

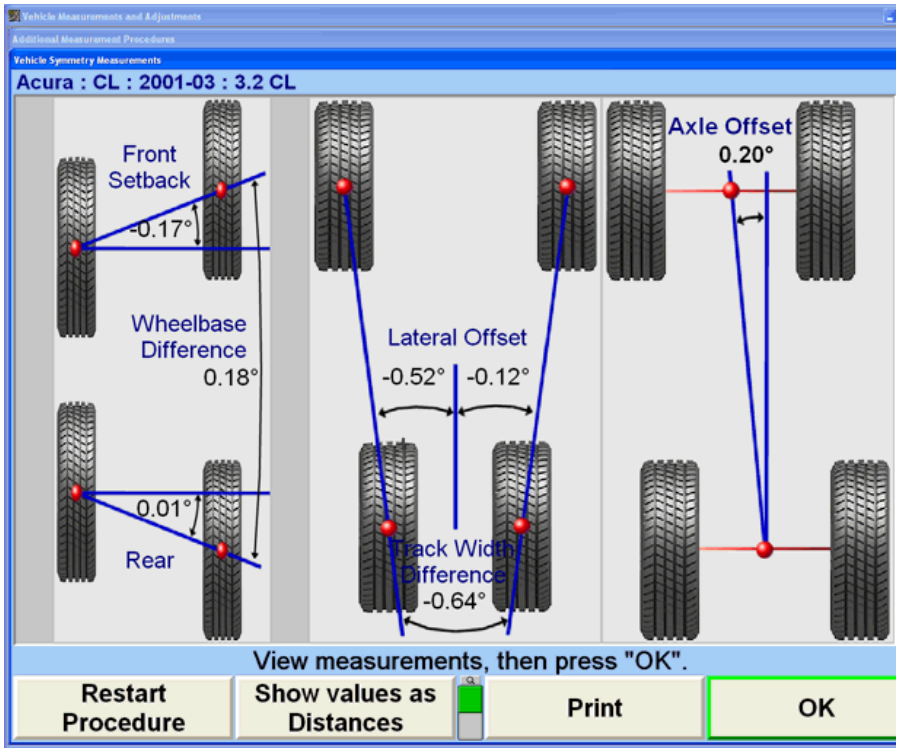
- ⇒ 0° ± 0.40° = damage unlikely, possible cradle/axle position problem
- ⇒ 0.41° to 0.75° or -0.41° to -0.75° = damage likely or severe component shift
- ⇒ Above 0.75° or lower than -0.75° = frame rail, subframe or control arm damage

Rear setback

Rear setback is an angle formed by a line drawn perpendicular to the centerline and a line connecting the centers of the rear wheels.

Positive rear setback - right rear wheel trails the left rear wheel

Negative rear setback -left rear wheel trails the right rear wheel



Rear setback is measured in degrees but can be displayed in inches or millimeters, if a rear track width specification is available.

Rear setback may be useful when diagnosing rear thrust angle problems.

	Left	Right
Rear toe	-0.85°	0.90°
Thrust angle	-0.88°	
Rear Setback	-1.13°	

The rear total toe on a rear fixed axle is 0.05°, which indicates the axle housing is not bent. The negative setback and thrust angle indicate a shifted axle housing to the left.

Turning angle

Turning angle is the difference in the angles of the front wheels when turned. The angle difference is determined by the steering arm design.

When turning a corner, the outside wheel must travel a greater distance and a wider turn than the inside wheel.

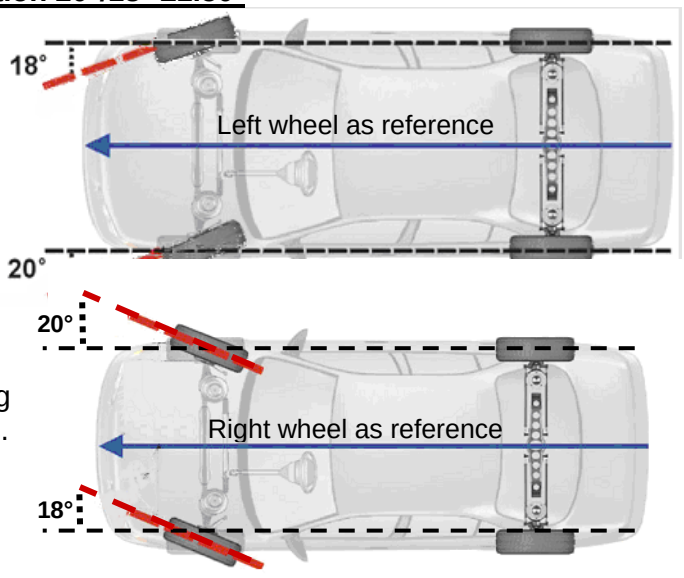
The most common approach in turning angle design is where the difference in the turning angles is symmetrical (equal).

Turning angle measurements outside manufacturer's specifications may cause front tire shoulder wear and improper handling.

Symmetrical example: **Specification 20°/18° ±1.50º**

When the left wheel is steered to the left 20º, the right wheel should be at 18º ±1.50º.

When the right wheel is steered to the right 20º, the left wheel should be at 18º ±1.50º.
The non-symmetrical design produces unequal turning angles. This design is found on various makes and models of vehicles to assist in controlling torque steer and various other problems.



Non-symmetrical example:

Specification

Left turn: 20°/18° ±1.50º When the left wheel is steered left 20º, the right wheel should be at 18º ±1.50º.

Right turn: 20°/20° ±1.50º
When the right wheel is steered right 20º, the left wheel should be at 20º ±1.50º.

Always use the manufacturer's turning angle specifications if possible. If a specification is not available, use the default spec of 20°/18° ±1.50º.

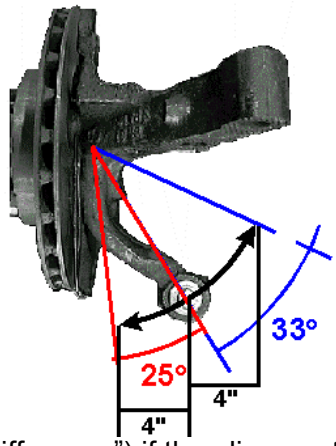
Turning angle measurements that vary more than 1.5° from specification generally indicate a bent steering arm.

The steering arms of the vehicle are designed to predetermine the relationship between the left and right front wheels when the vehicle is steered left or right.

The steering arm connects the outer tie rod to the steering knuckle. The steering arm on most vehicles is an integral part of the steering knuckle.

How turning angle works

The steering arm moves equal distance laterally as the rack moves back and forth. The steering arm must move farther up its curve when the wheel is steered left than when the wheel is steered right.



In this example, the rack moves laterally 4" in each direction and the steer arm is behind the spindle on the driver's-side knuckle.

The left wheel turns left 33º outward as the arm climbs the arc.

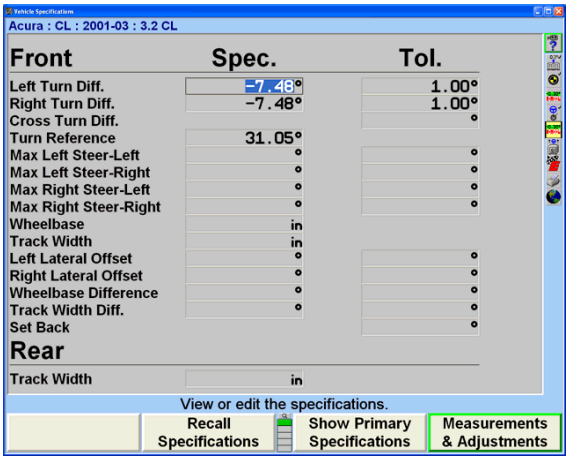
The left wheel turns right only 25º as the arm move slightly down and across the arc.

Turning Angle Measurement

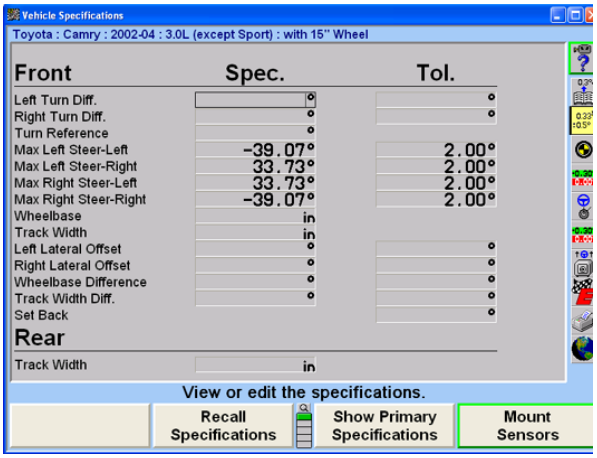
The aligner can measure toe-out-on-turns ("turning angle difference") if the alignment system is equipped with electronic turn plates, encoders and elastic lines, or DSP 300, 400, 500 or 600 sensors.

A mechanical method is available by using turn plates with turning angle scales.
A specification must be available on the secondary specification display for the measurement process to work properly when measuring electronically.

In many cases the specification must be added to the existing factory specification.



With turning angle spec



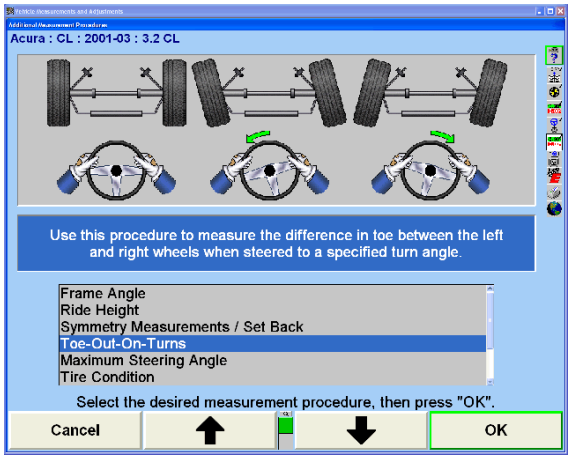
Without turning angle spec

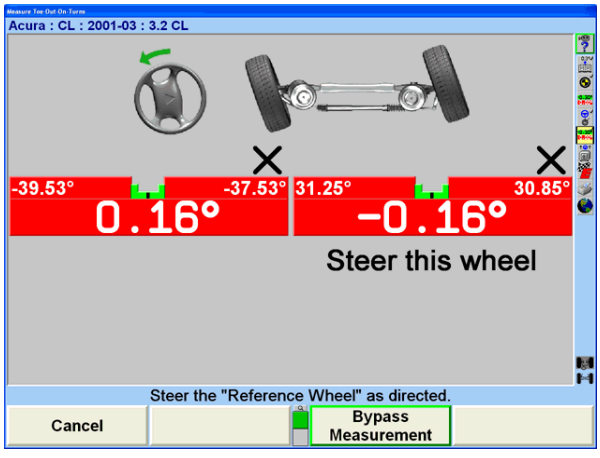
If turning angle specs are not available, it is recommended to use the default specification of 20° / 18° ± 2°.

WinAlign® secondary specification screen should be filled in as follows:

Front total toe must be within specified tolerances before measuring turning angle.

Locate the “Make Additional Measurements” soft key. Locate and select “Toe-Out-On-Turns” from the list of measurements.





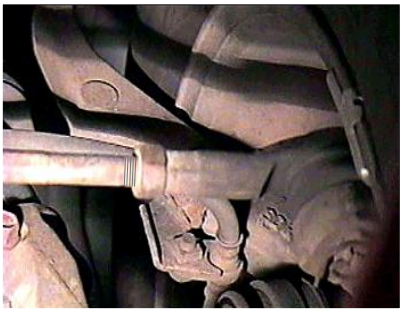
Steer the wheels as directed by the bar graphs. The “Steer this wheel” bar graph and the graphics above the bar graphs indicate which way to steer. Note: Do not pause for more than 2 seconds once the wheels are steered beyond 10 degrees.

Turning angle Diagnosis

Problem

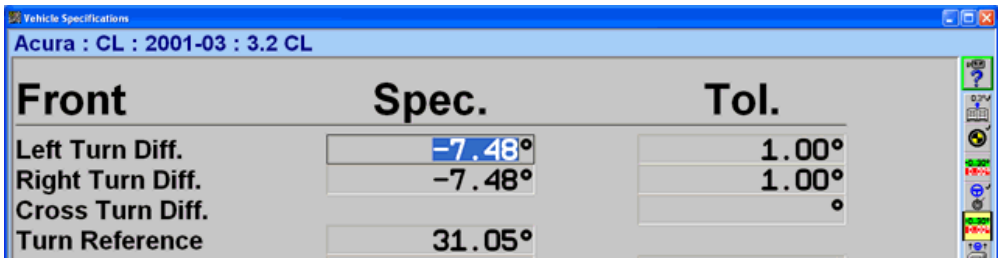
A 2002 Acura 3.2CL hit a guard rail with the left front wheel and fender. A local body shop replaced the damaged sheet metal. The car drives straight and the steering wheel is level; however, when making a left “U-turn” the tires squeal excessively and the car shudders.

Inspect the steering linkage. Normally, the exposed tie rod threads on each tie rod should be virtually equal. Note the lack of exposed threads on the left tie rod assembly.



The left tie rod no exposed tie rod threads.

The specification calls for the reference wheel to be steered 31.05°. The opposing wheel should have a steer angle of 31.05° - 7.48° or 23.57° ± 1°



Turning angle was measured with the mechanical turning angle gauges first by steering the left wheel to the left 31°. The right wheel measured 23.5°.

The right wheel was then steered to the right 31°. The left wheel measured 29º.
This is outside the allowable range of 23.57° ± 1°.

Turning angle specifications

Acura’s specifications states the difference in turning angle should be 7.48° with an allowable tolerance of 6.48° to 8.48°.

This chart shows the “turning angle difference” for a left and right turn.

	Left Wheel	Right Wheel	Turning Angle Difference
Left Turn	Reference 31.00°	23.00°	7.00° OK
Right Turn	29.00°	Reference 31.00°	**4.00° Not OK**

The test using the left front wheel as the reference was within specifications as the right wheel was within 23.53° ± 1°.

The test using the right front wheel as the reference was not within tolerances as the left wheel measured 29°, well beyond the 23.53° ± 1°specifications.

On symmetrical steering systems, use your fingers to verify the distance from the steering arm to the wheel is equal side-to-side.

Note: On this Acura, the left steering arm is bent slightly causing the -4.00º out of specification measurement.

Left side

Right side

A “T square” may also be used to check for a bent steering arm. Compare one side to the other.

A nonsymmetrical steering system was used on a few vehicles. (e.g. 1986 Ford Escort)

The length and angle of these steering arms may vary side-to-side.

Maximum Steering Angle

Maximum steering angle is the angle of the front wheels when turned to the inward and outward lock position.

In some cases, the steering limit may be adjusted. Most vehicles use a mechanical limit such as control arms or steering gear stops.

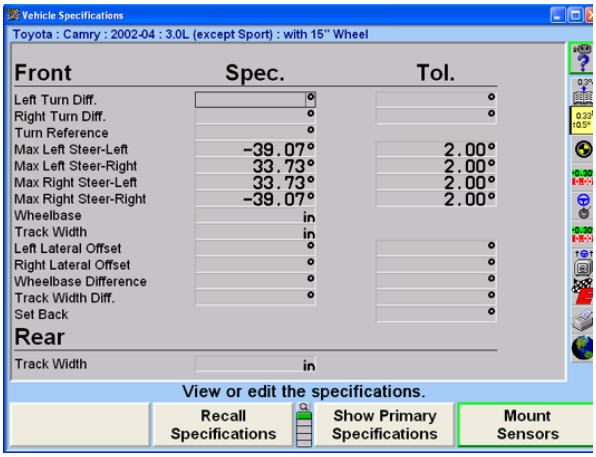
A wheel that turns beyond the maximum steering angle may create hazardous conditions when driving and cause premature tire wear.

Measurement

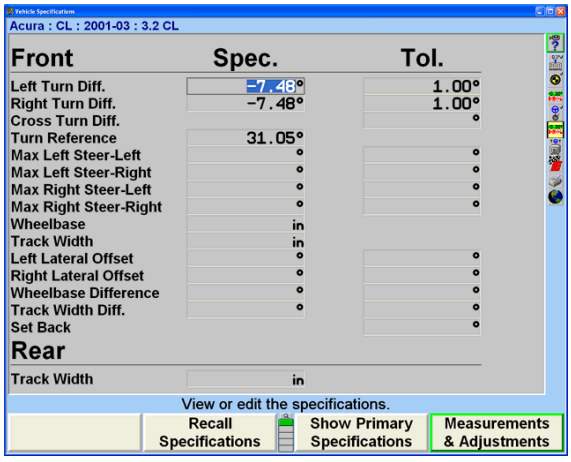
Maximum steering angle may be measured using the following methods:

- Standard front turn plate with scale and pointer
- Electronic turn plates
- DSP sensor with TOOT option
- Sensors using camera technology.

A specification must be available on the secondary specification display for the measurement process to work properly when using electronic measuring equipment. In many cases, the specification must be added manually.

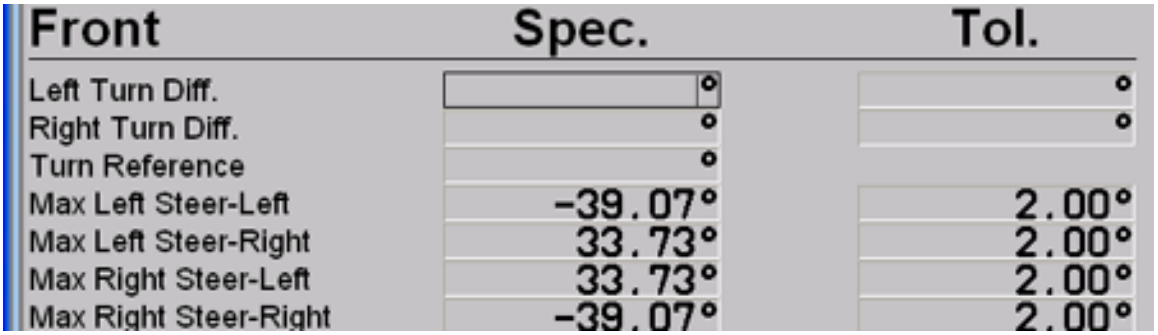


With Max Steer spec



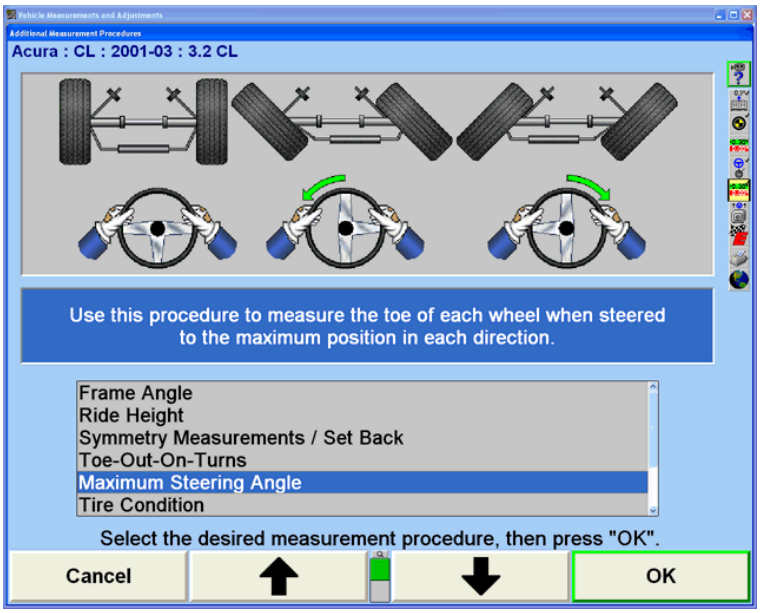
Without Max Steer spec

WinAlign's® secondary specification should be filled in as follows:



Front total toe must be within specified tolerances before measuring turning angle.

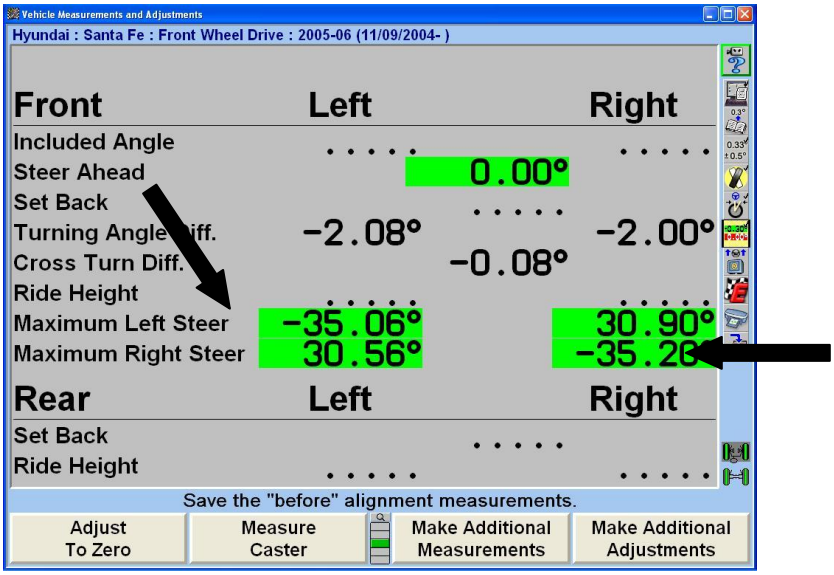
Locate the "Make Additional Measurements" soft key. Locate and select "Maximum Steering Angle" from the list of measurements.



Steer the wheels as directed by the bar graph display.

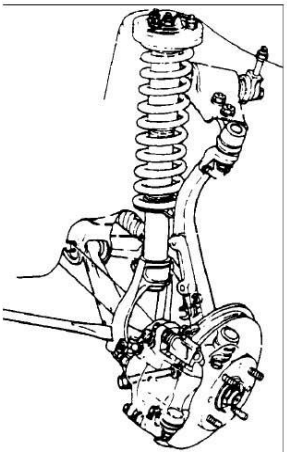
Maximum steering angle diagnosis:

- Look for symmetrical negative numbers on each side.
- Large differences side to side (over 2 degrees) may indicate:
  - ⇒ Steering stops out of adjustment
  - ⇒ Steering wheel is not centered on the steering column when the rack or center-link is centered
  - ⇒ Steering column to gear mismatch at the steering coupler
  - ⇒ Damaged steering linkage



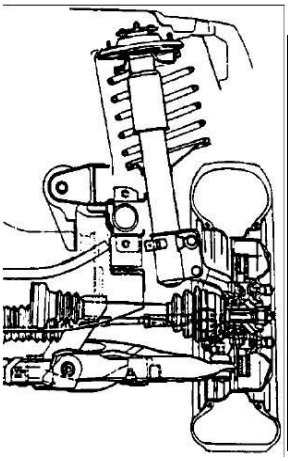
SAI / Included Angle Charts

Short Long Arm & Double Wishbone



Camber	SAI	IA	Check
Positive	Negative	OK	Bent lower control arm or frame
Positive	OK	Positive	Bent knuckle or ball joint
Positive	Negative	Positive	Bent lower control arm or frame and Bent knuckle or ball joint
Negative	Positive	OK	Bent upper control arm or frame
Negative	OK	Negative	Bent knuckle or ball joint
Negative	Positive	Negative	Bent upper control arm or frame and Bent knuckle or ball joint

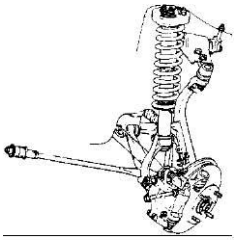
Strut



Camber	SAI	IA	Check
Positive	Negative	OK	Bent lower control arm or frame
Positive	OK	Positive	Bent strut, knuckle or ball joint
Positive	Negative	Positive	Bent lower control arm or frame and Bent strut, knuckle or ball joint
Negative	Positive	OK	Strut tower in at top
Negative	OK	Negative	Bent strut, knuckle or ball joint
Negative	Positive	Negative	Strut tower in at top and Bent strut, knuckle or ball joint

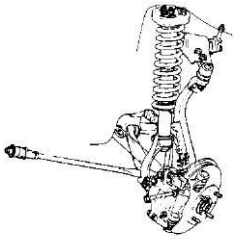
Camber	SAI	IA	Check
Positive	Negative	OK	Bent Axle
Positive	OK	Positive	Bent knuckle or ball joint
Positive	Negative	Positive	Bent axle, knuckle or ball joint
Negative	Positive	OK	Bent Axle
Negative	OK	Negative	Bent knuckle or ball joint
Negative	Positive	Negative	Bent axle, knuckle or ball joint

Caster Diagnostic Chart



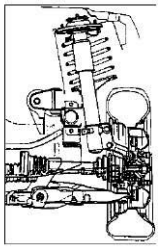
Short-Long Arm Driver side

Caster	Setback	Check
Negative	Negative	Lower control arm too far back
Negative	Positive	Upper control arm too far forward
Positive	Negative	Upper control arm too far back
Positive	Positive	Lower control arm too far forward



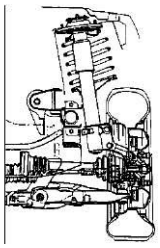
Short-Long Arm Passenger side

Caster	Setback	Check
Negative	Positive	Lower control arm too far back
Negative	Negative	Upper control arm too far forward
Positive	Negative	Lower control arm too far forward
Positive	Positive	Upper control arm too far back



Strut Driver side

Caster	Setback	Check
Negative	Negative	Lower control arm too far back
Negative	Positive	Strut tower too far forward
Positive	Negative	Strut tower too far back
Positive	Positive	Lower control arm too far forward



Strut Passenger side

Caster	Setback	Check
Negative	Positive	Lower control arm too far back
Negative	Negative	Strut tower too far forward
Positive	Negative	Lower control arm too far forward
Positive	Positive	Strut tower too far back