

Suspension and Handling



Basic Suspension and Setup Principles

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Basic Principles of Tuning

The three major elements of handling :

1. Grip Level

- Determines the maximum possible cornering speeds / G-levels

2. Balance

- Understeer / oversteer

3. Controllability

- How hard is it to drive ?

Basic Principles of Tuning

Major characteristics that affect handling:

- Tire characteristics
- CG height
- Vehicle weight and weight distribution
- Rate-related roll stiffness (over-all and front vs. rear)
 - Controlled by A-R bars, springs, dampers
- Roll center heights and roll axis - contributes to roll stiffnesses
 - Tuned using chassis attitude (pitch & ride height) control
 - Controlled by springs, dampers, motion limiters, but not swaybars
- Aerodynamic downforce (ground effects, wings, etc.)
 - Also affected by chassis attitude and ride height
- Brake characteristics - see "Brake System Basics," last page

Items Controlling Grip Level & Handling

•Tires

Construction

Radial

Bias

Aspect ratio and stiffness

Size (overall, side-side, and front vs. rear)

Pressure effects (overall and acceleration vs. deceleration)

Stagger (used mostly on ovals, can occur unintentionally – check tire diameters)

Tread

Pattern

Compound

Depth

•Suspension

Type

Struts

SLA (unequal length A-arms)

Trailing arms

Solid axle (Panhard rod, Watts links, etc.)

Other types

•Suspension (continued)

Spring rates

Swaybars

Shocks

Friction (less suspension friction \Rightarrow more mechanical grip)

Compliance (bushings, etc.)

Ride ht., roll center ht., other alignment settings

•Weight Distribution

Front to rear

CG height

Polar moment

•Drive arrangement

Front drive

Rear drive

All wheel

Limited slip (spool)

•Aerodynamic down-force

Wings

"Tunnels" or "Flat-bottoms"

Spoilers, air dams, and splitters

How Rubber and Tire Properties Affect Handling

- Rubber friction coefficient ↓ as contact pressure ↑

Therefore:

- Tire friction coefficient ↓ as tire load ↑
- More weight transfer ⇒ less grip
- Uneven tire footprint loading ⇒ less grip
- Deviation from “critical damping” (excess dynamic load variation) ⇒ less grip : i.e., suspension friction, too much damping, too little damping ⇒ less grip

Everything that affects handling starts with these principles!

How to Tune Your Handling: to get more understeer (to get more oversteer)

- More weight in front (rear)
 - May increase (decrease) wheelspin w/o limited slip [Opposite for Front Wheel Drive]
- Soften or lower rear (front)
 - May decrease (increase) wheelspin w/o limited slip [Opposite for Front Wheel Drive]
 - Items involved in stiffening/softening: springs, shocks, swaybars, roll center heights
- Chassis attitude control
 - Increase or lower all spring rates - may need to soften or stiffen swaybars to maintain roll stiffness. Raising all spring rates results in more power oversteer, less trailing-throttle oversteer, and more consistent ride height - ride height affects roll center height and flat-bottom or undertray downforce.
 - Add rebound damping in rear (front) and/or jounce damping in front (rear)
- Wider rear (front) or narrower front (rear) tires
- Wider rear (front) or narrower front (rear) track width
- Change tire pressures: see tire pressure page
- More negative camber in rear (front) – aided by pyrometer readings
- More front or rear toe-in (toe-out) - also affected by amount of “Ackerman”
- Diagonal weight jacking ⇒ different left/right handling
 - Heavy LF & RR, light RF & LR ⇒ more RH understeer, more LH oversteer
- Stiffen everything ⇒ more precise handling, but possibly less mechanical grip
- More (less) limited slip - this mostly affects handling during acceleration
- Stagger on spool or limited slip drive axle - rotates car toward smaller tire
- Aero effects

Shock Tuning (1)

Basic adjustments

Adjustment →	More Compression		More Rebound		More Canister Pressure	Larger Bleed Area
Location ↓	High-speed	Low-speed	High-speed	Low-speed		
Front	More front unsprung mass control, possible excess suspension loads over bumps or curbs, possible loss of grip over bumps	Less front chassis drop, less trailing-throttle oversteer, possible loss of grip	Better front unsprung mass control, possible loss of front grip over bumps	Less front chassis rise, less power-on understeer, possible loss of grip	More front height control, possibly less front grip	Shallower nose angle, more front grip, possible loss of low-speed front chassis control
Rear	More rear unsprung mass control, possible excess suspension loads over bumps or curbs, possible loss of grip over bumps	Less rear chassis drop, less power-on understeer, possible loss of grip	Better rear unsprung mass control, possible loss of rear grip over bumps	Less rear chassis rise, less trailing-throttle oversteer, possible loss of grip	More rear height control, possibly less rear grip	Shallower nose angle, more rear grip, possible loss of low-speed rear chassis control

Shock Tuning (2)

What other symptoms do you look for?

- Try to achieve “critical damping” to optimize response and grip (“chassis shock dyno” is useful approximation). Deviation from “critical damping” \Rightarrow less grip : i.e., suspension friction, too much damping, too little damping \Rightarrow less grip
- Low speed bump (bleed) – optimizes platform control and grip.
 - Too much bleed makes the car feel unresponsive and mushy.
 - Too little bleed reduces grip and tire life, and causes the tire to alternate between grip and slip.
- Low speed rebound (bleed) – controls trailing-throttle oversteer and power understeer.
 - More bleed allows increased dynamic ride (roll-center) height.
 - Too little bleed reduces grip and tire life.
- High speed (canister) bump – “support” vs. too harsh on bumps
- Low speed (canister) bump – “support” vs. too harsh on bumps
- After car balance has been attained, adjust low-speed bump and low-speed rebound together, both stiffer or softer, to optimize damping for track conditions.
- Higher canister pressure acts similar to reduced bleed.
- For rain – use more bleed and/or lower canister pressure (less low speed control)

Alignment Techniques and Equipment

– ***If it worked the last time out, measure it (“set-down”)!!***

- Check alignment before every race or test session
- Check for excessively loose components and match tire diameters side-to-side before checking alignment
- Need to check basic settings (arm lengths, etc.) and caster / bumpsteer only after disassembly or accident
 - Use "sight gage" to zero bumpsteer
 - Set caster using "camber-change" method (caster $\approx 1.4 \times$ camber change for $\pm 20^\circ$ steer)
- Don't waste time being too accurate – the following are usually acceptable tolerances for road-racing:
 - Ride height: ± 0.03 " with consistent car weight & tire radius, flat reference plane (floor)
 - Toe: ± 0.03 " per side
 - Camber: ± 0.1 degree (likely to be readjusted using pyrometer at the track, anyway)
 - Bumpsteer: < 0.02 " through normal suspension travel - modify for roll understeer, etc.)

How to Get More from a Test Session

– BASICS

- Plan in advance!!
- Make one change at a time if possible
- Make large changes at first
- Keep a sequential record of everything you do, the current tire, weather, and track conditions, and the results so that you can review them later!!

– POSSIBLE TESTING SEQUENCE (MODIFY TO YOUR NEEDS)

- Basic aerodynamic balance (high vs. Low speed)
- Tire pressures (see next page)
- Spring rates and ride heights
- Shock valving and settings
- Camber (use pyrometer)
- Other (toe, caster, brake bias,...)
- Repeat (This is an iterative process)

USE GOOD TIRES!

Unevenly worn or mismatched tires will give misleading readings, since thinner, worn areas will run cooler than thicker, non-worn areas, and mismatched tire diameters will change weight balance, ride height, temperature distribution, etc.

How to Determine Tire Pressures

- ***THIS PROCEDURE SHOULD BE DONE BEFORE AND RECHECKED AFTER PERFORMING OTHER SET-UP PROCEDURES.***
- 1. Ask tire supplier / competitors for nominal starting point if you have no experience with this setup.
- 2. Make initial changes of about 10% of nominal pressure.
- 3. Use pyrometer to arrive at nominal settings such that the average of the outer readings is close to the center reading.
- 4. Balance front-to-rear handling and tire temperatures using swaybars, shocks, camber, etc., if possible.
- 5. If car oversteers (understeers) entering and understeers (oversteers) exiting corner, lower (raise) all pressures.
- 6. If #5 only occurs late (early) in race or session, start with lower (higher) pressures.
- 7. Modify above for individual handling (and wear) needs:
i.e, raise or lower front or rear pressures knowing that lower pressure works better at lighter loads and that higher pressure works better at higher loads.

BRAKE SYSTEM BASICS

- ❑ Wheel braking torque requirements (related to car weight, tire type, etc.): Adjust braking capacity using pedal and hydraulic mechanical advantage, pad material, rotor size, etc.
- ❑ Balance (hydraulic mechanical advantage front-vs.-rear, balance bar settings, etc.)
- ❑ Response linearity (temperature operating range and release characteristics of pad compound)
- ❑ System stiffness as related to pedal travel and mechanical advantage
- ❑ Rotor configuration
 - Vented (greater long-term cooling capacity, possibly lower mass and heat-sink capacity)
 - Cross-drilled, slotted, etc. (May aid modulation, fade, but causes faster pad wear. Reduces rotor mass and heat-sink capacity; may accelerate rotor cracking.)
 - Floating vs. solid-mount (Less knock-back, vibration, and heat transfer to bearings, but mounting is critical)
- ❑ Possible brake problems and solutions:
 - Instability or Lockup:
 - Instability related to vehicle attitude control: Modify vehicle attitude with damper settings, ride height or higher spring rates
 - Lockup due to poor modulation characteristics (poor linearity or release characteristics): Try other pad materials or manufacturers
 - Lockup due to improper setup: Check for cross-weighting, rotor problems, etc.
 - Low Stopping Power:
 - Fade (good pedal height, but brakes progressively lose stopping power): Add cooling ducts to rotors, change pad material, and/or use larger or vented brakes
 - Low stopping power due to rotor glazing or sequential use of incompatible brake pad compounds: Deglaze, machine, or replace rotors
 - Low stopping power due to low pad coefficient of friction: Use pads with higher coefficient of friction
 - Low stopping power due low mechanical advantage: Use higher lever ratio, smaller master cyls., or larger fluid-area calipers – need enough system stiffness to avoid low pedal
 - Low Pedal:
 - Low pedal due to too much system flex: Use stiffer brake lines, calipers, etc. or decrease mechanical advantage
 - Low pedal due to fluid boiling (too hot or water in fluid): Replace brake fluid, add cooling to calipers
 - Low pedal due to fluid foaming (master cylinder vibration): Revise master cylinder reservoirs/mounting or fill reservoirs with fuel-cell foam (beware of loose foam particles)
 - Low pedal due to pad knock-back: Use anti-knock-back springs (may cause excessive drag) or revise/replace caliper seals
 - Low pedal due to taper-worn pads: Machine pads flat or replace
 - Miscellaneous:
 - Balance bar problems (binding, out of adjustment): Check binding (lube, check alignment of master cylinder rods, allow sufficient balance-bar angularity) and/or adjust
 - Uneven pad wear due to rotor drag, surface velocity difference, caliper configuration: Revise calipers, taper pad trailing edges, machine pads flat, rotate pads. Inspect pads before each session.
 - Rotor cracking (caused by thermal shock - some pad and rotor types are worse than others): Inspect and replace if cracks are severe.
 - Brake drag with brakes released due to high pad friction at very light contact: Use pads with less drag under light-contact conditions
 - Brake drag with brakes released due to binding caliper pistons: Clean pistons, make sure pads are not excessively tapered